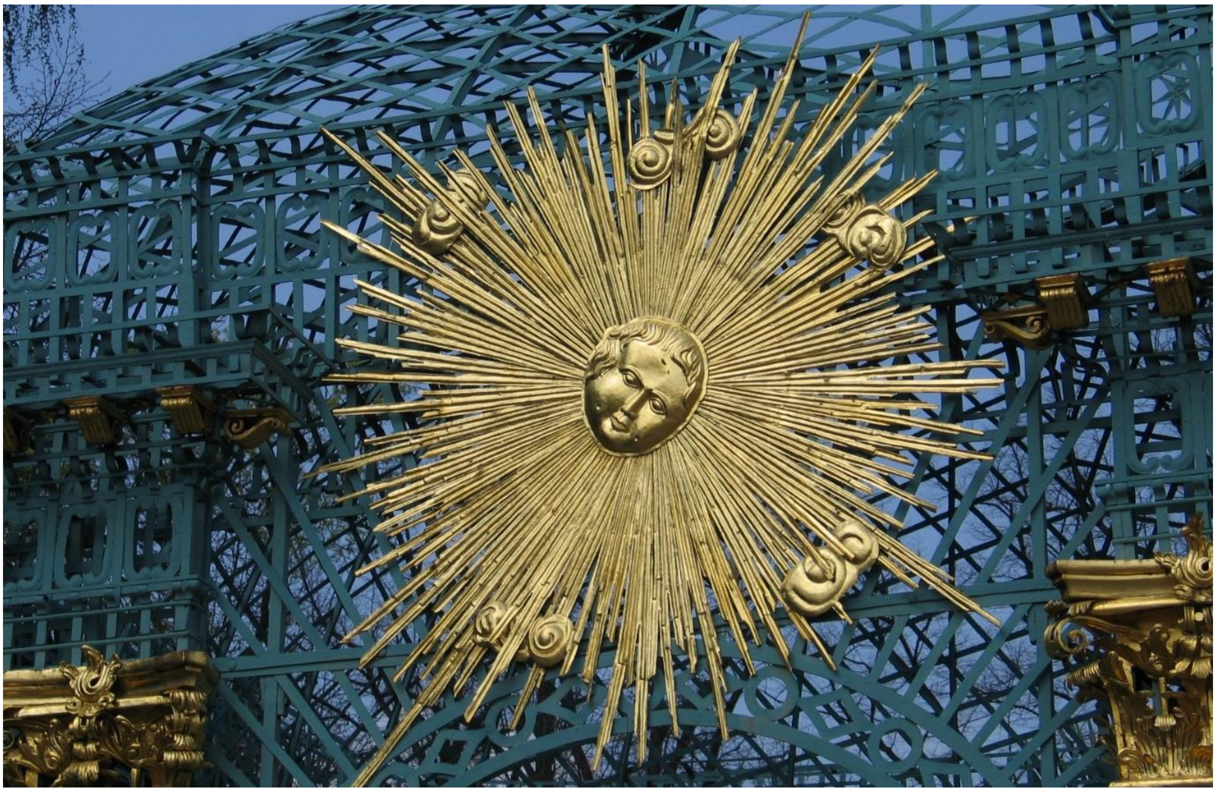
CESRA

CESRA Workshop 2019:

The Sun and the Inner Heliosphere

July 8-12, 2019, Albert Einstein Science Park, Telegrafenberg

Potsdam, Germany



Programme and abstracts

AIP

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CESRA, the Community of European Solar Radio Astronomers, organizes triennial workshops on investigations of the solar atmosphere using radio and other observations. Although special emphasis is given to radio diagnostics, the workshop topics are of interest to a large community of solar physicists. The format of the workshop will combine plenary sessions and working group sessions, with invited review talks, oral contributions, and posters.

The CESRA 2019 workshop will place an emphasis on linking the Sun with the heliosphere, motivated by the launch of Parker Solar Probe in 2018 and the upcoming launch of Solar Orbiter in 2020. It will provide the community with a forum for discussing the first relevant science results and future science opportunities, as well as on opportunity for evaluating how to maximize science return by combining space-borne observations with the wealth of data provided by new and future ground-based radio instruments, such as ALMA, E-OVSA, EVLA, LOFAR, MUSER, MWA, and SKA, and by the large number of well-established radio observatories.

Scientific Organising Committee:

Eduard Kontar, Miroslav Barta, Richard Fallows, Jasmina Magdalenic, Alexander Nindos, Alexander Warmuth

Local Organising Committee:

Gottfried Mann, Alexander Warmuth, Doris Lehmann, Jürgen Rendtel, Christian Vocks

Acknowledgements

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CESRA Workshop 2019:
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Programme Overview

Monday, July 8, 2019

10:00 - 12:00 Registration

12:00 - 12:20 Opening session

12:20 – 12:30 WG introduction

12:30 – 13:00 Plenary session

12:30 – 13:00 Gottfried Mann: *Coronal and Interplanetary Shocks (invited talk)*

13:00 – 14:30 Lunch break

14:30 – 16:00 Plenary session

14:30 – 15:00 James Drake: *Solar Flare Electron Acceleration: progress and challenges (invited talk)*

15:00 – 15:30 Rami Vainio: *Simulations of shock acceleration in the corona and inner heliosphere: progress and challenges (invited talk)*

15:30 – 16:00 Karl-Ludwig Klein: *Solar energetic particle observations and radio emission: progress and challenges (invited talk)*

16:00 – 16:30 Coffee break & poster viewing

16:30 – 18:00 WG sessions

Tuesday, July 9, 2019

09:00 - 10:30 Plenary session

09:00 – 09:30 Costas Alissandrakis: *Chromospheric diagnostics with ALMA (invited talk)*

09:30 – 10:00 Alexander Stepanov: *Models for Frequency Rising sub-THz Emission from Solar Flares: Progress and Challenges (invited talk)*

10:00 – 10:15 Dale Gary: *Dynamic Microwave imaging Spectroscopy with the Expanded Owens Valley Solar Array*

10:15 – 10:30 Yihua Yan: *MUSER Observations of an M8.7 Flare Event on 2014 December 17*

10:30 – 11:00 Coffee break & poster viewing

11:00 – 13:00 WG sessions

13:00 – 14:30 Lunch break

14:30 – 15:15 Plenary session

14:30 – 15:00 Christophe Marque: *Impact of solar radio bursts on technologies (invited talk)*

15:00 – 15:15 Surajit Mondal: *Routine estimation of Coronal Mass Ejection magnetic fields at coronal heights*

15:15 – 16:30 Coffee break & poster viewing

16:30 – 18:00 WG sessions

18:00 – 19:00 CESRA business meeting

Wednesday, July 10, 2019

09:00 - 10:30 Plenary session

09:00 – 09:30 Hamish Reid: *Simulations and observations of type III bursts: current progress and challenges (invited talk)*

09:30 – 10:00 Vratislav Krupar: *Type III bursts observations in the heliosphere: progress and challenges (invited talk)*

10:00 – 10:30 Prasad Subramanian: *Radio-wave propagation and scattering: current progress and challenges (invited talk)*

10:30 – 11:00 Coffee break & poster viewing

11:00 – 13:00 WG sessions

13:00 – 14:30 Lunch break

14:30 – 18:00 Excursion/Social

18:00 – 21:30 Boat trip and conference dinner

Thursday, July 11, 2019

09:00 - 10:30 Plenary session

09:00 – 09:30 Nina Dresing: *STEREO observations of non-thermal electrons in the heliosphere (invited talk)*

09:30 – 10:00 Jörg Büchner: *From electron acceleration by reconnection to radio wave generation (invited talk)*

10:00 – 10:15 Frederic Effenberger: *Linking Solar Flares and Solar Energetic Particles through Observations and Modelling*

10:15 – 10:30 Arik Posner: *SEP Warnings for the Moon and Mars*

10:30 – 11:00 Coffee break & poster viewing

11:00 – 13:00 WG sessions

13:00 – 14:30 Lunch break

14:30 – 15:30 Plenary session

- 14:30 – 15:00 Stuart Bale: *Some first results from the FIELDS instrument suite on Parker Solar Probe (invited talk)*
- 15:00 – 15:15 Milan Maksimovic: *Solar Radioastronomy with Solar Orbiter and Parker Solar Probe: capabilities and expectations*
- 15:15 – 15:30 Thejappa Golla: *Observations of Spatial Collapse of Langmuir Waves in Solar Type III Bursts*

15:30 – 16:30 Coffee break & poster viewing

16:30 – 18:00 WG sessions

Friday, July 12, 2019

09:00 - 10:30 Plenary session: reports from WG1 and WG2

10:30 – 11:00 Coffee break & poster viewing

11:00 – 12:30 Plenary session: reports from WG3 and WG4

12:30 – 13:00 Closing of the meeting

13:00 – 14:30 Lunch break

14:30 – open end LOFAR business meeting

Working group schedules

Working Group Topics:

- **WG1:** *Acceleration and transport of energetic particles*
  leaders: Miroslav Barta and Mykola Gordovskyy
- **WG2:** *Solar eruptions, CMEs, and shock waves*
  leaders: Jasmina Magdalenic and Eoin Carley
- **WG3:** *Turbulent corona, radio wave propagation, and new instruments/capabilities*
  leaders: Alexander Nindos and Tim Bastian
- **WG4:** *Radio burst fine structures, solar transients in the heliosphere, and space weather*
  leaders: Alexander Warmuth and Thejappa Golla

CESRA 2019: WG1

Acceleration and transport of energetic particles

<u>Monday, July 8, 2019</u>

16:30 – 18:00 WG1 afternoon session

Gelu Nita: *Statistical analysis of evolving flare parameters inferred from spatially-resolved microwave spectra observed with the Expanded Owens Valley Solar Array*

Larisa Kashapova: *Microwave features of behind-the-limb (BLT) solar flares with significant emission in hard X-ray*

<u>Tuesday, July 9, 2019</u>

11:00 – 13:00 WG1 morning session

Susanta Kumar Bisoi: *Tracing of energetic electron beams in solar corona with imaging spectroscopy from MUSER*

Jana Kasparova: *The very beginning of the 2011 Jun 7 flare*

Alexey Kuznetsov: *Simulations of microwave emission of solar and stellar active regions*

16:30 – 18:00 WG1 afternoon session

Eoin Carley: *Loss-cone instability modulation due to a magnetohydrodynamic sausage mode oscillation in the solar corona*

Elena Kupriyanova: *On the origin of non-stationary properties of QPP in radio emission of solar flares*

Discussion

<u>Wednesday, July 10, 2019</u>

11:00 – 13:00 WG1 morning session

Miroslav Barta: *ALMA Solar Script Generator: First step towards automated and robust processing of solar ALMA science data*

Galina Motorina: *Statistical approach to frequency rising sub-terahertz emission from solar flares*

Victoria Smirnova: *Sub-THz radio emission from the 02.04.2017 solar flare*

Thursday, July 11, 2019

11:00 – 13:00 WG1 morning session

Hamish Reid: *Using simulations and LOFAR observations to understand the speed and expansion of escaping solar electron beams*

Viktor Melnikov: *Microwave radiation of a flare loop in the presence of whistler turbulence*

Discussion

16:30 – 18:00 WG1 afternoon session

Khalil Daiffallah: *Plasma acceleration by the non-linear interaction of three crossed parallel Alfvén wave packets*

Alexandr Afanasiev: *Modelling of proton transport in application to solar long-duration gamma-ray events*

Discussion

CESRA 2019: WG2

Solar eruptions, CMEs, and shock waves

Monday, July 8, 2019

16:30 – 18:00 WG2 afternoon session: magnetic fields, shocks

Sergey Anfinogentov: *Coronal magnetography using multiwavelength observations of the Sun by Siberian Radioheliograph*

Nataliia Meshalkina: *Dynamics of microwave sources in eruptive flares on 23 July 2016 observed by the Siberian Radioheliograph, Nobeyama Radioheliograph, and SSRT*

Alexander Warmuth: *Termination shocks in reconnection outflow jets: constraints from radio & EUV observations and numerical simulations*

Tuesday, July 9, 2019

11:00 – 13:00 WG2 morning session: shocks

Gennady Chernov: *Solar radio bursts associated with standing shock waves (termination shocks)*

Suli Ma: *Imaging Solved Solar Radio Burst Associated with Initiation of a CME and a Low Coronal Shock*

Ciara Maguire: *Insights into Coronal Mass Ejection Shocks with the Irish Low FrequencyArray (I-LOFAR)*

16:30 – 18:00 WG2 afternoon session: shocks

Nicolina Chrysaphi: *The effect of scattering on split-band Type II solar radio bursts*

Diana Morosan: *Radio Imaging of Signatures of Shock Accelerated Electrons during Coronal Mass Ejections*

Immanuel Christopher Jebaraj: *Complex shock wave signatures associated with CME on September 27/28, 2012*

<u>Wednesday, July 10, 2019</u>

11:00 – 13:00 WG2 morning session

Alexander Stepanov: *A Dynamic Model of Flux Ropes*

Virendra Verma: *Relationship of EIT Waves Phenomena with Coronal Mass Ejections*

Carolina Salas Matamoros: *On the Study of Stationary Type IV Radio Sources*

<u>Thursday, July 11, 2019</u>

11:00 – 13:00 WG2 morning session: type IV bursts, MHD waves

Nicole Vilmer: *Extreme narrow-band radio emission associated with a moderate X-ray flare*

Valentin Melnik: *Interferometer observations of Type III, Type II and Type IV bursts at 20 and 25 MHz on 29 May 2014*

Hana Meszarosova: *Dispersive fast wave trains in magnetically coupled atmosphere above a sunspot and coronal heating problem*

16:30 – 18:00 WG2 afternoon session: interferometry

Christian Vocks: *First LOFAR interferometric observations of a solar X-class flare*

Alexey Kochanov: *Microwave observations with the Siberian Radioheliograph*

Discussion

CESRA 2019: WG3

Turbulent corona, radio wave propagation, and new instruments/capabilities

<u>Monday, July 8, 2019</u>

16:30 – 18:00 WG3 afternoon session: turbulence & propagation

Eduard Kontar: *Radio wave scattering in anisotropic density turbulence of the solar corona*

Mykola Gordovskyy: *Frequency-distance structure of the solar radio sources observed by LOFAR*

Discussion

<u>Tuesday, July 9, 2019</u>

11:00 – 13:00 WG3 morning session: turbulence & propagation

Tim Bastian: *Radio Propagation Diagnostics of the Inner Heliosphere in the Era of the Parker Solar Probe*

Sha Li: *The simulated results of the Interplanetary Scintillation antenna system*

Discussion

16:30 – 18:00 WG3 afternoon session: turbulence & propagation

Caterina Tiburzi: *Pulsars track the Solar wind*

Rajab Ismayilli: *MHD-shear instability in solar wind plasma with anisotropy and heat flux effects*

Alberto Pellizzoni*: Imaging of the Solar Atmosphere in K-Band through Single-Dish Observations*

Discussion

<u>Wednesday, July 10, 2019</u>

11:00 – 13:00 WG3 morning session: new instruments & capabilities

Alexander Nindos: *First high-resolution look at the quiet Sun with ALMA*

Tatiana Kaltman: *Recent results of wide wavelength range observations by radiotelescope RATAN-600*

Discussion

Thursday, July 11, 2019

11:00 – 13:00 WG3 morning session: new instruments & capabilities

Sergey Lesovoi: *Immediate prospects of the Siberian Radio Heliograph*

Mariia Globa: *High dynamic range imaging of the Sun with the Siberian Radioheliograph*

Aoife Maria Ryan: *Imaging the Solar Corona during the 2015 March 20 Eclipse using LOFAR*

Discussion

16:30 – 18:00 WG3 afternoon session: new instruments & capabilities

Rohit Sharma: *Study of Quiet Sun Low Frequency Emission Using MWA*

Discussion and short poster presentations

CESRA 2019: WG4

Radio burst fine structures, solar transients in the heliosphere, and space weather

Monday, July 8, 2019

16:30 – 18:00 WG4 afternoon session: coronal loops

Andrei Afanasev: *Random excitation of decay-less transverse oscillations of coronal loops*

Vladimir Dorovskyy: *Coronal loops diagnostics through the parameters of type U burst with equally developed branches*

Tuesday, July 9, 2019

11:00 – 13:00 WG4 morning session: radio fine structures I

Jan Benáček: *Growth-rates of the electrostatic waves in the double plasma resonance model of solar radio zebras*

Spyridon Armatas: *Spikes detected in Type II metric Radio bursts*

16:30 – 18:00 WG4 afternoon session: radio fine structures II

Costas Bouratzis: *High resolution observations of Intermediate Drift Bursts with the ARTEMIS-JLS Radio spectrograph and the Nançay Radioheliograph*

Alexey Kuznetsov: *First imaging spectroscopy observations of solar drift pair bursts*

Wednesday, July 10, 2019

11:00 – 13:00 WG4 morning session: radio fine structures III

Baolin Tan: *Solar radio spectral fine structures and diagnostics of non-thermal processes*

Chengming Tan: *Microwave fine structure events during solar Minimum*

Thursday, July 11, 2019

11:00 – 13:00 WG4 morning session: type III bursts

Pearse Murphy: *Interferometric imaging of Type III bursts in the solar corona*

Peijin Zhang: *Forward Modeling of the Type III Radio Burst Exciter*

Jasmina Magdalenic: *Active region jets on August 25, 2011*

16:30 – 18:00 WG4 afternoon session: solar-terrestrial

Mahir Pirguliyev: *Very low frequency oscillations of the differentially rotating Solar Interior and Earth's climate*

Extended discussion session

Abstracts: Plenary sessions

The abstracts are listed in chronological order. For contributions with more than one author, the submitting/presenting author's name is underlined, and only his/her affiliation is given.

Abstracts: Plenary sessions (Monday)

Coronal and Interplanetary Shocks

Gottfried Mann

Leibniz Instituite for Astrophysics Potsdam (AIP), Germany

Shock waves play an important role in astrophysics, since they are regarded as the source of energetic particles in space. Nowhere as in the corona and interplanetary space shocks can be studied in such detail by remote sensing observations and/or in-situ measurements. In the solar and interplanetary radio radiation, shock waves can be observed as so-called type II radio bursts. That indicates that shocks are able to accelerate electrons to high energies, so that they can generate Langmuir waves which convert into escaping radio waves. In the corona, shock waves are generated either by the pressure pulse due to the flare and/or driven by coronal mass ejections (CMEs). A CME travelling through the corona and interplanetary space can establish multiple shocks at the nose and/or flanks of itself. These shocks are also considered as the source of solar energetic particles (i.e. electrons and ions). Both observational and theoretical results are presented to confront both with the aim to get a better understanding under which conditions shock waves are able to accelerate particles in space efficiently.

Solar Flare Electron Acceleration: progress and challenges

James Drake, J. T. Dahlin, M. Swisdak

University of Maryland, USA

Magnetic reconnection is a significant driver of energetic particles in flares both on the sun and beyond. Simple estimates reveal that reconnection electric fields in solar flares greatly exceed the Dreiser runaway field so collisions are not expected to play a significant role in energetic electron production. Single x-line models fail to explain the large number of energetic electrons seen in flares. However, simulations reveal that reconnection becomes turbulent in the flare environment, consistent with observations of non-thermal broadening of spectral lines. Magnetic energy release and particle acceleration therefore take place in a multi-x-line environment. There are three basic mechanisms for particle energy gain in such a system: motion along parallel electric fields; and the magnetic curvature and gradient B drifts along perpendicular fields. The latter two produce the classical Fermi and betatron acceleration, respectively. Simulations reveal that electron heating and acceleration are dominated by parallel electric fields and Fermi reflection with Fermi dominating in reconnection with modest guide fields and parallel electric fields dominating with strong guide fields. A major surprise is that in the strong guide field limit where parallel electric fields dominate electron energy gain, the production of the most energetic electrons drops precipitously. Parallel electric fields are therefore inefficient drivers of very energetic electrons. The rate of production of energetic electrons dramatically increases in turbulent reconnecting systems (in 3D). Major challenges are to understand how relativistic electrons are "confined" as they gain significant energy and what mechanisms lead to and control the powerlaw energy spectra that characterize energetic electrons in flares. Finally, the enormous separation between kinetic and macroscales means that modeling particle acceleration during energy release in flares is a major computational challenge.

Simulations of shock acceleration in the corona and inner heliosphere: progress and challenges

Rami Vainio

University of Turku, Finland

I will present an overview talk on the simulations of shock acceleration in the solar corona and inner heliosphere, concentrating on recent advances and remaining challenges. While most progress has been made on understanding shock acceleration of ions, electron acceleration at shocks has been modeled as well. The presentation will include the various test-particle approaches as well as approaches with various levels of self-consistency added to the modelling from inclusion of self-generated waves to full plasma simulations of shocks. I will discuss the challenges faced by the simulation models especially in terms of very large separation of scales relevant to the problem, and discuss possible future avenues to overcome these issues.

Solar energetic particle observations and radio emission: progress and challenges

Karl-Ludwig Klein

LESIA, Observatoire de Paris, Meudon, France

The origin of solar energetic particle (SEP) events is still uncertain. It is widely advocated that SEP events can be divided in two categories, based on the elemental abundances, ion charge states, durations and the parent activity, and that this distinction is a key to identify the acceleration mechanism. The numerous smaller "impulsive" SEP events are ascribed to flares and acceleration processes that are broadly related to magnetic reconnection and turbulence. Radio observations of electron beams, especially bidirectional ones, then give evidence on the acceleration region at thermal electron densities of 10^9 to 10^{11} cm^{-3}, depending on the events. This shows some consistency with density estimates derived from the observed charge states of Fe. Intense long-duration SEP events, so-called gradual SEP events, are usually ascribed to the acceleration at CME shocks. This conclusion has some observational support, such as the long durations of gradual SEP events at MeV-energies, and their association with fast coronal mass ejections (CMEs) and with type II radio bursts. However, it is generally overlooked that type II bursts are usually accompanied by type IV bursts, which indicate continued energy release related to the evolution of the driver of the shock wave traced by the type II burst, and which are independent signatures of energy release and particle acceleration in the corona, behind the rising CME. Another intriguing fact is that few, if any, of the distinctive criteria between impulsive and gradual events established in the 1990s for SEPs at MeV energies are confirmed by SEP-observations at higher energies. It will be argued in this talk that rather than an a priori conviction on the plausibility of different acceleration processes, a thorough observational analysis that compares SEP events with remote sensing signatures of energetic particles at hard X-ray, gamma-ray and radio wavelengths is needed. Such comparative studies will be furthered by the availability of SEP measurements from vantage points close to the Sun (Parker Solar Probe, Solar Orbiter), where we expect to be able to see acceleration signatures in the time profiles of SEP events that are wiped out by interplanetary particle transport when observed at 1 AU. Radio observations will be an important contribution to this endeavour, because they show acceleration signatures in dilute plasmas, give evidence on magnetic activity between coronal acceleration sites and interplanetary.

Abstracts: Plenary sessions (Tuesday)

Chromospheric diagnostics with ALMA

Costas Allisandrakis

University of Ioannina, Greece

We are well in the ALMA era, as far a solar mm-λ astronomy is concerned. Arc-second resolution images, with a 1-2 sec cadence, as well as high quality, low resolution, full disk images are accumulating, starting with the commissioning period of December 2015 and extending over three cycles of solar observations so far. A variety of chromospheric structures, from spicules to sunspots, has been observed, as well as some dynamic phenomena. In this review I will focus on the information on the physical parameters of the solar chromosphere that ALMA images provide, exploiting the basic advantage of radio observations, that of simple diagnostics of thermal plasmas. I will summarize results obtained so far and will attempt an extrapolation to the future.

Models for Frequency Rising sub-THz Emission from Solar Flares: Progress and Challenges

Alexander Stepanov

Pulkovo Observatory of RAS, Russia

Progress and challenges in existing models for the mysterious positive slope in the frequency spectra of sub-THz emission from solar flares distinct from the microwave component are discussed. Examples for the sub-THz frequency rising emission observed with KOSMA (230 and 345 GHz), SST (212 and 405 GHz), and RT-7.5 of Bauman Technical University (93 and 140 GHz) are presented. Both thermal and non-thermal models of solar sub-THz emission are considered. It is shown that the most of sub-THz events with frequency rise can be interpreted in terms of free-free emission of hot flare plasma of the chromosphere and/or the transition region. The non-thermal models suggest Vavilov-Cherenkov emission, gyrosynchrotron radiation of accelerated electrons, and plasma radiation. The possible mechanisms for electron acceleration in non-thermal models are presented. The origin of second and sub-second temporal structures in sub-THz emission from solar flares is also discussed. The further progress in modeling of peculiarities of the spectrum and origin of sub-THz and THz emission is related to the idea of Pierre Kaufmann about observations at 3, 7 and 30 THz.

Dynamic Microwave imaging Spectroscopy with the Expanded Owens Valley Solar Array

Dale Gary, Bin Chen, Gregory Fleishman, Gelu Nita, Sijie Yu

New Jersey Institute of Technology, Newark, USA

The Expanded Owens Valley Solar Array (EOVSA) has been operating since April 2017, obtaining multi-frequency images of flares and active regions in the microwave (2.5-18 GHz) frequency range at 1 s cadence. The resulting 4-D image cubes (two spatial, spectral, and temporal) provide the opportunity for true dynamic imaging spectroscopy. EOVSA observations of the 2017 September 10 X8.2 solar limb flare are used to illustrate the power of imaging spectroscopy in this frequency range for studying the details of magnetic reconnection, energy release, particle acceleration, and transport over the entire duration of the event. For the first time, we are able to measure the dynamic changes in coronal magnetic field and its associated energy density as a function of position in the flaring region. The simultaneous microwave diagnostics of high-energy electrons additionally allows us to "follow the energy" and relate magnetic energy release to acceleration of particles. In the later phase of the flare, the emission is dominated by superhot thermal plasma, modulated by episodic particle acceleration from collapsing loops. EOVSA's 7-day-per-week, full-Sun coverage of solar flares since April 2017, and during the upcoming solar cycle 25, is producing a fantastic new, open data source for the world-wide solar community. We encourage the community of European solar radio astronomers to help us build the tools and techniques for exploiting this rich data set.

MUSER Observations of an M8.7 Flare Event on 2014 December 17

Yihua Yan, Xingyao Chen, Baolin Tan, Jing Huang, Wei Wang, Linjie Chen, Yin Zhang, Chengming Tan, Donghao Liu

CAS Key Laboratory of Solar Activity, National Astronomical Observatories, Chinese Academy of Sciences, China

The solar radio bursts are strongly related to solar activities. We present the solar radio bursts observed by the Mingantu Spectral Radioheliograph (MUSER) in China with 25 ms cadence and 25 MHz spectral resolution at 0.4-2.0 GHz and other multi-wavelengths imaging observations of an M8.7 flare/CME event in a circular active region on 2014 December 17. The solar radio spectral observations show quasi-periodic pulsations overlaid on a type IV radio continuum, which present oscillations of the non-thermal emission at a period of about 2 minutes during the flaring impulsive phase. The imaging observations show that the radio bursts cover above a region with positive magnetic field in the middle of this active region. Additionally, the modelling extrapolation shows that there are three magnetic topological structures with different scales of lengths, which coincide with the EUV imaging observations. We also find that the circular ribbon is brightening, expanding and oscillating at a period of about 3 minutes during the preflare phase. The above associated spatial locations suggest that the EUV oscillations during preflare phase are possibly related to the radio oscillations during the flaring impulsive phase. Those results also suggest that the null-point reconnection may happen before the flare onset and the preflare oscillations may play an important role in triggering the following solar flare.

Impact of solar radio bursts on technologies

Christophe Marqué

Royal Observatory of Belgium, Brussels, Belgium

Our civilisation relies more and more on the radio spectrum for essential applications in communications, broadcasting, navigation or airspace monitoring. As of today, most of these services use frequency bands below ~ 5 GHz, a part of the spectrum where the Sun is known to produce intense radio bursts related to eruptive events, which makes these services prone to interferences from solar origin. This talk will provide an overview of the impact of Solar Radio Bursts on these technologies, discussing the possible mechanisms producing these extreme radio events, and the process by which these emissions can impact different essential services.

Routine estimation of Coronal Mass Ejection magnetic fields at coronal heights

Surajit Mondal, Divya Oberoi, Kamen Kozarev, Atul Mohan

National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, India

The importance of measurement and modelling of the coronal magnetic fields has been appreciated for a long time. In view of the fact that magnetic fields of Coronal Mass Ejections (CMEs) play a crucial role in determining their geo-effectiveness, this also has considerable societal impact. The coronal magnetic fields are, however, very hard to measure directly. Unlike those at play in X-ray, EUV and optical regimes, radio emission mechanisms are sensitive to the local magnetic fields and hence can potentially lead to their measurements. In practise, however, this potential has been hard to realize. To the best of our knowledge, there are only two instances where it was possible to estimate CME magnetic fields by fitting the measured spectra with gyrosynchrotron models. Using data from the Murchison Widefield Array (MWA), a precursor of the Square Kilometre Array located in Western Australia, we have detected radio emission from two CMEs. These radio structures are cospatial and cotemporal with the white light coronagraph images of the CME and we can convincingly demonstrate that this is not plasma emission. The maximum heliocentric distance where we can detect such emission is 4.74 solar radii, and the flux densities we measure are among the lowest reported. We note that these detections have been enabled by the confluence of the availability of data from the modern arrays like the MWA; and an automated interferometric solar radio imaging which we have developed. The MWA provides unprecedentedly dense sampling of Fourier (uv) plane, an essential pre-requisite for high imaging fidelity; and the imaging pipeline is tuned to extract the best imaging performance from these data, while relieving the tedium of an otherwise human effort intensive process. We present the hypothesis that gyrosynchrotron emission from CMEs intrinsically is not rare, it only appeared so because the dynamic range and imaging fidelity of available solar radio images was typically insufficient to convincingly detect this emission. If true, this then provides an exciting opportunity for routine estimation of the CME magnetic fields at coronal heights and a host of other coronal diagnostics, uniquely associated with gyrosynchrotron emissions.

Estimates of solar coronal magnetic fields with full Stokes observations of the Sun using LOFAR

Anshu Kumari, Pietro Zucca, R. Ramesh, C. Kathiravan

Indian Institute of Astrophysics, India

Corona, the outermost layer of the Sun, is believed to permeate from a heliocentric distance of ~1.01 R⊙ to more than 1 AU. Being highly tenuous plasma medium, it harbours large scale structures, as multi-frequency observations reveal. One of the most common signatures of any flicker on the Sun is known as solar type III radio bursts. These bursts are an important diagnostic tool to understand the acceleration of non-thermal electron beams along the coronal magnetic field lines. Using the interferometric and beam formed capabilities of LOw Frequency ARray (LOFAR), we analysed a group of type III radio bursts observed between 80-20 MHz, on 30 March 2018. Taking advantage of the high spectral, temporal and spatial resolution of LOFAR, we were able to distinguish five different trajectories of propagation of the electron beams in the type III group. Using full Stokes observations (frequency and time resolution of 10 ms and 12 kHz, respectively) by the simultaneous beam formed LOFAR observations, we estimated the coronal magnetic field along these five electron beam trajectories. This was done by calculating the degree of circular polarisation of the harmonic plasma emission from the type III bursts. The methods and results will be discussed in this talk.

Abstracts: Plenary session (Wednesday)

Simulations and observations of type III bursts: current progress and challenges

Hamish Reid

University of Glasgow, UK

Solar type III radio bursts are the signatures of electron beams propagating out from the Sun, into interplanetary space. Type III burst analysis provides a powerful remote sensing diagnostic tool for these propagating electron beams, and contains information about the solar corona and solar wind plasma they travel through. Advanced radio telescopes, like the LOw Frequency ARray (LOFAR), are now giving us type III imaging spectroscopy with orders of magnitude better resolution that before. I will discuss recent observational progress in the analysis of type III bursts, including how this enhanced resolution has opened a new window that facilitates study of type III burst fine structure. I will also discuss recent numerical work which has improved our understanding of how electron beams, Langmuir waves and radio waves evolve through the turbulent solar system plasma. Looking towards the future, I will talk about the theoretical challenges, some old and some new, that we need to overcome on our quest to understand type III bursts and the electron beams that drive them.

Type III bursts observations in the heliosphere: progress and challenges

Vratislav Krupar

USRA-NASA/GSFC-IAP/CAS

Type III bursts are fast drifting emissions generated by suprathermal electron beams originated from magnetic reconnection sites of solar flares. Although type III bursts generated in the solar corona are routinely measured from the ground, spacecraft observations of those originating further from the Sun are necessary as the ionosphere blocks radio signal in the decametric and hectometric ranges. Over the last decade, we have benefited from multipoint radio measurements obtained by the twin-spacecraft STEREO mission, which also allow us to localize radio sources in the solar wind. Since propagation of radio waves is strongly affected by random electron density fluctuations, type III bursts provide us with a unique diagnostic tool for solar wind remote plasma measurements. One of the current challenges in solar radio astronomy is to disentangle real source properties of solar radio bursts from wave propagation effects.

Radio-wave propagation and scattering: current progress and challenges

Prasad Subramanian

Indian Institute of Science Education and Research, India

Density fluctuations associated with turbulence in the solar corona result in refractive index changes. Such refractive index fluctuations corrugate the phase fronts of radio waves travelling through the turbulent medium, often causing shifts in the source position and broadening of the source extent. We will present an overview of observations that illustrate these effects. We show how such observations can be used to infer properties of the turbulent density spectrum (such as the dissipation scale) in the solar corona and the solar wind. Our inferences are expected to be relevant to understanding turbulent dissipation and proton heating in the solar wind acceleration region. We will also outline the need for progress in this area, by way of observations and theoretical interpretation.

Abstracts: Plenary sessions (Thursday)

STEREO observations of non-thermal electrons in the heliosphere

Nina Dresing, M. Bruedern, F. Effenberger, A. Fischer, R. Gómez-Herrero, B. Heber, A. Klassen, A. Kollhoff, R. Strauss, S. Theesen

University of Kiel, Germany

The two STEREO spacecraft have accumulated a vast database of solar energetic particle (SEP) events since their launch in 2006. We use data of the Solar Electron and Proton Telescope (SEPT) providing directional measurements of near-relativistic electrons in 15 energy channels to study the energy spectra of solar energetic electron events. From 2007 to 2017 we collect in total 765 events with sufficiently high signal to noise ratio for a statistical analysis including all types of events, e.g. impulsive, gradual, accompanied by large CMEs or not. A mean spectral index of -2.7 at 70 keV is found for the whole sample where about half of the events show a broken power law shape. A spectral difference is observed when comparing the spectra detected in the sunward and anti-sunward pointing telescopes. On average harder spectra are observed from the backside direction, which we attribute to transport effects. We further analyze the electron spectra with respect to anisotropies, event rise times, longitudinal separations to the parent flaring active regions, and presence of high energy SEPs to gain further insight on acceleration, injection, and transport effects.

From electron acceleration by reconnection to radio wave generation

Jörg Büchner, Patricio Munoz-Sepulvedo

MPS Göttingen and TU Berlin, Germany

One of the hypotheses about radio wave generation in the solar corona is the electron acceleration by magnetic reconnection. By means of PIC code simulations we recently derived the energy spectrum and velocity space distribution of electrons accelerated by 3D magnetic reconnection for conditions typical for the flaring solar coronal plasma. We further discuss the consequences of parametrized, accordingly, electron distibution functions for possible plasma and cyclotron emissions.

Linking Solar Flares and Solar Energetic Particles through Observations and Modelling

Frederic Effenberger

GFZ Potsdam, Germany

The relation between different energetic particle populations accelerated in the solar atmosphere and detected in interplanetary space is not well-established. Observational studies during the RHESSI era demonstrated the still poorly understood existence of a connection between solar flare signatures of accelerated electrons at the Sun and the corresponding solar energetic particles (SEPs) detected at 1 AU. It is thus important to make progress towards answering the question: Under which circumstances do these two observations point to the same population of accelerated electrons? Here, we will discuss our recent studies concerned with this issue. We illustrate the potential for observations and the simultaneous modelling of the escaping and precipitating electron populations to constrain the plasma properties of the flaring region (e.g., its size, temperature, density, turbulence). We emphazize the importance of such studies for the fundamental understanding of processes that impact on energetic particle transport and acceleration in space plasmas.

SEP Warnings for the Moon and Mars

Arik Posner, R. D. Strauss

NASA/HQ Heliophysics Division

Long-term goals of space exploration are a safe human return to the moon and travel to and from Mars. In particular, the problem of astronaut radiation exposure from cosmic rays and solar energetic particles (SEPs) at the moon and on the way to and from Mars needs to be addressed. The sudden occurrence of solar energetic particles in the inner heliosphere can, in extreme cases, lead to acute radiation sickness and related detrimental consequences. A solar energetic particle warning system can reduce radiation exposure and limit adverse effects by allowing astronauts sufficient time to temporarily move to a radiation shielded location in the spacecraft. One possible scenario providing the early warning to the explorers is the placement of a Relativistic Electron Alert System for Exploration (REleASE) at Earth-Sun L1 and Mars-Sun L1. This system would use the arrival of fast SEP electrons to forecast occurrence of high fluxes of harmful (but slower) solar energetic ions at their respective locations, and along significant stretches of the interplanetary magnetic field. While at times far from the human explorers, the REleASE system would exploit the Hohmann-Parker effect, as the explorers on Hohmann trajectories to and from Mars at all times stay rather well connected to either the vicinity of Earth or Mars via the Parker magnetic field in the heliosphere. This work investigates the relative timing of alert occurrence of particle escape signatures and the arrival of harmful ions at the spacecraft through data analysis and realistic SEP event modeling applicable to lunar stays and all stages of a round-trip mission to Mars.

Some first results from the FIELDS instrument suite on Parker Solar Probe

Stuart Bale, J. W. Bonnell, T. Dudok de Wit, K. Goetz, P. R. Harvey, R. J. MacDowall, D. M. Malaspina, M. Pulupa, + the PSP/FIELDS team

University of California, Berkeley, USA

The NASA Parker Solar Probe mission launched on August 12, 2018 and reached its first perihelion of 35.7 solar radii on November 5, 2018 and a second encounter on April 4, 2019. The FIELDS instrument suite made the first measurements the solar wind magnetic field, DC electric fields, plasma waves, quasi-thermal noise, and radio emissions below ~20 MHz at this distance from the Sun. Here we present the status of the FIELDS instrument and an overview of early results from the first perihelion, with a focus on first measurements of solar radio emissions.

Solar Radioastronomy with Solar Orbiter and Parker Solar Probe: capabilities and expectations

Milan Maksimovic & Stuart Bale

LESIA, Observatoire de Paris, Meudon, France

We will review some of the open questions in Solar Radioastronomy and the way they can be addressed by the RPW and FIELDS instruments on the Solar Orbiter and Parker Solar Probe missions. Among those questions the study of the connectivity between the solar corona and the inner Heliosphere are of prime importance. We will review the technical capabilities in the radio domain for both of the of the two instruments which allow observations up to 16 MHz for RPW and 20 MHz for FIELDS. We discuss also about the importance of making observations from two vantage points in the heliosphere and as close as 10 Solar radii from the Sun.

Observations of Spatial Collapse of Langmuir Waves in Solar Type III Bursts

Thejappa Golla and R. J. MacDowall

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High-time-resolution in situ wave observations show that Langmuir waves associated with solar type III radio bursts often occur as coherent localized one-dimensional magnetic-field-aligned wave packets with short durations of a few milliseconds and peak intensities well above the strong turbulence thresholds. We report the observations of one of such wave packets obtained by the time domain sampler of the STEREO WAVES experiment, which is unique in the sense that it is the most intense wave packet ever detected in association with a solar type III radio burst, with peak intensity of E_t ~ 215 mV m^{-1}, which is equivalent to the normalized peak energy density of $W_L/(n_e T_e) \sim 2.3\times10^{-2}$. We show that this wave packet provides evidence for (1) oscillating two-stream instability (OTSI), (2) a collapsing soliton formed as a result of OTSI, and (3) a density cavity created by its ponderomotive force. We also show that the peak intensity and spatial width of this wave packet also satisfy the threshold condition for it to be the collapsing Langmuir wave packet formed as a result of nucleation processes even when $\delta n_b > \delta n_p$, where δnb and δn_p are the levels of background and ponderomotive-force-induced density fluctuations, respectively. Thus, these observations provide unambiguous evidence for the spatial collapse of Langmuir waves in the source region of a type III radio burst, and the observed spectral evidence for OTSI and the ponderomotive-force-induced density cavity strongly suggest that the OTSI is mostly likely responsible for the collapse of the observed wave packet. We also report that the FFT spectrum of this wave packet contains peaks at harmonics of the electron plasma frequency, f_{pe} up to n = 5, whose peak intensities fall off with increasing frequency. We discuss the implication of these observations for theories of solar radio bursts.

Abstracts: Oral contributions WG1

(Acceleration and transport of energetic particles)

Statistical analysis of evolving flare parameters inferred from spatially-resolved microwave spectra observed with the Expanded Owens Valley Solar Array

Gelu M Nita, Gregory D. Fleishman, Dale E Gary, Bin Chen, Sijie Yu, and Natsuha Kuroda

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The newly completed Expanded Owens Valley Solar Array (EOVSA) performed microwave (MW) imaging spectroscopy observations during several flares that occurred during the first half of September 2017. The unprecedented high frequency and spatial resolution of these observations allowed us for the first time to infer, with 2-arcsecond spatial resolution and 1-second temporal cadence, the spatial distribution and evolution of the coronal magnetic field strength, the number density of the accelerated electrons, the power-law index of their energy distribution, as well as other associated flare parameters. Our methodology, which consists of independently fitting the MW spectra corresponding to each individual pixel of the evolving multi-frequency maps with uniform gyrosynchrotron source models, generated a statistically significant collection of evolving flare parameters whose generally smooth spatial and time variation demonstrates a collective behavior of the neighboring volume elements, and thus validates our approach. Here we report on the statistical properties of these physical flare parameters, their spatial distributions, and their temporal trends for significant portions of the duration of each flare, and we interpret our results in the context of the standard solar flare model involving magnetic energy release, magnetic reconnection, and particle acceleration.

Microwave features of behind-the-limb (BLT) solar flares with significant emission in hard X-ray

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Solar flares occurring behind the limb (BTL) often show high coronal sources, while the foot points are hidden from direct view. Usually, this coronal emission has a thermal origin. But in some cases, the coronal sources demonstrate the clear presence of non-thermal contribution. Such events occur rarely and are still only weakly understood. Such X-ray emission could be generated both by electrons in the acceleration site, and trapped electrons. Combination of the X-ray and radio observations and especially microwave data help to clarify the origin of emitting electrons. We present results of the microwave data analysis for about 20 events selected from continuous observations of the Konus-WIND instrument in the hard X-ray range from November 1994 till the present. The preliminary criterion for BTL candidate selection was a low thermal soft X-ray response as compared to prominent non-thermal hard X-ray emission. Konus-WIND does not provide any spatial information, and we excluded all on-disc and limb flares from the preliminary list based on localization obtained from different instruments providing images at a different wavelength. We discuss the correlation between time profiles and spectral properties of microwave and X-ray observations for this BTL event sample.
L.K. Kashapova thanks the Russian Science Foundation grant 18-12-00172 for financial support.

Tracing of energetic electron beams in solar corona with imaging spectroscopy from MUSER

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The energy release during flare accelerates electrons in solar corona and these energetic electrons propagate along coronal magnetic field lines that appear as rapidly drifting structures in radio dynamic spectra. They are commonly known as Type III bursts. The Type III bursts identified in decimetric frequency range is typically associated with the location of electron acceleration and flare energy release. However, due to the limited imaging available at the decimetric frequency range, the exact location of electron acceleration and so the flare energy release has still remained poorly known. The new radio interferometer Miangtu Spectra Radio Heliograph (MUSER), operating in the frequency range 400-2000 MHz, has provided simultaneous spectral and imaging opportunities at the decimetric frequency range. Here we present MUSER spectral and imaging observations of decimetric Type III bursts with high spectral (25 MHz), spatial (1.3 to 50 arcsec) and temporal (25 ms) resolution. The strong narrow band Type III bursts are identified right at the start of a C2.3 solar flare. Subsequently, few seconds apart, a series of Type III bursts are identified coinciding with hard X-ray (HXR) and microwave radio burst activities. The MUSER images of these Type III bursts show propagation of radio sources along coronal magnetic field lines that located far from the location of HXR and microwave burst sources. Each Type III burst, as revealed by MUSER, show different line of propagation suggesting propagation of varying energetic electrons with different speed. The different source location of each energetic electron beam suggests the existence of multiple reconnection sites with a wide spaced energy release volume indicating that the flare energy release is fragmentary in nature.

The very beginning of the 2011 Jun 7 flare

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We present detailed analysis of the very beginning of the well-known 2011 Jun 7 flare as observed in radio, HXR, and UV emission. We found oscillations with the same period in the multi-wavelength data. Furthermore, temporal and spatial evolution of UV and HXR sources suggests their close relation to the early stage of the filament eruption. Results are discussed within the frame of reconnection model occurring in the low corona.

Simulations of microwave emission of solar and stellar active regions

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Institute of Solar-Terrestrial Physics, Russia

Solar active regions are known as sources of thermal gyroresonance and free-free emission in microwave range; this emission can be used to diagnose the magnetic field and plasma parameters. Quantitative interpretation of observations usually requires simulations with realistic three-dimensional models that account for many factors, including spherical geometry. I present here the new numerical tools that extend the existing framework for simulating the solar radio emission (e.g., GX Simulator) by adding the capabilities to build atmospheric models of active regions and compute gyroresonance and free-free emission from them in the spherical coordinate system. The new codes are freely available online. I present the simulation results (based on the PFSS magnetic field extrapolation) for a solar active region. The new codes have been also applied to simulate microwave emission of active regions on other solar-like stars, using the available information about their starspot and coronal parameters; the possibility to detect this emission is discussed.

Loss-cone instability modulation due to a magnetohydrodynamic sausage mode oscillation in the solar corona

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Solar flares often involve the acceleration of particles to relativistic energies and the generation of high-intensity bursts of radio emission. In some cases, the radio bursts can show periodic or quasiperiodic intensity pulsations. However, precisely how these pulsations are generated is still subject to debate. Prominent theories employ mechanisms such as periodic magnetic reconnection, magnetohydrodynamic (MHD) oscillations, or some combination of both. Here we report on high-cadence (0.25 seconds) radio imaging of a 228 MHz radio source pulsating with a period of 2.3 seconds during a solar flare on 2014-April-18. The pulsating source is due to an MHD sausage mode oscillation periodically triggering electron acceleration in the corona. The periodic electron acceleration results in the modulation of a loss-cone instability, ultimately resulting in pulsating plasma emission. The results show a complex combination of MHD oscillations and plasma instability modulation can lead to pulsating radio emission in astrophysical environments.

On the origin of non-stationary properties of QPP in radio emission of solar flares

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Radio emission of solar flare radio is a sensitive indicator of various processes showing a significant part of the information in time profiles. The interesting feature of time profiles is a quasi-periodic modulation superposed over a slowly varying trend, or quasi-periodic pulsations (QPP) frequently observing in solar flare emission. The main aim of techniques based on QPP analysis is to extract hidden parameters of the QPP (period, amplitude, phase). Usually, these parameters are considered as stationary or slowly varying. However, special attention should be given to the non-stationary (or time-dependent) parameters of QPP signals. The non-stationarity appears as a strong variation of the oscillation amplitude, period, or phase with time making the signal looking anharmonic. Such features could be caused by the time variations of the physical parameters in the flaring site or as a superposition of several physical processes ongoing simultaneously, including power-law distributed background noise. In this study, we reveal and analyze the non-stationary properties of QPP observed in the microwave radio emission of three solar flares (SOL2017-07-14T01:07, SOL2017-09-05T01:30, SOL2017-09-05T07:06). The characteristic time scales of the QPP are from 15 s to 400 s. Initially, we revealed the non-stationarity in the correlation plots of Siberian Radioheliograph (SRH-48). We carried out a study based on the available microwave data from different instruments to exclude instrumental effects and looked for the same properties in X-ray data. The periodic properties are analyzed using a unique combination of the analytical methods, such as the autocorrelation, Fourier periodogram, wavelet, and EMD. Impacts of the flare trend and colored noise are considered. We distinguish between the real time-dependent signals and signals whose non-stationary characteristics are due to multi-mode composition. This study was supported by RFBR according to the research project No. 17-52-10001.

ALMA Solar Script Generator: First step towards automated and robust processing of solar ALMA science data

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After more than three years of development and commissioning Solar ALMA Observing Mode has been introduced in early 2017 for acquiring science solar data with the ALMA observatory. The solar observations still work in so called "non-standard mode" which also means that the data calibration and interferometric synthesis (imaging) is being done manually - the Data Analysts at the ALMA Regional Centers (ARCs) or PIs (if they wish and are able to re-process the data) have to prepare 'ad hoc' calibration and imaging scripts tailored to a given dataset. This is a big difference to the standard (non-solar) ALMA observations, where the data undergo automated and robust pipeline calibration and imaging. However, even for the non-solar data the pipeline was not always the standard: Their calibration had started (a few years ago) also as fully manual, later being replaced by an intermediate semi-automated approach based on the "Script Generator" – a Python utility that researches inside the ALMA Measurement Set and creates the tailored calibration and imaging scripts automatically. In order to approach the Solar ALMA Observing Mode towards the standard calibration pipeline, we have started developing the Solar Script Generator - the collection of Python classes and their methods derived from those used in the non-solar Script Generator that incorporates specifics of the solar calibration and imaging procedures. In this contribution we shall present the current state and our vision of solar ALMA science data processing.

Statistical approach to frequency rising sub-terahertz emission from solar flares

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Sub-terahertz (sub-THz) emission from solar flares showing an increase of the spectral flux density with frequency has been of great interest, since its origin to date is unclear. Further, sub-THz radio observations may allow us to diagnose the properties of flaring plasma in the transition region and chromosphere, which is difficult using other methods. In this work, we conduct for the first time, a statistical study of flares with frequency rising sub-THz emission in the 200-400 GHz range. Assuming that thermal free-free emission is responsible for the sub-THz rising component, 17 solar flares with a growing spectrum have been considered in detail. Taking into account the effect of signal saturation, based on data from TRACE and SDO/AIA (1600 A), we estimate the areas of flare ribbons. The results demonstrate that large fluxes of sub-THz emission correspond to large flare ribbon areas. We conclude that the optically thick thermal plasma of the transition region makes the decisive contribution to the rising sub-THz component. Finally, we show that radiation losses from the heated dense plasma can provide the observed sub-second pulsations of the sub-THz emission.

Sub-THz radio emission from the 02.04.2017 solar flare

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Analysis of sub-THz emission from the M 6.4 class solar flare observed on April 2, 2017, by the Bauman Moscow State Technical University radiotelescope at frequencies 93 and 140 GHz is presented. It is found that the spectral flux density of radio emission increases with frequency. Based on the model of solar atmosphere provided by Machado et al. (1980) the contribution function of the radiation source was estimated. It is shown that the observed radiation is formed in a thin chromospheric interlayer with a thickness of about 10 km, in which the plasma temperature is about 0.1 MK. A homogeneous model of the interlayer is proposed, which makes it possible to explain the observed spectral features. Obtained results shown that the chromospheric flare source is heated by the hot flows generated in the overlying areas.

Using simulations and LOFAR observations to understand the speed and expansion of escaping solar electron beams

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Solar type III radio bursts contain a wealth of information about electron dynamics. They provide the best remote sensing diagnostics of electron beams escaping from the Sun and can simultaneously provide parameters of the solar corona and solar wind plasma they travel through. Studies routinely use type III bursts to estimate the bulk velocity of escaping electron beams from the Sun. However, the motion of different regions of an electron beam (front, middle and back) have never been systematically analysed before. We present our electron beam dynamics results which utilise both the high-resolution LOFAR observations and numerical simulations of escaping solar electron beam propagation through the solar corona. We show how type III frequency drift rates have rise times < decay times, driven by electron beam speeds being faster at the front of the beam and slower at the back. The difference in speed naturally elongates the beam in space. The energy density of electron beams strongly dictates their speed and expansion, and produces type IIIs with higher peak brightness temperatures. Higher background plasma temperatures also increase beam speeds, particularly at the back of the beam. Our radial predictions can be tested by the upcoming in situ measurements made by Solar Orbiter and Parker Solar Probe..

Microwave radiation of a flare loop in the presence of whistler turbulence

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Influence of whistlers on the nonthermal electrons' energy, pitch-angle, spatial distributions, and on characteristics of their gyrosynchrotron emission in a flaring loop is considered. We solve the problem in the frame of quasi-linear theory taking into account interrelation between whistler turbulence and nonthermal electrons propagating in an inhomogeneous magnetic loop. The system of kinetic equations in the Fokker–Planck approximation for fast electrons and in geometric optics approximation for whistlers is solved. As a result, we get electron temporal, spatial, energy, and pitch-angle distributions. Having found the fast electron distributions, the characteristics of their gyrosynchrotron microwave emission are calculated. It is shown that under some specific conditions interrelations of whistlers and electrons can considerably modify microwave emission characteristics of a flaring loop. The obtained findings are useful for microwave diagnostics of plasma turbulence and fast electron distributions in flare loops.

Plasma acceleration by the non-linear interaction of three crossed parallel Alfvén wave packets

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We are doing numerical simulation with a (PIC) code to interact a parallel Alfvén wave packet with two another parallel Alfvén wave packets that have already interacted. The crossing of the two initial Alfvén waves generates density gradients in the plasma (APAWI process, Mottez (2012, 2015)). Then, the passage of the third Alfvén wave across this interaction region gives rise to powerful accelerated electron beams in the parallel direction through phase-mixing process. The efficiency of this process depends substantially on the polarity and the amplitude of the wave packets.

Modelling of proton transport in application to solar long-duration gamma-ray events

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The discovery of solar >100 MeV gamma-ray events lasting for many hours has questioned the origin of high-energy ions required for the gamma-ray production, which was conventionally attributed to flares. The long-duration gamma-ray events are also associated with fast coronal mass ejections (CMEs), so an idea that the interacting ions can be accelerated in a CME-driven shock came into consideration. In this hypothesis, ions must be able to propagate from the shock downstream back to the solar surface. This point being under strong debate in the community requires thorough modelling. In this study, we model the transport of protons from the shock towards the Sun, assuming that it is diffusive. Application of a one-dimensional (1-D) model including only parallel (along magnetic field line) spatial diffusion shows that the proton transport is governed by the flux tube expansion parameter, controlling the mirroring of particles close to the solar surface, and the proton mean free path in the flux tube. For the cases considered, a larger flux tube expansion parameter and a shorter mean free path both lead to a smaller number of precipitating protons. We also apply a new 2-D transport model that includes perpendicular diffusion and a highly turbulent sheath behind the shock that can serve as a particle reservoir.

Abstracts: Oral contributions WG2

(Solar eruptions, CMEs, and shock waves)

Coronal magnetography using multiwavelength observations of the Sun by Siberian Radioheliograph

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The magnetic field is a key element in solar activity that controls most processes in the solar corona including energy accumulation and its explosive release during solar flares and coronal mass ejections. Thus, the information about the magnetic field in the solar corona is crucial for understanding and forecasting of geoeffective events such as solar flares and coronal mass ejections. At the level of the photosphere, the magnetic field can be measured directly using the Zeeman effect. Unfortunately, in the corona where plasma is extremely hot and rarefied, such measurements are not possible. Nowadays, the most valuable information about the magnetic field in the corona is obtained by its reconstruction from photospheric magnetograms in potential or force-free approximation. However, this approach has a number of difficulties connected with the underlying assumptions and available boundary conditions. Hence, the reconstruction methods are a subject of improvement. Here, observations in the microwave range can essentially help. Allowing us to measure the magnetic field in the corona directly, they can test the results of the extrapolation and provide additional constraints for its improving. We present the results of mapping the absolute value of the magnetic field at the transition region by observing gyroresonant emission at 32 frequencies in 4-8 GHz range with Siberian Radioheliograph (SRH). The absolute value of the magnetic field is estimated by determining the frequency where the brightness temperature of the microwave emission drops down to the chromospheric values. Also, we discuss a more rigorous approach of forward fitting synthetic microwave spectrum calculated from a 1D model of the solar atmosphere to the observed data. The parameters of the models are inferred using the Bayesian analysis and Markov chain Monte-Carlo sampling. The reliability of these methods has been tested on a realistic model of a solar active region created with the GX-simulator package and based on a 3D NLFF magnetic cube reconstructed from a photospheric magnetogram. The SRH data has been verified by comparing them with the RATAN-600 observations.
Thus, mapping the magnetic field in solar active regions is now available on a regular basis thanks to the routine spatially resolved multiwavelength observations of the Sun carried out by SRH team since 2016.
This work is supported by the RFBR grant18-32-20165 mol_a_ved.

Dynamics of microwave sources in eruptive flares on 23 July 2016 observed by the Siberian Radioheliograph, Nobeyama Radioheliograph, and SSRT

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Microwave emission can provide important information on processes in eruptive flares. Starting from 2016, the Siberian Radioheliograph (SRH) routinely supplies multi-frequency imaging and non-imaging data in total intensity and circular polarization. The observing frequencies of the SRH (five frequencies from 4 to 8 GHz), Siberian Solar Radio Telescope (SSRT, 5.7 GHz), and Nobeyama Radioheliograph (NoRH, 17 and 34 GHz) sample both sides of the gyrosynchrotron spectrum around the turnover frequency for most flares. We address two eruptive flares that occurred on 23 July 2016 in the same active region 12565 located near the west limb. Combining microwave observations of the two events, we follow the dynamics of microwave sources in different parts of the gyrosynchrotron spectrum and identify the structures visible in microwave images. Invoking extreme-ultraviolet and X-ray data, we pursue understanding the nature and properties of microwave sources and reconstruct the overall picture of the eruptive flares.

Termination shocks in reconnection outflow jets: constraints from radio & EUV observations and numerical simulations

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The existence of fast-mode termination shocks in reconnection outflow jets has been predicted by theory and supported by the observation of stationary type II - like radio sources in the decimetric-metric regime. These classical observations will be reviewed and then compared to more recent microwave observations of a possible termination shock. The emphasis will be on how the observations can be used to constrain the shock parameters. Then, recent results from UV spectroscopy that could be attributed to termination shocks will be set into the context. The various observational characteristics will then be compared to the results of stat-of-the-art numerical simulations. Finally, the possible role of termination shocks for particle acceleration will be discussed.

Solar radio bursts associated with standing shock waves (termination shocks)

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The standard model of the solar flare in the region of magnetic reconnection contains fast shock fronts outgoing upward and downward from the current sheet. This conventional scheme is used to interpret many flare phenomena observed in extreme ultraviolet, hard X-ray and radio emission. To explain the numerous data SDO and RHESSI, as well as radio bursts (including various fine structures of radio emission), the appearance of accelerated particles is often associated with acceleration on the shock front. In recent years, this acceleration has been attributed to a standing shock wave (termination shock), and in a number of works (Aurass, Mann, Warmuth (2009)), the slowing down of frequency drift of bursts similar to type II bursts (and even their reverse drift) is associated with this phenomenon. An additional confirmation of this mechanism is given in Chen, Bastian et al. (2015). At the same time, classical type II bursts always observed in large flares (with initial frequencies in the meter range) are usually not associated with these shock fronts. It is believed that they are caused by coronal matter emissions (CME), which excite piston shock waves. But in the decimeter and microwave ranges, there are sometimes unusual bands in the radiation (slowly drifting to both low and high frequencies), similar to short-term bursts of type II. The numerous examples of spectra of presented here such bursts give grounds for assuming their connection with termination shocks, moreover with both the lower and the upper outgoing fronts. The lower termination shock is explained by the collision of the shock front with a closed flare loop, and the upper termination shock can be caused by a collision of the upper front with the global loop located above (or with a magnetic cloud, a potential CME). Drift acceleration of particles in a termination shock should lead to the generation of fast radio bursts such as spikes and bursts in soft and hard X-rays. In all considered here events these bursts are revealed. We considered four events with radio bursts in the decimeter and microwave ranges, similar to meter type II bursts. Estimates of the critical Mach number Mcr for ordinary parameters of a flare plasma showed that the obtained values (Mcr = 1.2–1.4) can be easily realized in the events under consideration, and the radiation can be associated with the Buneman instability. Thus, we actually observed miniature type II bursts.

Imaging Solved Solar Radio Burst Associated with Initiation of a CME and a Low Coronal Shock

Suli Ma, Yao Chen, Huadong Chen, Chengming Tan, Baolin Tan, Yan Yihua

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We present a study of a complicated solar radio burst and its associated CME and low coronal shock occurred on 2013 Nov 19, by mainly using the data from the Atmospheric Imaging Assembly (AIA) and Nancay Radioheliograph. The evolution of the CME along with the radio sources and are displayed. The relationship between the radio sources, CME, and shock as well as the radio emission mechanism are discussed.

Insights into Coronal Mass Ejection Shocks with the Irish Low Frequency Array (I-LOFAR)

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The Sun can produce large-scale energetic events such as solar flares and coronal mass ejections (CMEs) which can excite shock waves that propagate through the corona. To date, the shock kinematics responsible for particle acceleration and emission at radio wavelengths are not well understood. Here, we investigate these phenomena using radio observations of the 2017 September 2, C7.7 solar flare at 10-240 MHz from Irish Low Frequency Array (I-LOFAR, www.lofar.ie). We investigate the relationship between the features in I-LOFAR's dynamics spectra and the shock kinematics as derived from imaging observations using the GOES/SUVI and SOHO/LASCO C2. We calculated the shock Mach number from both shock geometry in SUVI and modelling of coronal Alfvén speed. The relationship between shock characteristics from SUVI and data driven modelling are compared to shock characteristics from radio in order to determine the plausibility of shock accelerated electron release into the solar corona.

The effect of scattering on split-band Type II solar radio bursts

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Shocks driven by coronal mass ejections (CMEs) can accelerate electrons which through the plasma emission mechanism can produce radio signatures known as Type II solar radio bursts. A characteristic of some Type II bursts is the splitting of a harmonic band into thinner lanes, a phenomenon known as band splitting. We present a detailed imaging and spectroscopic observation of a split-band Type II burst recorded with the LOw-Frequency ARray (LOFAR). We show, for the first time, simultaneous images of the higher- and lower-frequency sub-band sources and find that they experience a large separation. The effect of radio-wave scattering—the dominant process affecting radio waves—is taken into account. We find that the amount by which scattering shifts the true location of a lower-frequency source is larger than the shift of a higher-frequency source such that two sources originating from virtually co-spatial regions will appear to be significantly separated. This provides supporting evidence for band-splitting models that require the emission sources of a split-band Type II burst to originate from nearly the same spatial location, like the model attributing band splitting to radiation emitted from the upstream and downstream regions of a shock front.

Radio Imaging of Signatures of Shock Accelerated Electrons during Coronal Mass Ejections

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The Sun is an active star that produces the most powerful explosions in the solar system, solar flares, often accompanied by coronal mass ejections (CMEs) that drive collisionless shocks in the corona. CME shocks are efficient particle accelerators and shock signatures associated with CMEs are often observed as solar radio bursts that move with the expanding CME. However, the relationship between radio shock signatures on the Sun and the expansion of a CME is still not well understood due to previous limitations of low radio frequency imaging (<200 MHz) where the most dramatic acceleration is believed to occur. Here, we exploit unique observations from the Low Frequency Array (LOFAR) of a strong X8.2-class solar flare and its associated very fast CME (3000 km/s). In particular, we image for the first time a multitude of radio shock signatures called herringbones with LOFAR. We also exploit another unique dataset from the Nancay Radioheliograph (NRH) of an M1.9-class flare associated with multiple moving radio bursts also accompanying a fast CME (1000 km/s). Using multi-wavelength analysis, we provide convincing evidence for shock accelerated electrons at multiple locations on the expanding CME flanks during the two separate coronal mass ejections observed.

Complex shock wave signatures associated with CME on September 27/28, 2012

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Eruptive events such as Coronal mass ejections (CMEs) and flares can accelerate particles and generate shock waves. Tracking of shock waves and predicting their arrival at the Earth is an important scientific goal. Space based radio observations provide us the unique opportunity to track shock waves in the inner heliosphere. We present study of the CME/flare event on September 27/28, 2012. The GOES C3.7 flare that originated from NOAA AR 1577 was associated with a full-halo CME (first seen in the SOHO/LASCO C2 field of view at 23:47 UT) and white light shock wave observed by all three spacecraft STEREO A, STEREO B, and SOHO. The associated radio event shows a group of type III bursts and two somewhat unusual type II bursts with significantly different starting frequencies. To understand the origin of the two shock waves we performed multi-wavelength and radio triangulation study. For the radio triangulation we used goniopolarimetric measurements from STEREO/WAVES and WIND/WAVES instruments. We also model propagation of the CME using the data-driven EUHFORIA cone model (EUropean Heliospheric FORecasting Information Asset) and compared results with in-situ observations. Results of this study indicate that, although temporal association between the shocks and the CME is good, the low frequency type II burst occurs significantly higher in the solar corona than the associated CME and has therefore unclear origin. Our analysis indicates that the interaction of the shock wave and the nearby streamer, situated close to the southern polar coronal hole, is the most probable source of the observed low frequency type II burst. We also demonstrate the importance of radio triangulation studies in understanding the relationship between the CMEs and associated radio emissions.

A Dynamic Model of Flux Ropes

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Developing ideas of the paper Zaitsev & Stepanov (JASTP, 2018) with regards to activation of a current-carrying filament with an increase in electric current, in which the Ampère force is opposed by gravity and medium viscosity, we take into account the influence of an external magnetic field. It is shown that, depending on mutual directions of the external magnetic field and electric current in the flux rope, the additional Ampère force can lead to the deceleration or to additional eruption of the flux rope. A phase diagram describing the peculiarities of flux rope dynamics has been constructed. The maximum height and velocity of the flux ropes are determined for several active events.

Relationship of EIT Waves Phenomena with Coronal Mass Ejections

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In the present paper, we have studied the relationship of Extreme Ultraviolet Imaging Telescope (EIT) waves phenomena with coronal mass ejections (CME) events. This study is a part of our research work to understand the origin of CMEs and its relationship with EIT waves phenomena. To carry out this study we have used EIT waves list (March 25, 1997-June 17, 1998) published by Thompson & Myers (2009) and CMEs data for the same period observed by LASCO/ SOHO. The EIT/ SOHO instrument recorded 176 EIT events during above period and after matching with CMEs phenomena we find that corresponding to 84 EIT wave events, no CMEs events were recorded and thus we excluded 84 EIT wave events from the present study. Out of 176 EIT wave events, only 92 are accompanied by CMEs phenomena. The correlation study of the speed of EIT wave events and CMEs events of 92 events shows poor correlation r=0.21 indicate that the EIT wave and CMEs events do not have a common mechanism of origin. Earlier Verma & Pande (1989), Verma (1998) and recently Verma & Mittal (2019) reported that the CMEs may have been produced by some mechanism, in which the mass ejected by solar flares or active prominences, gets connected with the open magnetic lines of CHs (source of high-speed solar wind streams) and moves along them to appear as CMEs. The results obtained in the present are also discussed in the view of the recent scenario of heliophysics.

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Extreme narrow-band radio emission associated with a moderate X-ray flare

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Very strong narrow-band radio emissions (>10^4 sfu) are sometimes observed in the 1GHz-2GHz range in association with moderate X-ray class flares. One of these extreme events (with a flux >10^5 sfu) has been shown recently to be responsible for a disturbance of aeronautical radio navigation (see Marqué et al., 2018). We shall present in this talk another example of a GOES M-class flare (18 November 2003) producing an episode (around 10 minutes) of very strong (>10^4 sfu) narrow-band emission around 1GHz. We will present combined observations from RHESSI, the Radio Solar Telescope Network (RSTN) and the PHOENIX spectrograph to investigate the possible emission mechanisms leading to the extreme narrow-band emissions. We shall also examine the conditions in the flaring active region which could lead to these strong radio enhancements.

On the Study of Stationary Type IV Radio Sources

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The conditions of the Solar System medium are governed by the solar activity, CMEs are the magnetic structures that mostly affect the geomagnetic field causing geomagnetic storms at the Earth. During their evolution in the solar corona, CMEs are usually associated to radio sources, which are related to the magnetic configuration of the solar corona. In particular, stationary type IV radio bursts are associated to electrons trapped in close magnetic configurations, more often observed at the place of the CME eruption. Since the CME magnetic structure remains rooted to the Sun close to the place of post-flare loops, in this work we aim to investigate if the stationary type IV emission comes from the base of the CME structure, and if electrons are emitted via plasma emission. We conducted a detailed analysis of radio observations (Nançay Radio Heliograph and Nançcay Decametre Array, ARTEMIS, Wind/Waves spectrograph), remote-sensing observations of the corona in extreme ultraviolet (EUV) and white light as well as time histories of SXR flux measurements by GOES satellites in the 0.1-0.8 nm, to study the evolution of eight radio sources and to identify the emission mechanism associated to them. We found that stationary type IV sources were, effectively, located at the post-flare loops structures, that they presented substantial polarisation degree as well as high values of brightness temperature which confirms that emission mechanism associated to these sources is plasma emission. Since the emission mechanism was identified, we also investigated their polarisation sense in order to provide an estimation of the orientation of the CME flux rope in the corona. We found that the results are consistent with the magnetic field orientation measured in the photosphere. Because the direction of the CME flux rope is one of the most relevant properties for space weather forecasting, this work presents the polarisation of stationary type IV radio sources as a potential tool to derive the orientation of their flux ropes in the solar corona.

Interferometer observations of Type III, Type II and Type IV bursts at 20 and 25 MHz on 29 May 2014

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Results of interferometer observations of Type IV durst, Type III bursts and Type II bursts by the UTR-2 radio telescope at frequencies 20 and 25 MHz on 29 May 2014 are discussed. For interferometer observations we used 4 sections of west-east arm of UTR-2 the radio telescope. These observations were supported by the URAN-2 radio telescope observations in the usual spectrographic regime. There were eight bright Type III bursts, some parts of Type II burst and Type IV burst during the event happened from 9:06 till 11:15 UT. We found that the source of the stationary Type IV burst was situated at the distance of 30-35 arcmin at both frequencies and had unchanged sizes of 27 and 37 arcmin at frequencies 25 and 20 MHz correspondingly. Parts of Type II burst and their fine structures were at distances from 25 to 30 arcmin at these frequencies. Their sizes were in the range 10-24 arcmin. We also measured distances and sizes of eight bright Type III bursts occurred from 9:06 to 11:15 UT. Sources places were turned out to be about 41-43 and 45-47 arcmin from the center of the Sun. At these distances radio emission at frequencies 25 and 20 MHz are radiated at the second harmonic in the Newkirk model. This result is confirmed by the low polarizations of all Type III bursts, which according to URAN-2 radio telescope were not higher than 5%. Sizes of Type III sources were 20-22 and 24-27 arcmin at frequencies 25 and 20 MHz correspondingly. This gives the brightness temperatures of Type III bursts in the range 2x10^9- 4x10^10 K. We also found that velocities of Type III electrons were 0.2-0.3c.

Dispersive fast wave trains in magnetically coupled atmosphere above a sunspot and coronal heating problem

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Flare magnetic field energy transferred to the solar outer atmosphere by magnetohydrodynamic waves can help solve the coronal heating problem. There is an unclear mechanism of wave transfer from the photosphere without a dissipation/reflection before reaching the corona and a mechanism of the wave energy distribution over corona outside the original waveguide. We report about flare plasma flows accompanied with impulsively generated fast magnetoacoustic wave trains propagating in cylindrical plasma waveguides. A common behaviour of the (E)UV plasma flows and wave trains in all atmospheric layers was observed by SDO/AIA and IRIS space instruments. Magnetically coupled solar atmosphere above a sunspot umbra was assumed. The solar seismology with trapped, leakage, and excited modes of the dispersive waves (dissipating especially in the solar corona) is discussed with respect to their possible contribution to the outer atmosphere heating.

First LOFAR interferometric observations of a solar X-class flare

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On 7 September 2017, we obtained the first interferometric imaging observations with LOFAR of a series of solar flares, including an X-class event. LOFAR dynamic spectra of these show several type III and a weak type II radio burst. We generate imaging time series from the interferometric data on several frequencies in LOFAR\'s low band, despite the large separation between the Sun and Tau A as external calibration source. We derive radio brightness curves from the imaging observations of the type III event associated with an M-class flare, and compare them to RHESSI X-ray fluxes, while both radio and X-ray intensities increase over several orders of magnitude within seconds. The X-class flare, associated with the type II event, is not accompanied by type III bursts or a strong increase of radio flux. This indicates that the flaring plasma stayed confined in the solar corona.

Microwave observations with the Siberian Radioheliograph

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The Siberian Radioheliograph (SRH) is a new multi-frequency interferometer located in the radio-quiet Badary area, 220 km southwest from Irkutsk, Russia. The SRH has a T-shaped 48-antenna array with a longest baseline of 107.4 m and routinely observes the Sun in the 4–8 GHz frequency range. We focus on our activities in the SRH data processing, including calibration methods and image-synthesis algorithms. We demonstrate SRH capabilities to trace the evolution of various solar phenomena in the microwave range by using examples of some eruptive events detected.

Abstracts: Oral contributions WG3

(Turbulent corona, radio wave propagation, and new instruments/capabilities)

Radio wave scattering in anisotropic density turbulence of the solar corona: simulations and implications for radio observations

Eduard P. Kontar, X. Chen, Nicolina Chrysaphi, Natasha L.S. Jeffrey, A. Gordon Emslie, Vratislav Krupar, Milan Maksimovic, Mykola Gordovskyy, and Philippa K. Browning

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Solar radio emission is produced in turbulent plasma of the solar atmosphere. Therefore, all radio observations are strongly affected by radio wave propagation effects. The density turbulence as well as the large scale density play an important role in the radio emission wave propagation. The stochastic description of radiowave transport in asymmetric, anisotropic density turbulence is presented. The simulations predict the observable parameters of plasma radio emission allowing interpretation of solar radio burst.

Frequency-distance structure of the solar radio sources observed by LOFAR

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Low-frequency radio observations make it possible to study the solar corona at distances up to 2–3 solar radii. Frequency of plasma emission is a proxy for electron density of the emitting plasma and, therefore, observations of solar radio bursts can be used to probe the density structure of the outer corona. In this study, positions of solar radio sources are investigated using LOFAR spectral imaging data in the frequency range 30-50 MHz. We show that there are events where apparent positions of the radio sources cannot be explained using the standard coronal density models (such as Newkirk, Baumbach-Allen and Saito models). Namely, the apparent heliocentric positions of the sources are 0.1–0.7 solar radii further from the Sun compared with model predictions, and these shifts are frequency-dependent. We discuss several possible explanations for this effect, including enhanced density in the flaring corona, as well as scattering and refraction of the radio waves due to the plasma turbulence.

Radio Propagation Diagnostics of the Inner Heliosphere in the Era of the Parker Solar Probe

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A variety of radio propagation techniques can be used to probe regions in the corona and solar wind that are otherwise inaccessible to direct observation. One of these is angular broadening observations, which allow the wave structure function D(s) of solar wind to be measured rather directly; s is the projected distance between any two antennas which, for the Jansky Very Large Array, ranges from ~0.1 up to several 10s of km. This, in turn, allows properties of the spatial spectrum of electron density fluctuations to be determined on small spatial scales, including the power law index, the degree of anisotropy, the presence of an inner scale, and the orientation of the local magnetic field. Another technique is refractive scintillation, caused by weak focusing and defocusing effects on much larger spatial scales - 100s to 1000s of km. We present pilot observations made by the JVLA in 2015 to illustrate their potential for deducing key properties of solar wind turbulence in the inner heliosphere. We discuss prospects for exploiting these techniques in a more systematic way in the era of the Parker Solar Probe and the Solar Obiter.

The simulated results of the Interplanetary Scintillation antenna system

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Interplanetary scintillation (IPS) remote-sensing observation provides a view of the solar wind covering a wide range of heliographic latitudes and heliocentric distances from the Sun between ~0.1 AU and 3.0 AU. It is used to study the development of solar transients and the solar wind while propagating out. Now, in China, a new IPS telescope will be established in recent years, three 140m*50m parabolic cylindrical antenna will be set in the main site. The observing frequency is at 327MHz and 654MHz, the feed array is located in the focal plane. A type of the microstrip antenna is presented. The return loss of this kind of feed is enhanced by optimizing the size of the feed line and the reflector, the following work is to choose he number of the feeds and find a proper way to get the maximum gain of the whole antenna system.

Pulsars track the Solar wind

Caterina Tiburzi

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The dispersive delay of the Solar wind introduces excess noise in high-precision pulsar-timing, which must be removed in order to achieve the accuracy needed to detect, e.g., low-frequency gravitational waves with pulsar timing array experiments. New, highly-sensitive test-bed for Solar wind effect in pulsar timing can be provided by low-frequency observations. In addition to this, the magnetic field of the Solar wind also modifies the polarization properties of pulsars through Faraday rotation. However, this allows us to exploit pulsars to probe the Solar wind in both its electron and magnetic content.

MHD-shear instability in solar wind plasma with anisotropy and heat flux effects

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We investigated a shear instability of the Kelvin-Helmholtz (KH) type in a plasma with temperature anisotropy under the MHD approximation. To solve the problem, a system of 16-moment MHD transport equations are used. We consider supersonic flows of two semi-infinite anisotropic and homogeneous plasma layers with different physical parameters and velocities. For the general case, i.e.\ when the interface between these two flows is a transition layer with a finite thickness, we derived a general linear differential equation framework for determining the eigenmodes in the system. Furthermore, we considered thoroughly the limiting case of a zero thickness transition zone (contact discontinuity). The analysis enabled applying appropriate boundary conditions to derive the dispersion equation for interface waves. The obtained equation is analyzed in detail with heat flux effect.

Imaging of the Solar Atmosphere in K-Band through Single-Dish Observations

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INAF - Osservatorio Astronomico di Cagliari, Italy

Single-dish mapping of the brightness temperature of the solar atmosphere in the radio band reveals free-free emission mostly originated by processes in local thermodynamic equilibrium plasma. In particular, long-term diachronic observations of the solar disk in K-band represents an effective tool to characterise the vertical structure and physical conditions of the solar chromosphere both for quiet and active regions, during their evolution at different phases of the solar cycle. We are performing continuum imaging of the solar chromosphere at 18-26.5 GHz (spatial resolution ~1 arcmin) by the 32-m diameter Medicina radio telescope and by the 64-m diameter Sardinia Radio Telescope (SRT), as a first scientific demonstration test for the potentialities of Italian single-dish antennas in this field. After a first test campaign aimed at defining and optimising hw/sw solar imaging requirements for the radio telescopes, the system will be fully ready in 2020 for systematic monitoring of the Sun providing: (1) accurate measurement of the brightness temperature of the quiet Sun radio component, presently poorly known in the 20-26 GHz range, and representing a significant constraint for atmospheric models; (2) characterisation of the flux density, spectral properties and long-term evolution of dynamical features (active regions, coronal holes, loop systems, streamers and the coronal plateau); (3) prediction tools for powerful flares through the detection of peculiar spectral variations in active regions, as a valuable forecasting aid for the Space Weather hazard network. We plan to publish our solar images on a dedicated web site, just after each solar observing session to ease their full exploitation by the wide multi-wavelength solar community, empowering both physical modelling and Space Weather forecast. We will present K-band solar images obtained during our early observations and prospects for joint observations with other facilities.

First high-resolution look at the quiet Sun with ALMA

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We present an overview of two sets of high resolution quiet Sun observations obtained with the Atacama Large mm and sub-mm Array (ALMA). The first set consisted of observations of seven regions from disk center to the limb at 3 mm, while the second set consisted of observations of a region close to disk center obtained sequentially at 1 mm and 3 mm. We produced both average and snapshot images by self-calibrating the ALMA visibilities and combining the interferometric images with full disk solar images. The spatial resolution of the images was better than 2.5'' by 4.5'' while their cadence was 1-2 s. The images show well the chromospheric network with a slight decrease of network/intranetwork contrast toward the limb. We detected spicular structures, rising up to 15'' above the limb with a width down to the image resolution and brightness temperature of ~1800 K above the local background. No trace of spicules, either in emission or absorption, was found on the disk. Several transient features were detected during the observations. We also observed p-mode oscillations with a peak frequency of 3.6 mHz. Our results highlight ALMA's potential for the study of the quiet chromosphere.

Recent results of multiwavelength observations with the radio telescope RATAN-600

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Special Astrophysical Observatory, Russia

We present the latest results obtained from the analysis of the RATAN-600 (Radio Astronomical Telescope of the Russian Academy of Sciences) observations in a wide range of wavelengths (3-18 GHz, in Stokes parameters I and V). The technical characteristics of the instrument make it possible to study solar radio emission of a variety of objects of different physical nature: from the chromosphere to the lower corona, from low-contrast supergranulation network and coronal holes to powerful bursts; the entire magnetosphere of active regions including spot sources, peculiar sources, halo, floccules and coronal loops. RATAN observations are also capable of providing data on fast events such as CME and jets. It is particularly important to carry out these studies, combining radio observations with data from optical, ultraviolet and X-ray instruments; extending magnetic field measurements with its modeling extrapolations into the corona, and taking into consideration various modeling methods to diagnose physical parameters of the emitting plasma. In this contribution we present recent examples of such studies. We used simulations and combined observations with RATAN-600 and ALMA to study solar atmosphere above sunspots. The simulations of spot radiation at short wavelengths allowed to reveal its lesser known properties such as the contribution of the 4-th harmonic of the gyro-radiation in extraordinary mode and the depression of the free-free radiation in ordinary mode. We also present an example of a fast-changing event. Based on the data from RATAN-600, RHESSI, and SDO spacecrafts, the analysis of the fine temporal structure of radiation in the solar B-class microflare was carried out. The quasi-periodic pulsations of radio emission with periods of 1.4 and 0.7 c were found. The registered temporal behavior of the parameter V in the RATAN-600 data showed the presence of the misbalance of the left- and right-hand polarized signals. This misbalance was interpreted as some asymmetry of nonthermal electron jets propagating downwards along the opposite legs of a flare loop. The properties of radio emission modulated by the pulsations, the geometry of the flaring region and associated spectrum of X-ray radiation allowed to interpret this event as a manifestation of the fast magnetoacoustic sausage oscillations of flaring loops. This work is supported by Grant 18-29-21016 and by Grant 18-02-00045 of the Russian Foundation for Basic Research.

Dynamics of long-lived facular formations

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The dynamic properties of small-scale, long-lived solitary magnetic structures on the solar photosphere, the so-called facular formations (FFs), are considered. FFs magnetic field varies from 350 to 1100 G, lifetime is about 10-35h and characteristic size just about 1500 km. The horizontal velocities of the FFs are studied relative to the speed of the differential rotation of the Sun, calculated in various ways. Using the long time-series (dozens hours) of magnetic field changes, it is shown that FFs have a complex dynamics associated with convective flows in supergranulation cells. The corrections to the FFs velocities on the solar photosphere relative to the speed of differential rotation at different latitudes are calculated. Their absolute values are found up to 2 km / s.

Immediate prospects of the Siberian Radio Heliograph

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The Siberian Radio Heliograph (SRH) is a 48-antenna T-shaped antenna array that uses Fourier synthesis for imaging the Sun in the 4-8 GHz frequency band. The image cadence of the SRH in single-frequency mode is about 0.2 s. The spectral resolution is 10 MHz and the number of frequency channels recorded sequentially is up to 64. The real time data of the SRH are at website http://badary.iszf.irk.ru/corrPlot.php. In this talk the immediate prospects of the SRH are presented. The new SRH will consist of three T-shaped antenna array for frequency ranges of 3-6, 6-12 and 12-24 GHz with spatial resolution up to 15, 12 and 6 arcsec respectively. The mounts of the new antennas will be alt-azimuth. The antenna array redundancy is provided. RF over fiber architecture will be used for antenna signal transmission. The dual polarization feeds, antenna front-ends, digital receivers and the correlator are described in detail and first results of test observations with new equipment are presented. The 3-6 GHz array should be built at the end of this year, the other two arrays - at the end of next year.

High dynamic range imaging of the Sun with the Siberian Radioheliograph

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The Siberian Radioheliograph (SRH) is capable of obtaining solar disk images at angular resolution of about 1 arcminute in 4 - 8 GHz frequency range. The time to switch from one frequency to another is currently about 0.3 s. The SRH calibration with redundant baselines provides the dynamic range from 40:1 for quiet Sun to several hundreds for flares. This is insufficient to observe faint solar features during powerful flare bursts. We consider factors that affect the dynamic range of SRH images and methods that can be used to enhance it, including those available in CASA.

Imaging the Solar Corona during the 2015 March 20 Eclipse using LOFAR

Aoife M. Ryan, Peter T. Gallagher , Eoin P. Carley, Diana E. Morosan, Michiel A. Brentjens , Pietro Zucca, Richard Fallows, Christian Vocks , Gottfried Mann, Frank Breitling, Jasmina Magdalenic, Alain Kerdraon, Hamish Reid

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The solar corona is a highly-structured plasma which reaches temperatures of more than ~2MK. At low radio frequencies (≤ 400 MHz), scattering and refraction of electromagnetic waves are thought to broaden sources to several arcminutes. However, exactly how source size relates to scattering due to turbulence is still subject to investigation. This is mainly due to the lack of high spatial resolution observations of the solar corona at low frequencies. Here, we use the LOw Frequency ARray (LOFAR) to observe the solar corona at 120-180 MHz using baselines of up to ~3.5 km (~1--2') during a partial solar eclipse of 2015 March 20. We use a lunar de-occultation technique to achieve higher spatial resolution than that attainable via traditional interferometric imaging. This provides a means of studying source sizes in the corona that are smaller than the angular width of the interferometric point spread function.

Study of Quiet Sun Low Frequency Emission Using MWA

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The Sun is very dynamic at metrewavelengths along both frequency and time, even during periods of low solar activity. A possible reason for this observed variability can be the presence of weak energetic events or scattering of radio waves from density inhomogeneities. High sensitivity data from new generation instruments like the Murchison Widefield Array (MWA) provide an opportunity to study these weak emissions. The MWA, located in Western Australia, is an excellent instrument to study the Sun at metrewavelengths. MWA covers a good frequency range from 80 to 300 MHz spanning a large range in coronal heights from 0.08 to 0.65 R$_{sun}$ simultaneously in meterwaves. We study radio emission from the quietest time observed by MWA. Quiet Sun brightness temperature maps reveal the variability of the order of ~ 2-5%. The observed variability shows a spatial association with the structures seen at EUV wavelengths. The low-level temporal variability can be attributed to the scattering by density inhomogeneities present at various coronal heights or weak energetic nanoflare-like events. The coronal radio emission itself varies across height suggesting large scale structural variation or a transition from weak scattering to strong scattering regime. The results from the non-imaging and imaging analysis of quiet Sun observations from the MWA will be presented.

Abstracts: Oral contributions WG4

(Radio burst fine structures, solar transients in the heliosphere, and space weather)

Random excitation of decay-less transverse oscillations of coronal loops

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Some of the observed quasi-periodic pulsations of solar flare emission are interpreted as a result of the impact of external perturbations on a flare process. Such perturbations can be generated by transverse loop oscillations detected abundantly in the solar corona. We study the excitation mechanism of transverse oscillations of coronal loops to get insight into the nature of quasi periodic pulsations. The relatively large-amplitude decaying regime of transverse oscillations of coronal loops has been known for two decades. They decay fast (in several oscillation cycles) and are interpreted in terms of MHD kink modes of cylindrical plasma waveguides. Analysis of SDO/AIA data has revealed also decay-less small-amplitude oscillations, with a multi-harmonic structure being detected. Several models were proposed to explain them. In particular, decay-less oscillations were interpreted in terms of standing kink waves driven with continuous monoperiodic motions of the loop footpoints, in terms of a simple oscillator model of forced oscillations due to harmonic external force, and as a self-oscillatory process due to the interaction of loops with quasi-steady flows. We consider the model of standing waves driven by random motions of the loop footpoints. The footpoint motions are modelled by broad-band coloured noise with the Kolmogorov exponent. We analyse the excitation of eigenmodes, frequency ratios of eigenmodes, and spatial distribution of the oscillation energy along the loop, taking into account effects of damping and varying kink speed. Our findings can be of importance for interpretation of the fine structure of solar emission. They can also contribute into seismological techniques applied to determine coronal plasma parameters.

Coronal loops diagnostics through the parameters of type U burst with equally developed branches

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Solar inverted U-bursts are manifestations of fast electron beams moving along closed magnetic field lines – coronal loops. We report about the solar inverted U-burst with equally developed ascending and descending branches observed with the new Ukrainian radio telescope GURT operated in frequency band 8-75 MHz. Such symmetric U-bursts are extremely rare events. The turning frequency of this burst equaled 57 MHz and absolute frequency drift rates of the ascending and descending branches at frequency 70 MHz were both equal to 4MHz/s. Neighboring type III bursts drifted 5 times of magnitude faster at the same frequency. Assuming the Newkirk coronal density model the velocity of the electrons responsible for the type III burst generation appeared to be 0.25c. Since there was the only active region on the Eastern limb of the Sun (NOAA 12651) we supposed that electron beams associated with inverted U and type III bursts originated from the same source and thus might have equal velocities, i.e. 0.25c. Under this assumption the length of the coronal loop segment which corresponds to the U-burst bounded by points at frequency of 70 MHz was found to be 0.94Rs, where Rs is the solar radius. Then we suppose that the plasma confined within the coronal loop is completely isolated from the ambient solar corona by the magnetic field of the loop. This plasma is supposed to be isothermal and following barometric (Boltzman) density distribution law. The temporal and frequency parameters of the inverted U burst allow us to retrieve the geometry of the part of the coronal loop associated with the observed fragment of the U-burst under given plasma temperature. For temperature of 1.4MK the coronal loop should be as high as 3.5Rs. To satisfy U-burst parameters the shape of the loop should be elliptical with radial to transvers axes ratio of 2:1. According to our analysis two unknown parameters of the loop – its height and confined plasma temperature are connected in such a way that the higher the loop the colder the confined plasma and vice versa. So for unambiguous determination of one of these two parameters another one has to be defined by either method. For example the height of the loop can be defined through source imaging methods realized at LOFAR and NenuFAR radio telescopes.

Growth-rates of the electrostatic waves in the double plasma resonance model of solar radio zebras

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Radio zebras are detected in radio observations from Sun, Jupiter and also from Crab Nebula pulsar. In solar case, they are fine structures of Type IV bursts and can be used for diagnostics of flare plasma parameters (density, magnetic field). One of the models of the solar radio zebra is based on the double plasma resonance instability, which supposes the dense and cold background isotropic plasma and rare hot component with a loss-cone type of the distribution function. At resonances between the plasma and cyclotron frequency, $\omega_{pe} = s\ \omega_{ce}$ (s is an integer), this instability generates the upper-hybrid waves which are transformed into electromagnetic radiation and emitted in a narrow cone towards the observer.
We used analytical theory for growth-rates and 3D electromagnetic relativistic Particle-in-Cell simulation for an analysis of this instability. For DGH velocity distribution function of hot electrons we found that increasing its temperature the growth-rate maxima are shifted to lower values of the ratio ω_{pe}/ω_{ce} and for temperatures $v_t \geq 0.3\ c$ the maxima are not distinguishable. From zebra observations, we estimated the brightness temperature of the zebra source, its size, the energy density in the source and the conversion rate to electromagnetic waves. We also calculated the growth-rates for loss-cone power-law and loss-cone kappa distributions having different loss-cone angles.

Spikes detected in Type II metric Radio bursts

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We report the detection of Type II-associated spike-like structures, in dynamic spectra obtained with the Artemis-JLS (ARTEMIS-IV) solar radio spectrograph. We selected 4 events recorded by the Artemis-JLS/SAO receiver in the 270-450 MHz range; the high time resolution (10ms) of this receiver facilitates fine structure detection and analysis on dynamic spectra. The spike-like structures observed were found to co-exist with herring-bones or pulsations. More than 600 short narrowband spikes were identified and their parameters (duration, bandwidth) were computed. These structures mainly appear in chains which drift almost parallel to the harmonic emission band of the Type II front, which is within the frequency range of the SAO receiver. Single isolated bursts have been rarely detected. The average duration and relative bandwidth were about 96 ms and 1.7% respectively. These values are very close to those of the spikes embedded in Type IV bursts, in the same frequency range. Small-scale reconnection along the front of the Type II burst could be the origin of the detected spikes.

High resolution observations of Intermediate Drift Bursts with the ARTEMIS-JLS Radio spectrograph and the Nançay Radioheliograph

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We used high time resolution dynamic spectra from the ARTEMIS-JLS solar radiospectrograph for the study of intermediate drift bursts. We found average fiber exciter speed of 5900 2400 km s-1, corresponding to average magnetic field of 4.6 1.5G for whistler exciter and consistent with values estimated by other methods. A simplified model of magnetic field along the exciter trajectory, gave an average frequency scale length of 220Mm and a ratio of the whistler frequency to the electron cyclotron frequency in the range of 0.3 to 0.6. With the additional assumptions of a 4xNewkirk coronal density and a semi-circular loop, we estimated an average fiber onset at a height of ~46Mm, a vertical extent ~15 Mm, a magnetic field scale height ~240Mm and mirror ratio ~2. We combined ARTEMIS-JLS and Nançay Radioheliograph observations for the July 14, 2000 large solar event Practically all fibers visible in the SAO dynamic spectra are identifiable in the NRH images. Fibers were first detected after the primary energy release, in a moving type IV, probably associated with the rapid eastward expansion of the flare and the post-flare loop arcade. We found that fibers appeared as a modulation of the continuum intensity with a root mean square value of the order of 10%. Both the fibers and the continuum were strongly circularly polarized in the ordinary mode sense, indicating plasma emission at the fundamental. We detected a number of discrete fiber emission sources along two ~300 Mm long parallel strands, apparently segments of large-scale loops encompassing both the EUV loops and the CME-associated flux rope. We found cases of multiple fiber emissions appearing at slightly different positions and times; their consecutive appearance can give the impression of apparent motion with supra-luminal velocities. Images of individual fibers were very similar at 432 and 410.5 MHz. From the position shift of the sources and the time delays at low and high frequencies we estimated, for a well observed group of fibers, the exciter speed and the frequency scale length along the loops; we obtained consistent values from imaging and spectral data, supporting the whistler origin of the fiber emission. Finally we found that fibers in absorption and in emission are very similar, thus confirming that they are manifestations of the same wave train.

First imaging spectroscopy observations of solar drift pair bursts

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Drift pairs are an unusual type of fine structures observed sometimes in dynamic spectra of metric solar radio emission. They appear as two identical short narrowband drifting bursts separated in time; both positive and negative frequency drifts are observed. Currently, there are no satisfactory explanation of this phenomenon. Observations with spatial resolution can be crucial to identify the formation mechanism of drift pair bursts. On 12 July 2017, the Low Frequency Array (LOFAR) observed a cluster of drift pair bursts in the frequency range of 30-70 MHz. Spectral imaging capabilities of this instrument for the first time have allowed us to study the emission sources of drift pair bursts in broad frequency range and to track their motion. Sources of two components of a drift pair propagate in the same direction along nearly the same trajectories; motion of the second burst source is delayed with respect to that of the first one. In general, negative or positive frequency drifts correspond to upward or downward motion, respectively, although the source trajectories can be complicated and non-radial. The drift pair bursts with positive and negative frequency drifts, as well as the associated broadband type III-like bursts, are produced in the same regions. The visible source velocities are of order of a few tens thousand km/s. The source sizes are not resolved with LOFAR, which indicates very compact emission sources. Our observations rule out all existing models of drift pair bursts; we discuss the key issues that need to be addressed. The broadband bursts observed simultaneously with the drift pairs differ in some aspects from common type III bursts and may represent a separate type of emission.

Solar radio spectral fine structures and diagnostics of non-thermal processes

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Solar radio observations at broadband frequency range with high temporal and spectral resolutions brought a series of new discoveries related to solar flare processes. Besides the general radio type II, III and IV bursts, spikes, dots, fibers, quasi-periodic pulsations, zebra patterns and various kinds of patches with complex structures are frequently reported. Especially in the decimeter and centimeter wavelength range for their source region very close to the flaring source region, these spectral structures are very complicated and intriguing. They are always composed with very small bursts (such as spikes, dots, and narrow band type III bursts, etc.) or bright stripes with sub-second timescales, very high brightness temperatures, and fast frequency drift rate, and sometimes strong circular polarizations. These radio spectral fine structures may present abundant useful information of the flaring source region: particles' energy, acceleration and propagation, the background plasma density and magnetic field strength. In this talk, I will introduce the observations of solar radio spectral fine structures obtained by Chinese solar radio telescopes and other instruments in recent years, try to explain their formations, and discuss the diagnostics of solar non-thermal processes by using the above observations. These diagnostics may help us to understand well the nature of solar eruptions.

Microwave fine structure events during solar Minimum

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The solar minimum is a period with relatively less of sunspots and solar eruptions, and has been studied less previously. Because the radio signal is agilely respond to the change of solar plasma and magnetic field, we made a comprehensive analysis of the high resolution spectrum data of Chinese spectrometer and spectral radioheliograph: 1) Search different kinds of solar radio bursts around recent solar minima (2007-2009 and 2016-2018); 2) Analyze several typical radio burst events, the negative and positive drifting burst, for example the event of 2015-11-22 and 2016-08-29; super fine spectral structure events with mini-flare and even without sunspot, for example the event of 2008-03-28 and 2017-07-04. These results showed that there were many radio bursts presenting fine structure during solar minima. These events occurred not only in main flares, but also in mini-flares or even without flares, but in regions related with H-alpha filament or magnetic network. We proposed that the weak solar radio bursts observed by telescopes with high sensibility and low interference will help us to understand the basic physical characteristics of small scale solar eruptions.

Interferometric imaging of Type III bursts in the solar corona

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The size of radio emission sources in the solar corona is thought to be fundamentally limited by scattering off of random density inhomogeneities, most prominently at the plasma frequency. Radio interferometers such as the LOw Frequency ARray (LOFAR) have been increasingly used to study radio bursts in the solar corona over the last number of decades. Observations with LOFAR's tied-array imaging technique suggest that the source sizes of Type III radio burst emission is limited by coronal scattering. However, it has yet to be determined whether source sizes observed with tied-array imaging are a result of this fundamental limit or an effect due to the unique nature of that imaging mode, i.e forming beams at different locations on the Sun to create an image. LOFAR interferometric imaging gives an alternative measure of source sizes with higher spatial resolution than tied-array imaging. Here, a Type III burst was imaged with LOFAR core and remote stations with baselines extending to 86 km (~22 arcseconds at 32MHz). We show that despite a sub-arcminute resolution, coronal source sizes are of the order of ~10 of arcminutes, significantly larger than would be suggested from the spectral fine structure. This further supports the theory of scattering being the limiting factor in coronal radio observations.

Forward Modeling of the Type III Radio Burst Exciter

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In this work, we propose a forward modeling method to study the trajectory and speed of the interplanetary (IP) type III radio burst exciter. The model assumes that the source of IP type III radio burst moves outward from the Sun following the Parker spiral field line. Using the arrival time of the radio waves at multiple spacecraft, we are able to determine the trajectory of the radio source in the ecliptic plane, the outward speed, as well as the injection time and longitude of the associated electron beam near the solar surface which triggers the type III radio burst. For the application of this method, we design a system to gather the arrival time of the radio wave from the radio dynamic spectra observed by STEREOs/WAVES and Wind/WAVES. Then, the system forward models the trajectory and speed of the radio burst exciter iteratively according to an evaluation function. Finally, we present a survey of four type III radio bursts which are well discussed in the literature. The modeled trajectories of the radio source are consistent with the previous radio triangulation results, the longitude of the associated active region, or the location of Langmuir waves excited by the electron beam.

Active region jets on August 25, 2011

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Solar coronal jets are impulsive, collimated features, observed at different energies. Jets are seen on the Sun at all scales - from those occurring in coronal holes to those in active regions. The process of creating jets is mostly considered to be related to reconnection between open and closed field lines. This study is focused on the active region jets which occur regularly at small-scale, but can also occur on a larger scale related to CMEs and SEPs. The aim of the study is to determine why the jets occurred in this particular active region, what their dynamics are, and possibly to predict what we might see with Solar Orbiter. Understanding the process of jets requires spectral and imaging data across different energy regimes. Therefore, we selected well observed series of jets which occurred on August 25, 2011, in the active region NOAA 1271 (located near the western solar limb). First results of the multiwavelength study show that the repeated jets observed on August 25, originate from the western part of the active region and were associated with a small flux emergence. Due to the existence of open field lines but also a large transequatorial loop system (closed field lines), some of the type III radio bursts associated with jets propagated to the interplanetary space and some did not. In the first radio triangulation study of radio emission associated with jets, we employed goniopolarimetric measurements taken simultaneously from STEREO A and WIND spacecraft. The reconstructed propagation paths of the interplanetary type III bursts associated with jets indicate that the fast electron beams are propagating towards the Earth, but the path does not completely coincide with the Parker spiral. This deviation in the propagation path of the electron beams associated with jets is probably due to the influence of a nearby coronal hole.

Very low frequency oscillations of the differentially rotating Solar Interior and Earth's climate

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MHD-equations are considered for the Solar Interior, taking into account the mechanism of generation of energy in the core and radiation losses. Using asymptotic methods, it is shown that from the problem of eigenfunctions at very small latitudinal rotational velocity gradients, Rossby-type modes are obtained for compressible, non-adiabatic waves with frequencies much lower than the rotation frequency. The solution of the corresponding boundary value problem gives us an integral dispersion relation for complex eigenfrequencies. Among the most unstable modes, modes with periods of 1500–20000 years, which is known from geophysical data on abrupt changes in the Earth's climate, are of great interest. in the past. This gives us the basis for the fact that these long-term fluctuations with a period of about 4,500 years may be the cause of the Dansgaard-Eshger event: these are abrupt onset of warm periods during the last ice age, the average distances of which were 4500 years.

Abstracts: Posters contributions

The poster sessions will be held every day of the workshop, so each accepted poster will be displayed Monday-Friday allowing time for in-depth discussions. The poster abstracts are therefore listed alphabetically by the first author.

Modeling of the Sunspot-Associated Microwave Emission Using a New Method of DEM Inversion

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We developed a method to compute the temperature and density structure along the line of sight by inversion of the differential emission measure (DEM), under the assumptions of stratification and hydrostatic equilibrium. We applied this method to the DEM obtained from AIA observations and used the results, together with potential extrapolations of the photospheric magnetic field, to compute the microwave emission of three sunspots, which we compared with observations from the RATAN-600 radio telescope and the Nobeyama Radioheliograph (NoRH). Our DEM based models reproduced very well the observations of the moderate-size spot on October 2011 and within 25% the data of a similar sized spot on March 2016 but predicted too low values for the big spot of 14 April 2016. The latter was better fitted by a constant conductive flux atmospheric model which, however, could not reproduce the peak brightness temperature of 4.7 MK and the shape of the source at the NoRH frequency. We propose that these deviations could be due to low intensity non-thermal emission associated to a moving pore and to an opposite polarity light bridge. We also found that the double structure of the big spot at high RATAN-600 frequencies could be interpreted in terms of the variation of the angle between the magnetic field and the line of sight along the sunspot.

Radio manifestation of the X 9.3 solar flare observed on 06.09.2017 in the frequency band of 8-33 MHz

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The results of radio observations of the powerful solar flare (class X 9.3) occurred on September 6, 2017 in the frequency band of 8-33 MHz are presented. Observations were carried out by the URAN-2 radio telescope (Poltava, Ukraine) with the frequency-time resolution of 4kHz-100ms. The radio bursts preceded the flare are discussed. There were IIIb–III storm, S-bursts, reversed drift pairs etc. The strongest solar flare in more than a decade was initiated by the active region NOAA 2673 at 12:02 UT. The CME with the velocity more than 1000 km/s was associated with this flare. This CME was accompanied with the usual consequence of radio events, namely, group of powerful Type III bursts (some of them J-bursts), Type II burst and Type IV burst. There was a group of powerful (fluxes more than 5000s.f.u.) unusual bursts with limited frequency band (up to 8 MHz) after the group of Type III bursts and before the type II burst. The maximum flux of Type III bursts was more than 1200 s.f.u. Type II burst with lanes had drift rate of 20 kHz/s, maximum fluxes of about 1000 s.f.u. and polarization of about 40%. Type IV burst belongs to moving Type IV burst class. Its drift rate was about 30 kHz/s. Type IV burst had flux more than 300 s.f.u. and polarization about 40%. Duration of Type IV burst was more than two hours. Type IV burst had fine structure in the form of fiber bursts. There were also some powerful strange bursts with fluxes more than 20000 s.f.u., polarizations of about 20% and durations of about 20 s. Some features of radio events and their connection with CME are discussed.

A study of the temperature evolution in solar flares using differential emission measure (DEM) analysis techniques

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In this project we investigate the temperature evolution of an M-class limb flare based on data recorded by the Solar Dynamics Observatory (SDO). We use Differential Emisision Measure (DEM) analysis techniques to derive the spatial temperature distribution from sets of EUV images (AIA). During dynamic heating and cooling processes in solar flares, these temperature distributions change in time. One of the project's key objective is to test the used DEM codes by applying the analysis technique to this limb event and compare the results with other observational data, e.g. from the GOES satellite.

LOFAR for Space Weather (LOFAR4SW): Redesigning the Low Frequency Array as a space weather instrument

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The Low Frequency Array (LOFAR) is a phased array interferometer consisting of 13 international stations across Europe and 38 stations surrounding a central hub in the Netherlands. The instrument operates in the frequency range of 20-240 MHz and is used for a variety of astrophysical science use cases. While it is not solar physics or space weather dedicated, a new European Commission-funded H2020 project entitled ‘LOFAR for SpaceWeather’ (LOFAR4SW) aims at designing a system upgrade to allow the entire array to observe the sun, heliosphere, and ionosphere constantly throughout its observing window. This system upgrade requires a redesign of the entire system, from receiving systems, to back-end computing, to software and scheduling pipelines. Here we describe some of the details of these system upgrade designs as well as an overview of the space-weather science and operations that a fully functional LOFAR4SW will perform in the future.

Effect of viscosity on propagation of MHD waves in astrophysical plasma

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We determine the general dispersion relation for the propagation of magnetohydrodynamic (MHD) waves in an astrophysical plasma by considering the effect of viscosity with an anisotropic pressure tensor. Basic MHD equations have been derived and linearized by the method of perturbation to develop the general form of the dispersion relation equation. Our result indicates that an astrophysical plasma with an anisotropic pressure tensor is stable in the presence of viscosity and a strong magnetic field at considerable wavelength.

Flare parameters inferred with 3D loop Models database

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A solar flare is one of the most intense energetic phenomena in active regions in the solar atmosphere. Imaging of these regions in extreme ultraviolet and soft X-rays have revealed their complex magnetic configurations. During flares, the field geometry can be analyzed through its microwave component of emission with moderate image resolution. The main problems in this type of analysis are contained in the integral equations that describe both the spectra and images do not have analytical solutions. Therefore, only forward-fitting methods are possible to describe them. To work around this scenario, a database of flare models with about two hundred and fifty thousand elements was constructed to become a catalogue for flare analysis. The database was constructed using the geometry and physics of dipolar magnetic fields. The dipole model consists of a three-dimensional digitized region and spatial distribution of non-thermal electrons. The aim of the database is to speed up the search for the parameters in a flare, using pre-calculated models with forward-fitting methods. On the other hand, a flare catalogue was built (reduced database) based on Nobeyama polarimeter (NoRP) flux densities and NoRH brightness maps observations (but not restricted to) including known general properties of a solar flare. Given images, the flare position and flux densities in four used frequencies in the database it returns the best model representation. We analysed two different methods to search for models in the database using a chi-squared and the weighted mean of one hundred best models in the database. As a result, we found that about ~80 percent of the ten analyzed parameters of 1000 simulated flares were recovered with the relative error <20 percent in average. From the statistic analyses of the NoRH flares, now using this database of non-homogeneous models, we found the following results: the distribution of the energy spectral index delta peaks ~3, nonthermal electrons density tending to be lower than $<10^7$ cm^{-3}, and the peak of the magnetic field distribution $B_{photosphere} > 2000$ G. We note some preferences for extended loops with height as greater than $\sim 2.6\times10^9$ cm and looptop events. We conclude that the use of this database with a moderate number of elements increases the possibility to find good results during a flare analysis and explore some statistical properties of flares. On the other hand, it also speeds up the search for the parameters in a flare with a high level of acceptance.

Type III radio bursts observations with Polish LOFAR station in Baldy

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We present a few examples of the type III solar radio bursts observed with LOFAR (LOw-Frequency Array) station in Baldy, located in Poland. Observations cover the period from October 2016 until December 2018. This station was used in the single mode and recorded the solar dynamic spectra in the frequency range from 10 MHz up to 240 MHz. Unique features of these observations conducted by the single station are: the high frequency resolution (0.39 MHz), high sensitivity, and also the high frequency bandwidth. The first observations in Baldy indicate that the LOFAR telescope is well suited for solar research at low frequencies. The observations from LOFAR in conjunction with other wavelengths to determine various events occurring on the Sun can give additional interesting results. We expect that observations with LOFAR telescope will contribute to a better understanding of the mechanism responsible for the type III radio bursts generation.

The introduce about VHF antenna array of Yunnan Observatories

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The VHF antenna array is consist of antenna, receiver, and data acquisition board. The antenna is designed to be transformation of half-wave dipole, which has four aluminium arms. The size of arm is 33cm*200cm, which can realize wider bandwidth compare to a single metal line. Receive can be operated in the frequency range from 55-65MHz. The gain and dynamic range of receiver are 65dB and 50 dB respectively. Data acquisition board uses the AD6657A-EBZ board whose sampling frequency, SFDR and quantization bits are 200MHz, 60dB and 12bits respectively. The AD board is controlled by XC4VFX20 which is belong to the Virtex4-FX family.

Radio Monitoring and Radio Solar Data Base: tools for fast access to space and ground based radio observations

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Solar Radio Monitoring (secchirh.obspm.fr) is a website for the combined visualization of solar radio data. This website is made possible by the support of the French Space Agency CNES. The main objective of this website is to support multi-wavelength data analysis and space missions dedicated to research on solar activity and on solar-terrestrial relationships, in particular SOHO, STEREO and SDO. It produces and provides synthetic data including mapping of sources observed by the Nançay Radio Heliograph (NRH), composite dynamic spectra and the CME's characteristics from LASCO. The combined survey permits to quickly identify and select solar events, to identify the complementary radio data for the space-based observations, and it gives an overview of the coronal and interplanetary situation. The dynamic spectra are collected from WIND and STEREO radio observations and ground-based spectrographs (Orfees, Humain, Nançay Decameter Array, Artemis, Culgoora, Yunnan and Gauribidanur spectrographs). In support of the radio monitoring website, a new radio solar database (https://rsdb.obs-nancay.fr/) is developed which gives an optimized and flexible access to the three solar radio instruments in Nançay: ORFEES, NRH and soon the NDA. This database facilitates the access to solar radio data for non-experts and permits to download the data instantly for radio-astronomers with the desired time resolution.

Statistical study of solar electron spike events observed with the STEREO spacecraft

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We present a statistical study of 87 short-lived impulsive solar electron events, so-called spikes, observed with the two STEREO spacecraft in the energy range above 55 keV. All spike events were detected around the solar maximum activity from February 2010 until August 2014. Onset time delays relative to interplanetary type III radio bursts, spike durations, and effective propagation path lengths are examined for all events. Using measurements of solar wind parameters we investigate the dependencies between spike onset time delays, durations and some other properties in relation to solar wind speed, density, magnetic field strength and their standard deviations. We put special attention to possible differences between spike properties observed at the STEREO-A and STEREO-B spacecraft.

Two-step flux rope evolution and microwave emission in a compound solar flare

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We present an analysis of a compound solar flare on 2015 June 21, which consisted of three confined precursor flares (C to M2.0 class), followed by an eruptive M2.6 flare and a coronal mass ejection (CME). EUV data from the Solar Dynamics Observatory reveal the formation of a sigmoidal hot channel during the confined flares, which can only be interpreted as a magnetic flux rope. The structure erupts in the eruptive flare and evolves into the CME. Overall, the sequence demonstrates that the erupting flux rope was formed prior to (not during) the CME. The microwave emission showed a stationary source between the similarly located main ribbons of all four flares, which perfectly corresponds to the location of the vertical (flare) current sheet in this event near disk center. A second, remote microwave source formed during the eruptive flare above a parasitic polarity, where also a closed, roughly circular ribbon developed. We suggest that these structures signify reconnection and particle acceleration in the separatrix layer associated with a coronal magnetic null above the parasitic polarity. Different from the standard picture of separatrix perturbation from below (often by an erupting filament), the energy release in the separatrix was here triggered by a lifting of overlying flux when the extended pre-formed sigmoidal flux rope erupted.

Null-point-associated tiny eruptions revealed with the Siberian Radioheliograph

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The Siberian Radioheliograph (SRH) commenced the test-mode observations at several frequencies in the 4–8 GHz range in August 2016. Up to the present time, the SRH has detected many small eruptions that were manifested in weak microwave bursts or microwave depressions caused by the screening of bright active regions by cool erupted plasma. Comparison of the SRH and SDO/AIA data shows that the majority of tiny eruptions detected were related to i) magnetic islands of a minor polarity near sunspots or ii) EUV structures that are typical of the magnetic null-point topology. We demonstrate examples of such phenomena. Their detection in microwaves is favored when the eruptions occur near the limb.

Warm target model and a solution to low-energy cut-off problem

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Solar flare hard X-ray (HXR) spectroscopy serves as a key diagnostic of the accelerated electron spectrum. However, the standard approach using the collisional cold thick-target model poorly constrains the lower-energy part of the accelerated electron spectrum, hence the overall energetics of the accelerated electrons are typically constrained only to within one or two orders of magnitude. Here, we demonstrate a physically self-consistent, warm-target approach that involves the use of both HXR spectroscopy and imaging data. This approach allows an accurate determination of the electron distribution low-energy cutoff, and hence the electron acceleration rate and the contribution of accelerated electrons to the total energy released, by constraining the coronal plasma parameters. Using a solar flare observed in X-rays by RHESSI, we demonstrate that using the standard cold-target methodology, the low-energy cutoff (hence the energy content in electrons) is essentially undetermined. However, the warm-target methodology can determine the low-energy electron cutoff with ~7% uncertainty at the 3σ level, hence it permits an accurate quantitative study of the importance of accelerated electron in solar flare energetics.

3D Finite Element MHD code for simulations in Solar atmosphere

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We present an innovative numerical code designed to study multiscale phenomena in the solar atmosphere such as magnetic reconnection, solar flares, quiescent and eruptive prominences as well as their oscillations. The three-dimensional code is based on Discontinuous Galerkin Finite Element Method and is fully adaptive. It is also designed to handle shocks well and can guarantee zero divergence of magnetic field naturally. Therefore, it should be well suited for simulations that would fill the gap between particle processes and observed large-scale structures. This makes the code relevant for comparing with both solar radio spectra and potentially also images. We show several tests of the code including those connected to the Solar atmosphere such as perturbed long current sheets and 3D Titov-Demoulin equilibrium. We also compare some of the results to an older code based on Finite Differences.

Geomagnetically Induced Currents (GICs) related to impulsive Space Weather events at Low Latitudes

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Intense space weather events (geomagnetic storms and sub-storms) are potential sources of electric induction within the earth. These events cause intense geomagnetic field variations which induce electric currents in the conducting layers of the Earth. Disruptions of technological equipments due to "Geomagnetically Induced Currents (GICs)" are experienced in the Scandinavian countries since mid XIX the century (Pulkkinen, 2003). Due to their harmful impacts on technological devices, the GICs have been mostly investigated at high latitudes (Pulkkinen et al., 2001a, 2001b, 2003, 2007). However, Kappenman (2003) demonstrated the risk of large GIC occurrence associated with large geomagnetic impulses like Storm sudden commencement (SSC) at low- and mid-latitudes. There are reports on GIC causing perturbation in technological structures in mid- and low-latitude (Ngwira et al., 2008; Torta et al., 2012, Trivedi et al., 2007). As consequence, intense GICs flow, causing frequent disturbances in technological devices like telecommunication and pipe lines, power grid and transformers. The effect of GICs is assumed to be negligible in low-latitude regions. For this reason, the effect of induced currents is poorly studied. Recently, GICs effects have been recorded in South Africa transformers (Gaunt and Coetzee 2007). Due to these threats, we study the induction effects related to space weather events such as solar flare and ssc at low latitudes. In our study, we estimate the geoelectric field from the magnetic data and compare it to the measured geoelectric field. We note that our results are in good agreement with the measures. Then, we estimate the intensity of the GICs from the geoelectric field calculated on the one hand and on the other hand, from the measured geoelectric field. Thus, participating to CESRA Workshop will be a great opportunity to improve our knowledge and evolve our research work.

Ultimate Fast Gyrosynchrotron Codes

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Microwave gyrosynchrotron emission can be a valuable diagnosing tool for solar flares and other astrophysical objects; quantitative interpretation of observations usually requires creating realistic three-dimensional models of the emission sources. A great progress in this field has been achieved in the past decade due to development of Fast Gyrosynchrotron Codes, which enormously reduced the computation time needed to calculate a single spectrum. However, the available fast codes are limited as they are only applicable to factorized electron distributions over the energy and pitch-angle, where the energy and pitch-angle distributions are chosen from a limited list of pre-defined analytical functions. In realistic astrophysical objects, these assumptions, as a rule, do not hold; thus, more versatile gyrosynchrotron codes are called for. To remedy this situation, we have extended our fast codes to work with arbitrary input distribution functions of radiating electrons; namely, we have implemented fast gyrosynchrotron codes for a distribution function described by a numerically defined array in the energy and pitch-angle space. The Ultimate Fast Codes presented here allow for an arbitrary combination of the analytically and numerically defined distributions, which offers the most flexible use of the fast codes; the computation speed and accuracy are comparable to those of the previous release. The codes are implemented as IDL-callable libraries; they are freely available online. We illustrate the code capabilities with a few simple examples.

The research for influence of solar radio burst on navigation signal and its early warning scheme

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Unlike other effects of solar activity on navigation satellites, solar radio bursts (SRB) propagate at the speed of light. The SRB event has the characteristics of fast action time, wide range and so on, the influence on the whole navigation system is immeasurable, but there is no way to predict at present. This study will focus on the following issues concerning the influence of SRB on navigation and communication signal events. At first, the threshold value of the influence of solar radio flow on navigation communication is calculated, which is between 1000-2600s.f.u, consisting with the observation data. The second, by reviewing the time relationship between multiple solar radio bursts and X-ray in the 23-24 solar activity week, this paper proposes that X-ray flow rise can be used as an effective warning point, and the warning time is longer than 2 minutes. The last, we are building a multi-freqencies monitoring system located in China which can get the precision flux information of L band radio solar emission to pre-alarm and vertify these events Through this study, a set of space weather evaluation system will be formed, which takes solar observation data as the benchmark, ground-based solar radio flux monitoring as the evaluation reference, and analysis and backtracking based on the influence mechanism equation.

The progress of upgrading MUSER receiver

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Mingantu Spectral Radioheliograph heliograph (MUSER) is a dedicated solar radio synthetic aperture array located on Mingantu Observing Station(MOS) in Inner-Mongolia of China, which is composed of two sub-arrays: MUSER-I and MUSER-H. The whole array includes 100 antennas lined along three spiral arms: 40 4.5m dish antennas in MUSER-I (0.4 ~ 2 GHz), and 60 2.5m dish in MUSER-H (2 ~15 GHz). The max antenna-pair baseline is around 3km. The existing MUSER-I correlator has been working quite well for a long time since 2010 at MOS. Although the daily solar radio observing is carried out almost all time and plenty of data and images have been acquired in the past several years, the correlator's performance, especially MUSER-I correlator, is degrading due to long-period running and harsh lab environment, along with the new demands of new antennas adding into MUSER array. Therefore a more flexible, reconfigurable and extendable correlator is on the top of the list. Thanks to lower cost and better performance digital computing components (FPGA & SOC), the idea of acquiring both imaging spectroscopy and power spectrum with finer frequency resolution seems pragmatic. As a result RFI can be effectively excised over according frequency bins. Moreover, the planned 4-bit correlation will help to improve correlation efficiency compared with 2-bit correlation; To verify the new correlator system, one eight-channel prototype is proposed and in developing stage. The prototype of uMUSER correlator are implemented with SNAP2. This project is under the collaboration with Institute of Automation Chinese Academy of Sciences.

Structured type III radio bursts observed by LOFAR

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On August 25, 2014, NOAA AR 2146 produced the M2.0 class flare (peaked at 15:11 UT). The flare was associated with a coronal dimming, an EIT wave, a halo CME and a radio event observed by LOFAR (the LOw-Frequency Array). The radio event consisted of a type II, type III and type IV radio emissions. In this study, we focus on LOFAR observations of the type III bursts, generally considered to be radio signatures of fast electron beams propagating along open or quasi open field lines. The group of type III bursts was, as usually, observed during the impulsive phase of the flare. At first hand, type III bursts show no peculiarity, but the high frequency/time resolution LOFAR observations reveal that only few of these type III bursts have a smooth emission profile. The majority of bursts is strongly fragmented. Some show a structuring similar to type IIIb bursts, but on a smaller frequency scale, and others show a non-organized patchy structure which gives indication on the possibly related turbulence processes. Although fine structures of type III bursts were already reported, the wealth of fine structures, and the fragmentation of the radio emission observed in this August 25 event is unprecedented. We show that these LOFAR observations bring completely new insight and pose a new challenge for the physics of the acceleration of electron beams and associated emission processes.

SAFIRE: An SDR-based Solar Flux Monitoring System

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As part of its observational activities, the Solar Influences Data analysis Center has developed an instrument using a Software Defined Radio device to measure the flux of the Sun at fixed frequencies within the range of 1 to 5 GHz. This poster shows its design and developing, as well as some preliminary results obtained towards its commissioning.

The observations of the radio burst fine structure by the new Solar Spectropolarimeter of the Meter-wave Range 50-500 MHz

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The dynamic spectra of solar radio emission in the meter range carry out information about various phenomena related to the active Sun. We present the block-diagram and characteristics and the first observational results of new Solar Spectropolarimeter of the Meter-wave Range (SSMR) 50-500 MHz designed and created in the Institute of Solar-Terrestrial Physics. SSMR started observations in May 2016 in Badary Radioastrophysical Observatory. The solar activity during September 2017 allowed showing possibilities of the new spectropolarimeter in detecting the fine structure of radio bursts within a wide dynamic range. We discuss the current advantages of SSMR and plans for its improvement.

Observations of Chromospheric Oscillations in the Quiet Sun with ALMA

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Oscillation and wave phenomena are omnipresent throughout the solar atmosphere. They could play a significant role in atmospheric heating and dynamics, and in addition, they could supply a means to diagnose the physical properties of the various layers of the solar atmosphere. Chromospheric oscillations, due to presumably leakage of photospheric 5-min oscillations, have been observed for decades in the EUV and UV. Observations in the mm-domain supply a direct probe of plasma temperatures in the chromosphere and do not suffer from complications of chromospheric diagnostics in the EUV and UV. We present a comprehensive study of chromospheric oscillations in the quiet Sun at 3 mm taken by ALMA with a few arcsec resolution. We present a center-to-limb analysis of chromospheric p-mode oscillations which includes their relative strength and frequency, spatial coherence and compare our findings with results obtained simultaneously in the 304 and 1600 A channels of AIA. In addition, we present a delay analysis of chromospheric oscillations in the different atmospheric layers scanned by ALMA and AIA. Finally, we compare our findings with lower spatial resolution BIMA observations in the mm-domain reported by White et al. 2006.

Investigation of mid-range periodicity during solar cycle 22 and 23 using empirical mode decomposition

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Aim: The data of Mg II core to wing ratio during solar cycle 22 and 23 is undergone for mid-range periodicity analysis. Method: Periodicity analysis has been performed using Empirical Mode Decomposition and Raleigh Power Spectrum Algorithm. Result: Various significant intermediate periodicities are observed in daily Mg II core to wing ratio data. The most significant periods are as follows: (i) the period of 7 days due to the presence of short-lived regions inside the Sun and 27 days due to the existence of rotational modulation; (ii) various mid-range periodicity including 54 days (due to emerging magnetic field inside the Sun), 160 days (due to concentration of a strong magnetic field), annual variation oscillation (328 days), quasi triennial periodicity (3.7 years); (iii) the 10.5 years period associated with the 11-year cycle of the sunspot which implies polarity interchange of the magnetic field of the Sun. The result indicates that that the Mg II core to wing ratio together with the other solar activities are originated from the same location and the Mg II core to wing ratio has a unique signature on the forecasting of space weather.

Open-Field Coronal Structures Neighboring the Sunspot of AR 8535

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We use the Potential Field Source Surface (PFSS) model to identify and analyze a sequence of open-field structures of the same magnetic polarity neighboring a large sunspot in the AR 8535. The sequence includes two narrow coronal corridors, which stem from narrow open-field structures on the photosphere with succeeding large expansion with height, and a pseudo-streamer connected to the polar coronal hole, and the sequence bears resemblance to the so-called S-web. The open-field structures overlap with wide coronal dark lanes observed in the Yohkoh / SXT soft X-ray and SOHO / EIT 284 Å images and with the plasma upflow observed as Doppler blue-shifts in a set of SOHO / CDS EUV emission lines. The overlap is suggestive of plasma outflow. Near-Earth instruments aboard the ACE spacecraft measure solar wind speed of ~ 400 km/s and charge state ratio O7+/O6+ = 0.4 (corresponding to coronal “freezing-in temperature” 1.7×106 K). These values are consistent with the interpretation that the open-field coronal structures neighboring the sunspot are sources of slow solar wind. We propose constructing a model atmosphere of the sunspot with a coronal dark lane to further investigate its magnetic structure through its effect on the observed microwave radiaton.

Spectral distribution of solar radio type III bursts from 20 kHz to 80 MHz

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Recently several ground-based and space-based radio telescopes have been used to continuously monitor the radio transient emissions from the solar atmosphere. In order to study various properties of radio bursts, we need to calibrate them carefully and bring them to the uniform units. Using the improved calibration techniques, we have been working on to investigate the spectral response of type III bursts that are commonly observed from 20 kHz to 80 MHz using the Nancay Decameter Array (NDA), LOFAR, WIND/WAVES, and STEREO/WAVES. We would present the improved calibration techniques, cross-comparisons, and obtain preliminary results.

On Determination of the Solar Atmosphere Parameters above Active Regions by Radio Observations

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We introduced new algorithm of atmosphere parameters (temperature height profile and electron density) determination above the active regions, based on the algorithm developed in our previous work [1]. In the method presented now we attribute the initial temperature to each height layer and scrupulously consider the contribution of each height layer at every observing radio map point in some frequency range. Such investigation allow us to correct temperatures. After the temperature profile correcting the algorithm applied iteratively until convergence. Using this algorithm for the dipole model of magnetic field, model of temperature height profile and simulated RATAN-600 radio telescope scans shows that we get very good correspondence between modeled and calculated temperature profiles (< 0.2%). Application of the method to the observation of the real active regions on RATAN-600 shows that we can get realistic temperatures in the lower corona (2-3 MK) and the height of transition region (about 1 Mm). Until this we suppose that the temperature above the whole active region is the same at each height. But semi-empirical models of solar atmosphere shows that the temperature height profiles are different above different regions of sunspots (such as umbra and penumbra). This, particularly, can explain wide transition regions which we get in calculations. We suggested ways of adaptation of the suggested method to more complex models of atmosphere and to the radio observations on telescopes provide 2-D radio maps.
References [1] A. G. Stupishin, T. I. Kaltman, V. M. Bogod, and L. V. Yasnov. Modeling of Solar Atmosphere Parameters Above Sunspots Using RATAN-600 Microwave Observations. Solar Phys., 293:13, January 2018.

Opening Metsähovi Radio Observatory’s solar observations database

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The year 2018 marked the 40th anniversary of solar radio observations at Aalto University Metsähovi Radio Observatory in Finland. The observatory’s 14-metre radio telescope has been used to create brightness maps mainly at 37 GHz since 1978; additionally, a 1.8-metre radio telescope has been monitoring the total brightness at 11.2 GHz since 2000. These data, together with essential data processing tools, documentation, metadata, etc., will be made directly and openly available online during the fall 2019. Here we will review the opened datasets, explain the structure and details of the data, and give instructions for accessing the data.

Reduced Microwave Brightness Temperature in a Sunspot Atmosphere due to Open Magnetic Fields

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Motivated by dark coronal lanes in SOHO / EIT 284 Å EUV and Yohkoh / SXT soft X-ray observations we construct an atmosphere model of the AR 8535 sunspot by adding a cool and less dense component in the volume of plasma along open field lines which are determined using the Potential Field Source Surface (PFSS) method. Our model matches the observed reduced microwave brightness temperature in the northern part of the sunspot in the VLA observations from May 13, 1999 and provides a physical explanation for the coronal dark lanes. We propose application of this method to other sunspots with such observed dark regions in EUV or soft X-rays and with concurrent radio observations to determine the significance of open field regions. The connection between open fields and the resulting plasma temperature and density decrease is of relevance for slow solar wind source investigations.

Current issues regarding the energy partition in solar flares

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The knowledge of the energetics of thermal and nonthermal particle populations is essential for our understanding of energy release and transport processes as well as particle acceleration mechanisms. Several recent studies have tried to quantitatively characterize the thermal-nonthermal energy partition, resulting in contradictory conclusions. We review these studies and point out several key aspects that require closer scrutiny before we can come to firm conclusions. This includes the role of conductive losses, bolometric energies, and the effect of flare importance.