IHY activities in India
and
Space Weather Studies at Ooty

P.K. Manoharan

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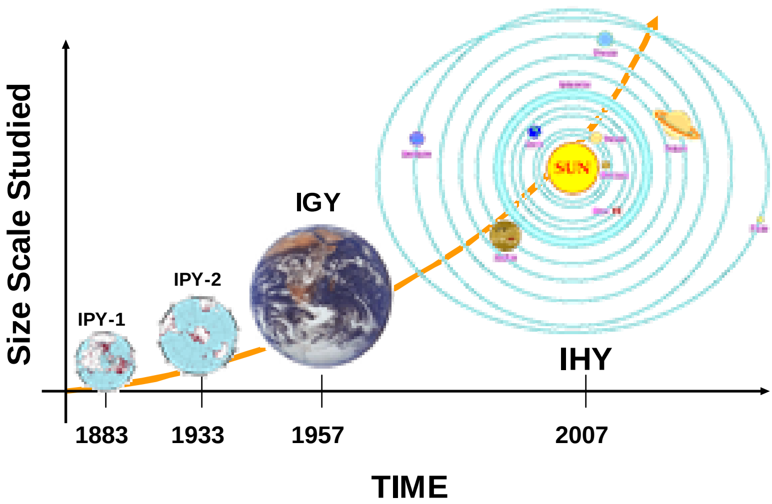
National Centre for Radio Astrophysics
Tata Institute of Fundamental Research
Ooty 643001, India

Workshop on International Science Years
INSA, New Delhi
October 3, 2007

International Studies – Time Line



Aims of IHY Program

IHY is an extensive international program to study the universal physical processes in the heliospace for a better understanding of the Sun-heliosphere system.

Four key elements of IHY:

- Science (coordinated investigation programs (CIPs) campaigns to investigate specific scientific questions),
- Instrument development (UNBSSI),
- Public Outreach (to communicate the significance of the space science to the general public and students), and
- The IGY Gold program (to identify and honor all those scientists who worked for the IGY program).

Most significant scientific questions related to the through understanding of heliophysics:

1. Structure and dynamics of the Sun's interior
2. Structure of the heliosphere
3. Space environment of the Earth and other solar system bodies
4. Basic physical principles manifest in processes observed in the Sun and in the magnetized plasma
5. Developing a predictive capability and quantifying the impact of dynamical processes at the Sun on the near-Earth space

India IHY Structure

- **International Steering Committee Members**
  - S.M. Chitre
  - Siraj Hasan
  - Arnab R. Choudhuri
- **National Advisory Committee**
  - Archana Bhattacharyya, IIG
  - S.M. Chitre, Mumbai University
  - Arnab R. Choudhuri, IISc
  - B.N. Dwivedi, BH University
  - J.N. Goswami, PRL
  - P.K. Manoharan, RAC-NCRA-TIFR (Chair)
  - P. Sreekumar, ISRO
  - Jagdev Singh, IIA
  - P. Venkatakrishnan, USO
- **Working Groups**
- **Participating members/Institutes/Universities**

India IHY Working Groups

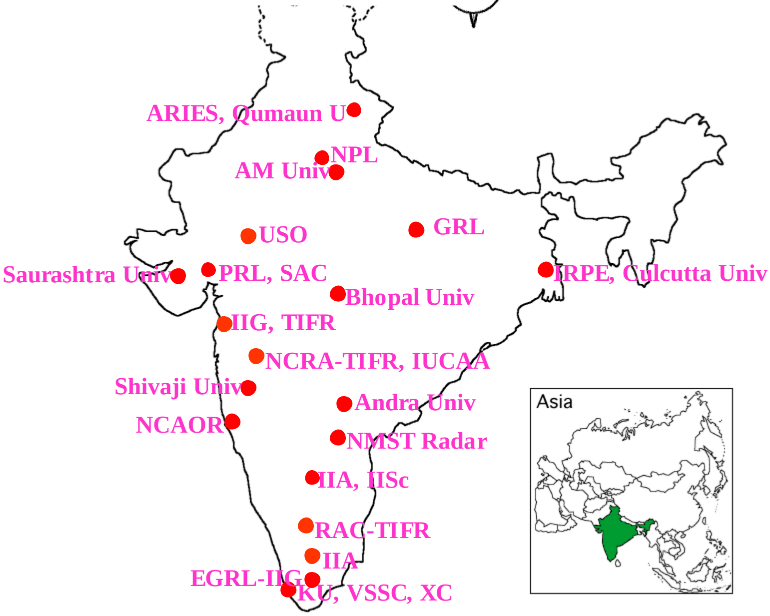
Six Working Groups

- ➢ Sun
- ➢ Space Weather
- ➢ Heliosphere and Solar Wind
- ➢ Climate and Earth Atmosphere
- ➢ Instrumentation
- ➢ Education, Public outreach, Data archival, and Dissemination

  - Each working group contains leaders and members from various institutes (observation, theory, and model).

www.prl.res.in/~ihy

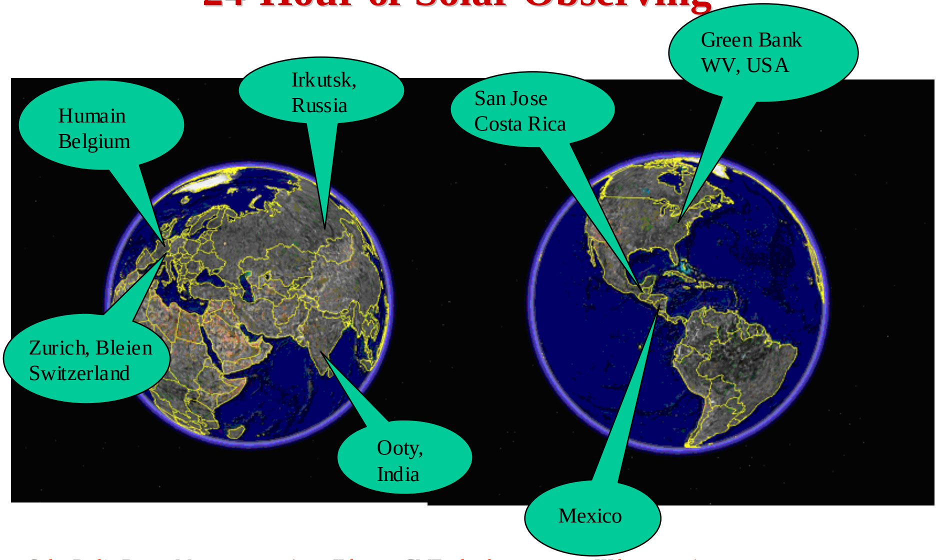
'India IHY' Participating Institutes



IHY UN BSS Initiatives - Instrumentations

- Several large-scale and small-scale instruments are in operation at several Indian institutions for researches related to IHY Program.
- Following instruments have been installed/planned through 'IHY - UN Basic Space Science Initiative' at different institutes:
  - AWESOME
  - CALLISTO
  - MAGDAS
  - RENOIR
  - SCINDA

IHY Worldwide Radio Net
24-Hour of Solar Observing



Solar Radio Bursts Measurements (type II bursts, CME, shock waves, type III bursts etc.)

Asia-Pacific Region IHY Activities

Multilateral activities to be promoted include

– Interplanetary Scintillation (IPS) network to study the propagation of geo-effective solar disturbances

– Asia-Pacific H-alpha network to study the early life of solar eruptions

– Possible collaboration with CALLISTO to monitor shock waves near the Sun

– Data Center for Solar and geo-space data to promote world-wide collaboration

– Magnetometer Data Acquisition System (MAGDAS) to study the geo-space impact of solar disturbances

– Particle Detector network to study cosmic ray modulation by magnetic structures in the heliosphere

India and Asia-Pacific Region IHY Program

- Many institutions in India have been working on several aspects of "Solar-Terrestrial Physics". IHY provides another opportunity for collaborative studies of 'Sun – Earth' system and the entire heliosphere.
- National 'India IHY Planning Workshop' July 2004, Ooty, India.
- AOGS-2005 – an IHY session was organized for Asia-Pacific Region
- IPS Network for Coordinated Observations (India – Japan)
- ILWS Conference, Feb 2006, Goa, India
- IHY Asia-Pacific Planning Meeting, October, 2006, Beijing, China
- UN/NASA/India IHY workshop, Nov-Dec 2006
- IHY Workshop on Solar Super Active Regions, May 2007
  - IGY Gold Program
- IHY Schools in the Asia-Pacific Region December 10 – 22, 2007
- Next year, A-P IHY School will be held in China
- Several Student Training programs and Public Outreach activities have been organized and more will be done

Asia Pacific Regional IHY School
December 10-22 2007

Kodaikanal Observatory
Indian Institute of Astrophysics

Financial Assistance Available for Students and Postdocs

Topics to be covered

0. Sun in the Universe
1. Solar interior and Solar system magnetic field
2. Solar Atmosphere and Eruptions
3. Shocks, flows and obstacles
4. Dynamo processes
5. Reconnection processes in Sun & heliosphere
6. Sun-Climate
7. Turbulence in the heliospace
8. Planetary atmospheres
9. Planetary Ionospheres
10. Planetary Magnetospheres
11. Radio emission processes
12. Energetic particles in the heliosphere
13. Elemental abundances in the heliosphere
14. Space Platforms for heliophysical Studies
15. Space weather

Directors: Nat Gopalswamy and Ashok Ambastha
Contact: K. E. Rangarajan, Convener of the School
P. K. Manoharan, India IHY Coordinator

http://www.iiap.res.in

'India IHY Planning Workshop'

July 10 – 12, 2004

Radio Astronomy Centre, NCRA, TIFR, Ooty.

Second UN/NASA Workshop on

The International Heliophysical Year and Basic Space Science

' Indian Institute of Astrophysics ' Bangalore, India November 27 - December 1, 2006

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Workshop Update: The presentations are available on this page from the link in the left menu Talks

Visit the Photo Album

A new feature of this workshop was to introduce data bases and relevant software tools that can promote space science activities. There have been enormous number of space missions that have been accumulating large data bases of scientific data. Similarly, long-term data bases are available from groundbased observations. These data can be utilized in ways different from originally intended for understanding the heliophysical processes. One of the goals of the second workshop is to identify such data bases and make them available to the world community with necessary software tools so that scientists from developing countries can benefit from them without having to deploy instruments.

IHY Workshop on Solar Super Active Regions and their Geo-space Impact, Nainital, India, May 2007

IGY- Gold People (May 2007)

IHY Coordinated Investigation Programmes (CIPs)

	Proposer	Title
1	Richard A. Harrison	Coronal Mass Ejection Studies: Development of Algorithms for CME Onset and Earth-Arrival Predictions
2	Tim Fuller-Rowell	Realtime Global Ionosphere
3	Marina Galand	Universality of Auroral Structure
4	Ian Mann	Global plasmaspheric dynamics
5	Eberhard Moebius	State of the LISM at the Heliopsheric Boundary and Inside
6	Matthew E. Hill	Environment Termination Shock and the Heliosheath
7	Barbara J.Thompson	3-D Structure of EUV CMEs in the inner corona
8	Dr Pierre Cilliers	Mid- and high latitude Ionospheric-Magnetospheric Observations
9	Klaus Scherer, Marius Potgieter	Modeling variable cosmic ray fluxes in the dynamic heliosphere, magnetosphere, and atmosphere as well as their imprints on Earth
10	Anna Milillo	Empirical model of ring current distributions

	Proposer	Title
11	P.K. Manoharan	Three-dimensional view of inner heliosphere and predicting the arrivals of coronal mass ejections
12	G. Poletto, S. Suess	SOHO-Ulysses Coordinated Studies during the two Extended Quadratures and the Alignment of 2007-2008
13	Jean-Pierre Raulin	High Energy Processes and Dynamics of the Low Solar Atmosphere During Explosive Events
14	J.-P. Raulin, E. Correia, V.S. Makhmutov	Ionospheric effects of the solar activity variations, solar flares, lightnings and energetic particle precipitations.
15	Saumitra Mukherjee	Influence of Sun and other cosmic factors on Environment of the Earth
16	Luis Eduardo Antunes Vieira	Investigation of the of the cosmic rays modulation of the cloud properties and net radiative flux in the southern hemisphere magnetic anomaly (SHMA)
17	Umberto Villante	Dynamics of the magnetosphere
18	Emília Correia	Spatial and temporal TEC characterization of the ionosphere in the South - Atlantic Magnetic Anomaly
19	M. F. Marcucci	Transport of mass and energy across the magnetopause during periods of northward IMF and their effects on the high latitude ionosphere.

	Proposer	Title
20	Larisa Trichtchenko, NRC Canada/ISES	Space Weather in Solar System (SWISS)
21	S Gibson	Evolution of Active Regions and Global Solar Magnetic Fields
22	John Raymond	CME initiation, evolution, and propagation throughout heliosphere
23	Patrick S McIntosh	Formation and Evolution of Filaments
24	P Fox	Effective Temperature of the Quiet Sun
25	A P van Eyken	ISPAM
26	Kiyohumi YUMOTO	Investigating Electromagnetic Couplings and Plasma Environment Change In Geospace Using MAGDAS Magnetometer Network

IHY Coordinated Investigation Programme (CIP)

http://www.ihy.rl.ac.uk/CIP_list.shtm

Recently Proposed

IHY Coordinated Investigation Programme (CIPs)

Integrated Whole Heliosphere

IHY – Associated National Facilities

Radio Astronomical Facilities

Existing National Facilities

- Optical telescopes
- Radio telescopes
- IPS Solar Wind data
- Magnetometers
- MST radar
- HF Doppler radar
- Meteor wind radar
- All sky imagers
- LIDARS
- High Altitude Balloons
- Cryo Sampler
- Rocket payloads

- HF, VHF coherent back scatter radars
- VHF, UHF scintillation receivers
- CRABEX network for ionospheric Tomography
- Optical experiments like Photometers
- High resolution spectrometers
- Day-glow photometers
- Partial Reflection radars
- Space Borne LIDAR
- Chain of Ionosondes
- Sounding Rockets
- SOXS- Solar X-ray Spectrometer
- Expected (RT-2 Indo-Russian Solar X-ray measurements)

National Centre for Radio Astrophysics (NCRA-TIFR)

- Giant Meter wavelength Radio Telescope (near Pune)
  - Multi-frequency synthesis imaging system
  - 27 km baseline
  - 30 antennas of each 45 m diameter
- Ooty Radio Telescope (Radio Astronomy Centre, Ooty)
  - Observing frequency 327 MHz
  - Steerable antenna of size 530m x 30m cylindrical
  - Various astronomical observations and solar wind studies
  - Callisto Solar Spectrograph (part of IHY radio net)
    - Frequency range 45 – 890 MHz (300 kHz – each channel bandwidth)
    - solar radio spectrograph
  - Muthorai Radio Telescope (plus a small dish) to track Sun
    - 290 – 350 MHz (fixed-frequency solar observations)
    - Steerable antenna of size 92m x 9m

IIA Bangalore – Gauribidanur Radio Telescope and Radio Heliograph (low frequency synthesis array)

Giant Metrewave Radio Telescope

NCRA • TIFR

Frequency bands covered 150, 235, 325, 610, 1000-1450 MHz.

In order to obtain higher resolution, array of antennas is used as interferometer giving resolution of approximately 1 arc second, equivalent a large optical telescope under good seeing condition.

GMRT (Pune, India) and VLA (Socorro, New Mexico)

Ooty Radio Telescope (ORT)

- Latitude: 11°23' North Longitude: 76°40' East
- Equatorially mounted, off-axis parabolic cylinder
- 530m (N-S) x 30m (E-W)
- Reflecting surface made of 1100 stainless steel wires
- Feed – 1056 $\lambda/2$ dipoles
- E-W Tracking and N-S Steering of ORT (~9.5 hours, ± 60°)

Solar Wind measurements

Importance of IPS technique increases when the day-to-day monitoring of the heliosphere (solar wind) is made on a grid of large number of radio sources

- large number of radio sources (~900/day)
- at 20 – 250 Rsun
- at all helio latitudes
- provide 3-D structures of solar wind density turbulence and speed

Operated by
Radio Astronomy Centre
National Centre for Radio Astrophysics
Tata Institute of Fundamental Research
(NCRA-TIFR)
Ooty, India

Coronal Mass Ejections and

Solar Wind Studies

Heliosphere and solar wind studies
Exploring Heliosphere in 3-D

Determination of overall morphology of the Heliosphere

- Acceleration of solar wind
- Generation of high speed streams with correct V, N, and T
- Coronal propagation of solar energetic particles
- Large scale variation of solar wind and magnetic field and the behavior of their turbulence levels
- Understanding solar wind transients and their evolution to the Earth or else where

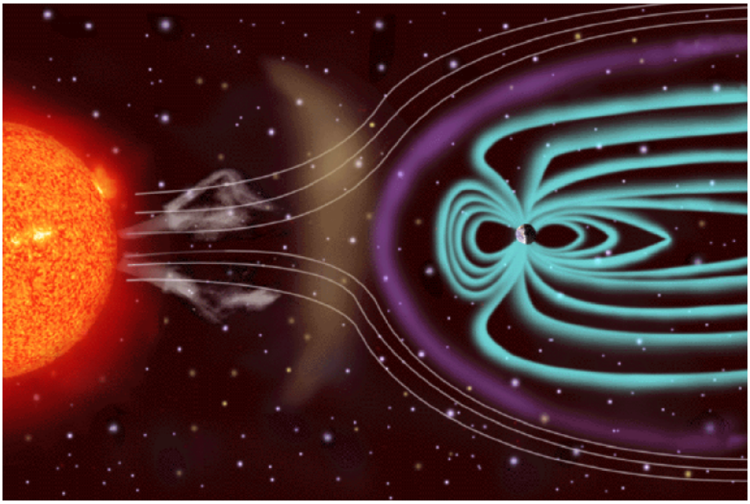
Interplanetary Scintillation (IPS) Network

- IPS network to study the propagation of geoeffective solar disturbances and characteristics of the inner heliosphere. IPS network would include

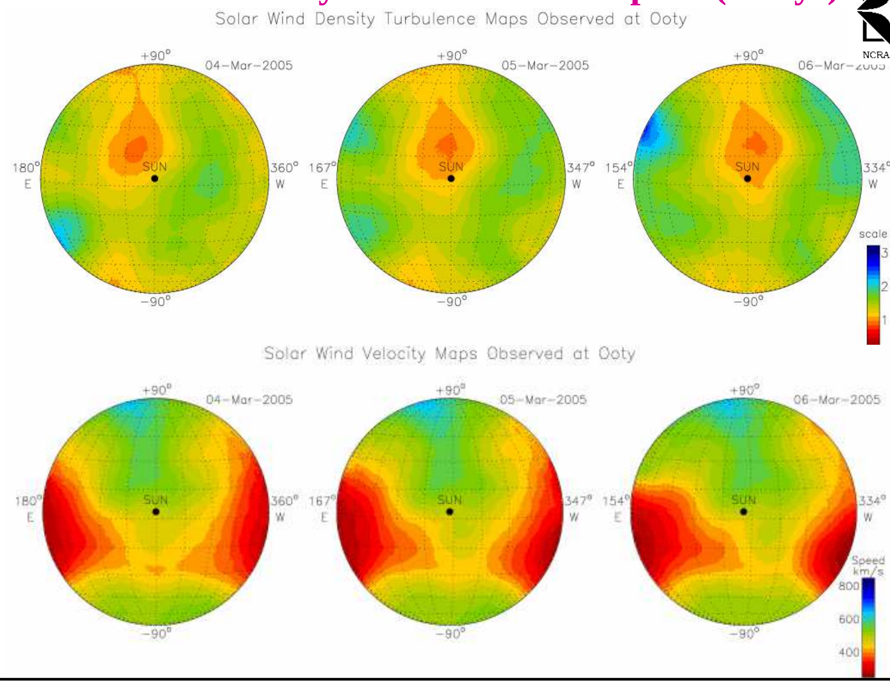
  1. P.K. Manoharan (TIFR-NCRA, RAC, India)
  2. Kojima (STE Lab, Nagoya University, Japan)
  3. Americo Gonzalez (UNAM, Mexico)
  4. B.V. Jackson (SMEI Group, UCSD, USA)
  5. Xizhen Zhang (China)

- IPS netweork will also collaborative with SMEI and Ulysses group

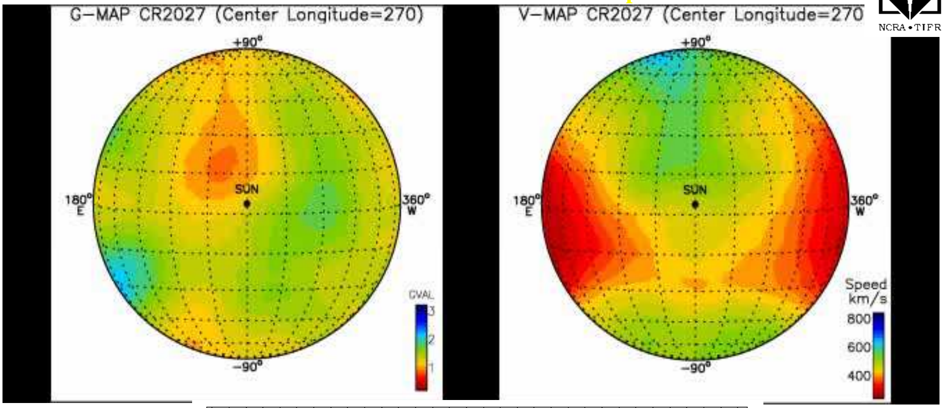
Priority is to understand better how Earth responds to its environment; how Sun and Earth are related

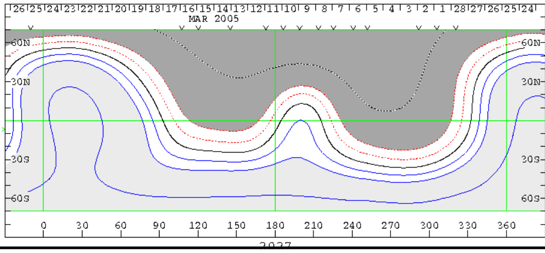


Solar Wind Density Turbulence and Speed (3 days)



Ooty IPS measurements: Density Turbulence and Speed of the Solar Wind in the Inner heliosphere





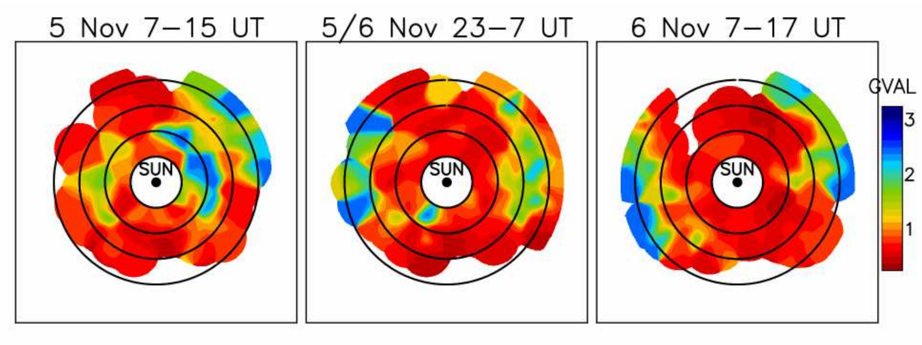
CR2027

February 25 – March 25, 2005

Coronal Mass Ejections

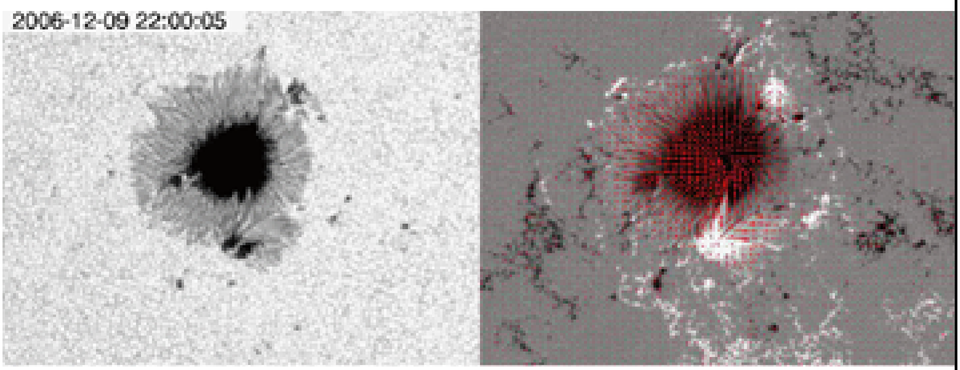
- Largest phenomenon associated with the dissipation of magnetic flux at and above the surface of the Sun
- Travel outward at range of speeds, 10 – 2500 km/s
- Mass involved in each ejection is $\sim 10^{14} - 10^{15}$ g
- Main cause of large geomagnetic storms
- CMEs appear to be an important factor of space weather, which has multiple geospheric, biospheric, and technological effects.
- A great interest in understanding the propagation and arrival of Earth-directed CMEs, which cause major storms at the Earth's magnetosphere.
- However, there are many open questions concerning CMEs origin, evolution, structure/extent in the interplanetary space
  - To progress in understanding the effects of CMEs requires detail 3-D data on them from Sun to Earth

Some example of November 2003 CMES



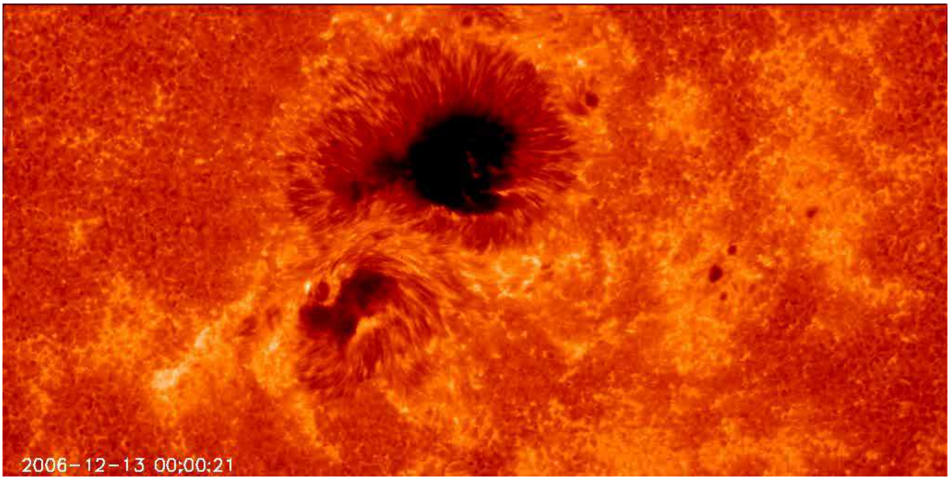
Hinode (Solar-B) Magnetic Field Twisting

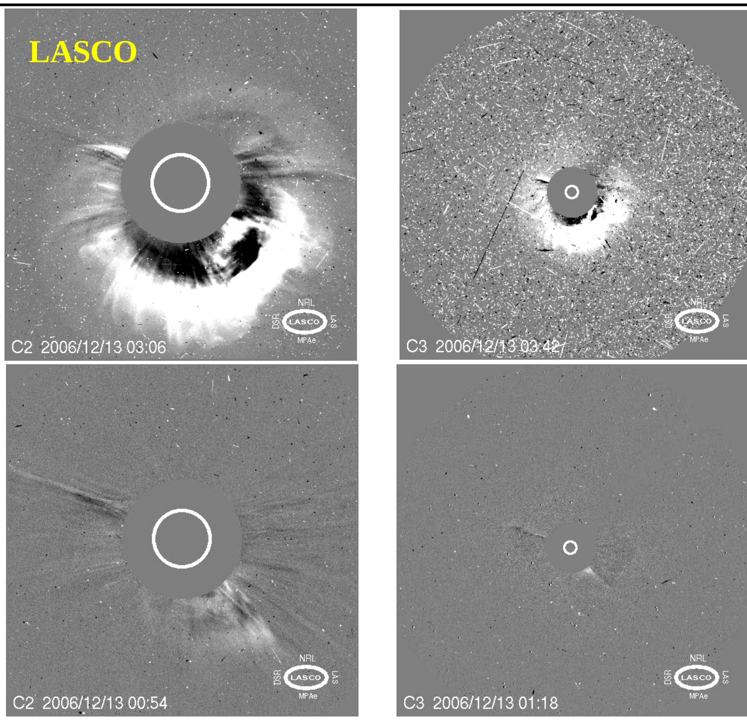
December 9-14, 2006

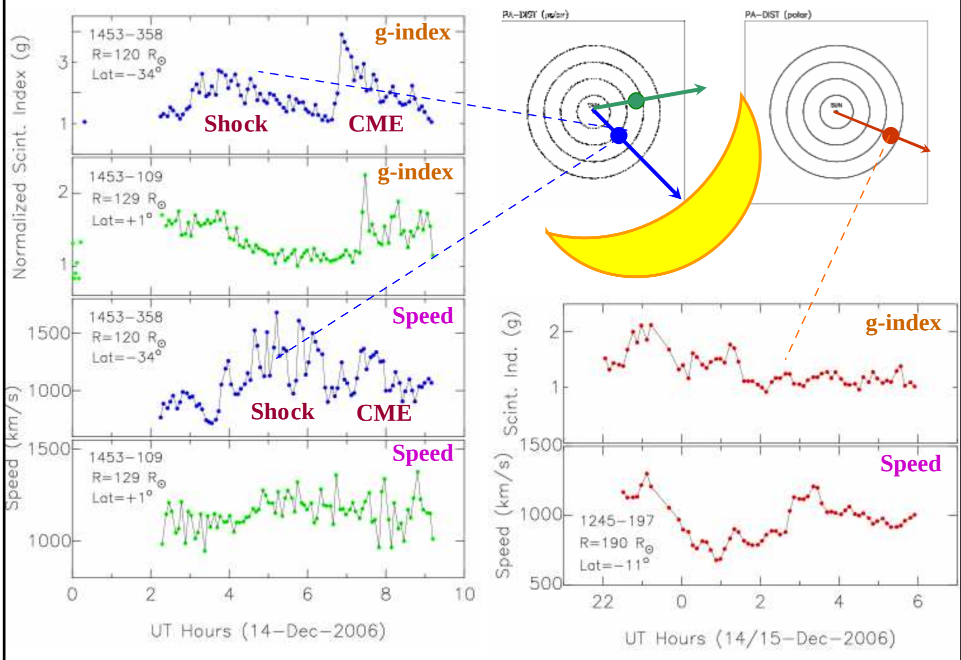


Hinode (Solar-B) SOT

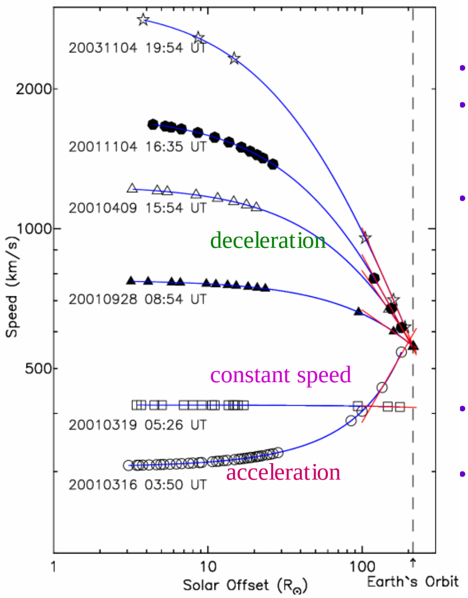
December 13, 2006







Speed Profiles: $V_{CME}(R)$

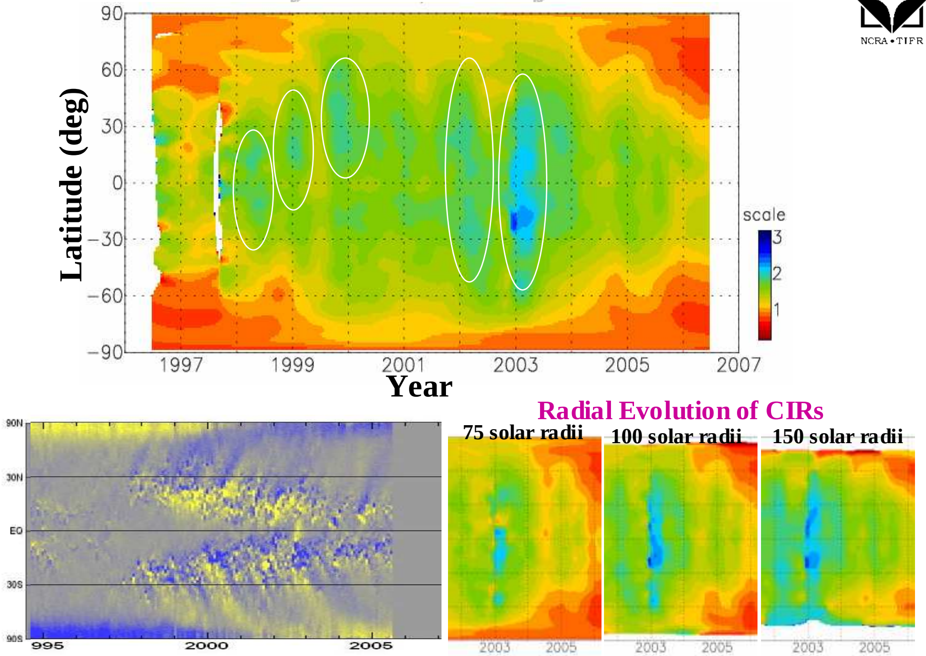


Radial Evolution of Halo and Partial halo CMEs

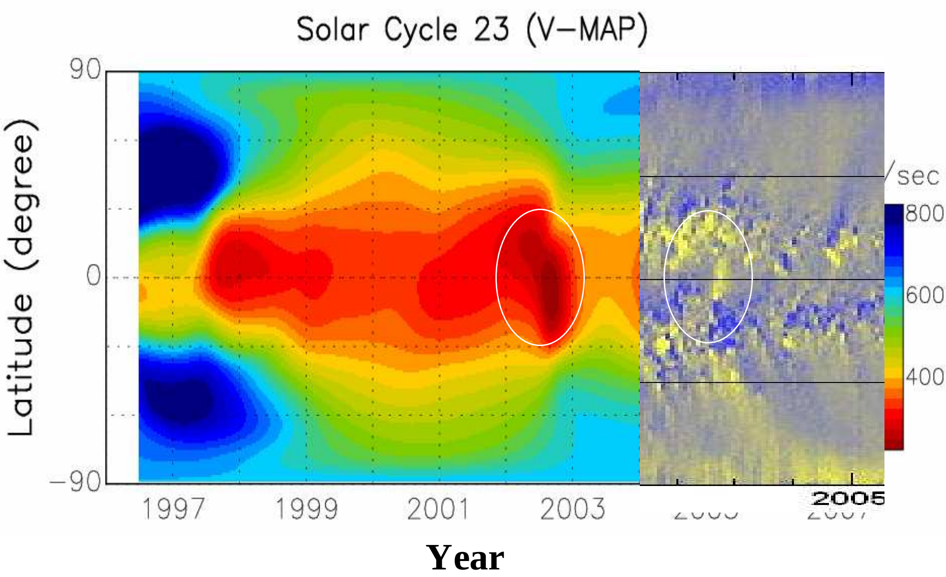
P.K. Manoharan

- IPS & LASCO provide sky-plane speeds
- Each CME goes through continuous changes depending on its interaction with the surrounding solar wind
- Mean travel time curve for different initial speeds suggests that up to a distance of ~80 Rsun, the internal energy of the CME (or its expansion) dominates and however, at larger distances, the CME's interaction with the solar wind appears to control the propagation
- Most of the CMEs tend to attain the speed of the ambient flow at 1 AU or further out.
- Results are useful to quantify the ‘drag force’ imposed on the CME by the interaction with the surrounding solar wind and it is essential in modeling the CME propagation.

Solar Cycle 23 – Density Distribution



Solar Cycle 23 – Solar wind Speed Distribution



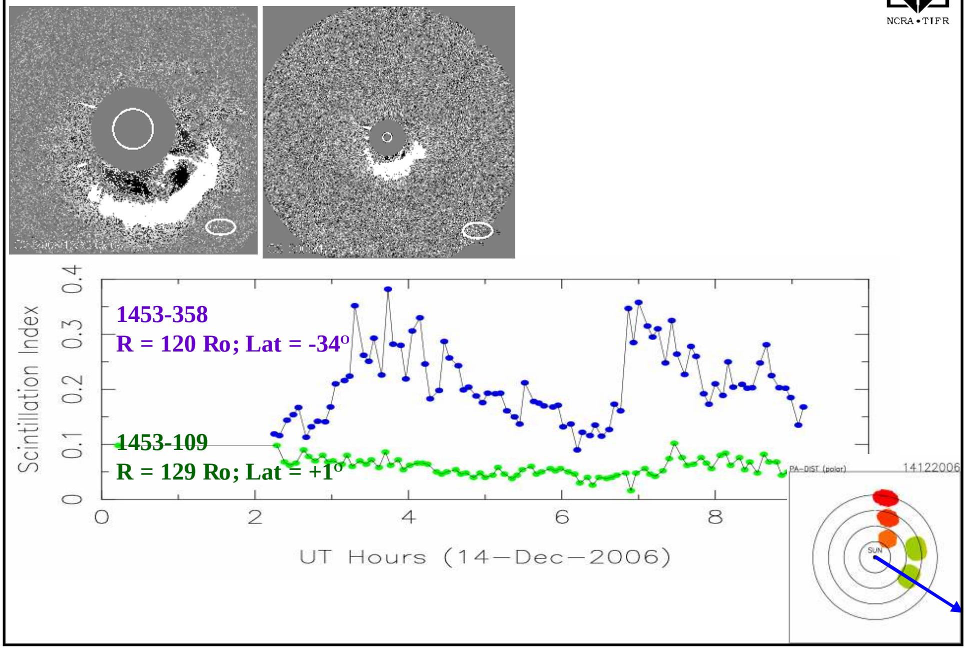
Summary

NCRA • TIFR

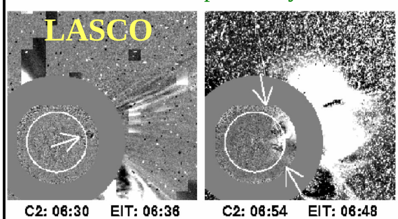
- **Ooty measurements provide important information on the evolution of solar events to better understand the geo-effect nature**
- **These studies indicate the importance of interaction of propagating IP disturbances with the ambient solar wind**
  - **Interactions between IP disturbance and solar wind shape the heliosphere**
  - **3-dimensional measurements of IP disturbances in the Sun-Earth distance are essential to understand their geo-space impact**

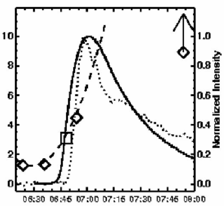
Thank You

Ooty IPS- CME Crossing Radio Source Line of sight Fence



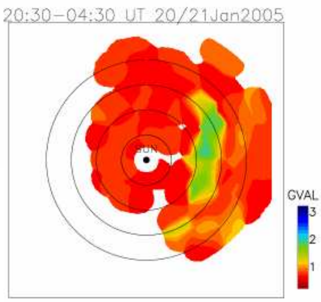
Gopalswamy et al. 2005

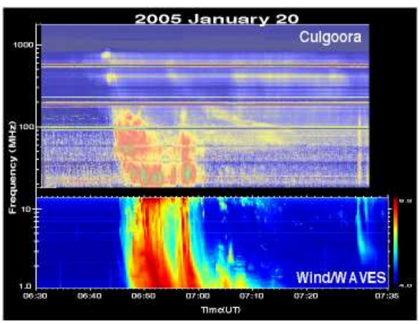


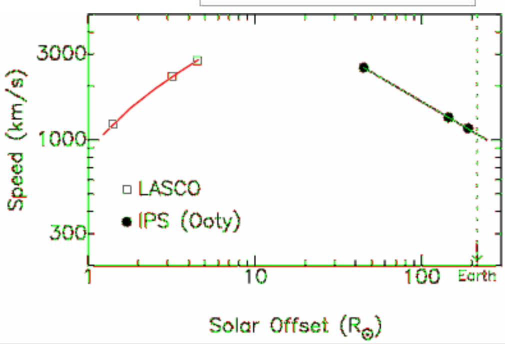


Ooty IPS IMAGE

Manoharan et al 2007



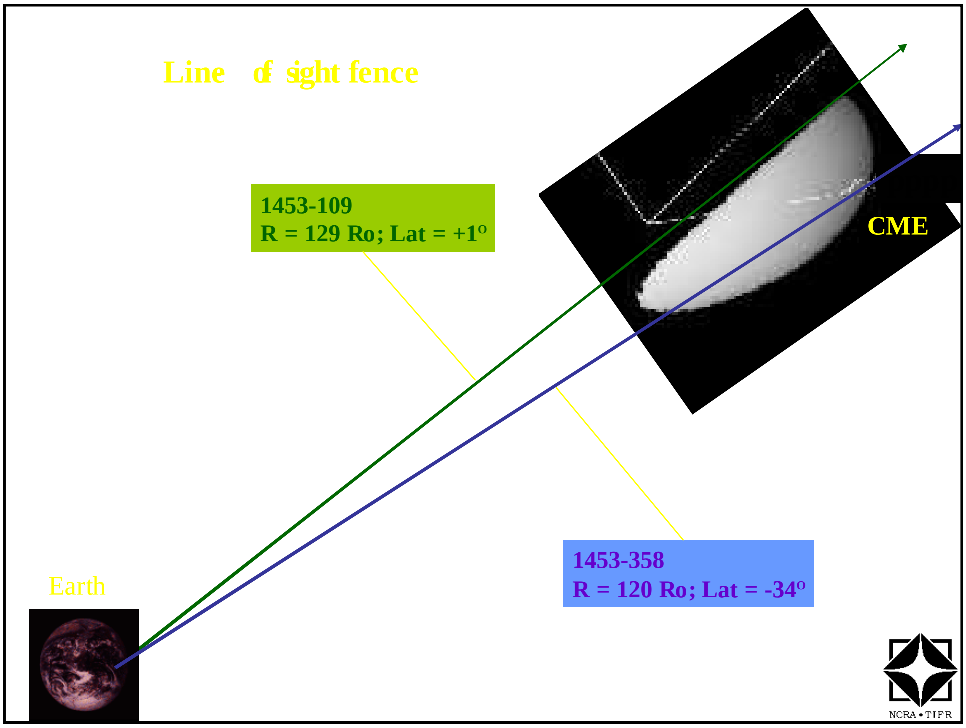




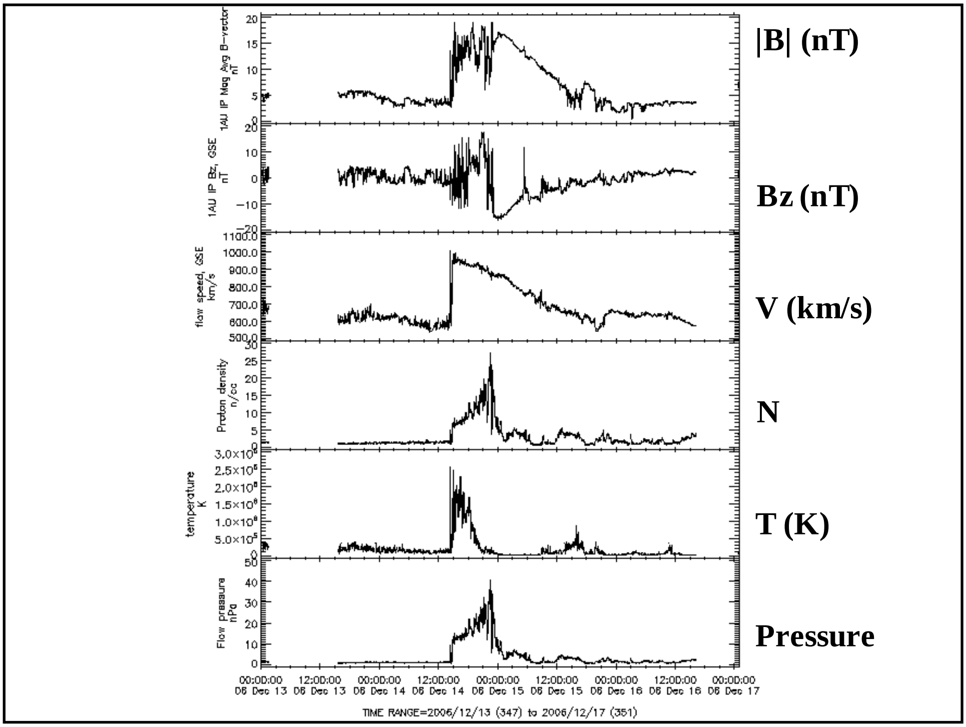
A fast CME Event
January 20, 2005

Satellite Tracking B-N Camera, ARIES, Nainital (IGY-1957 Program)

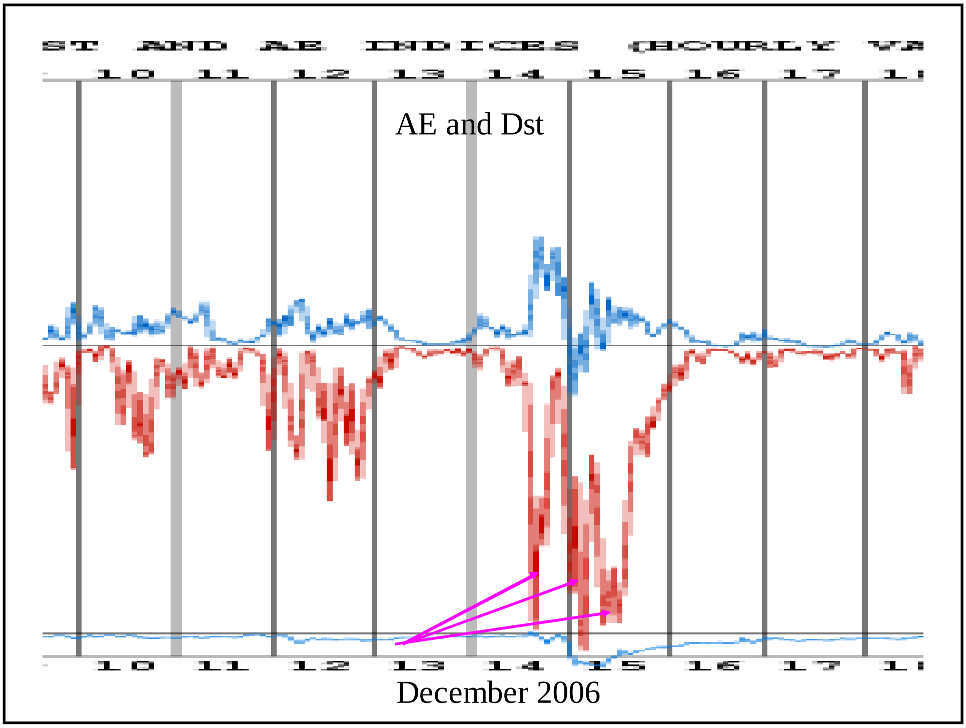
A closer look!

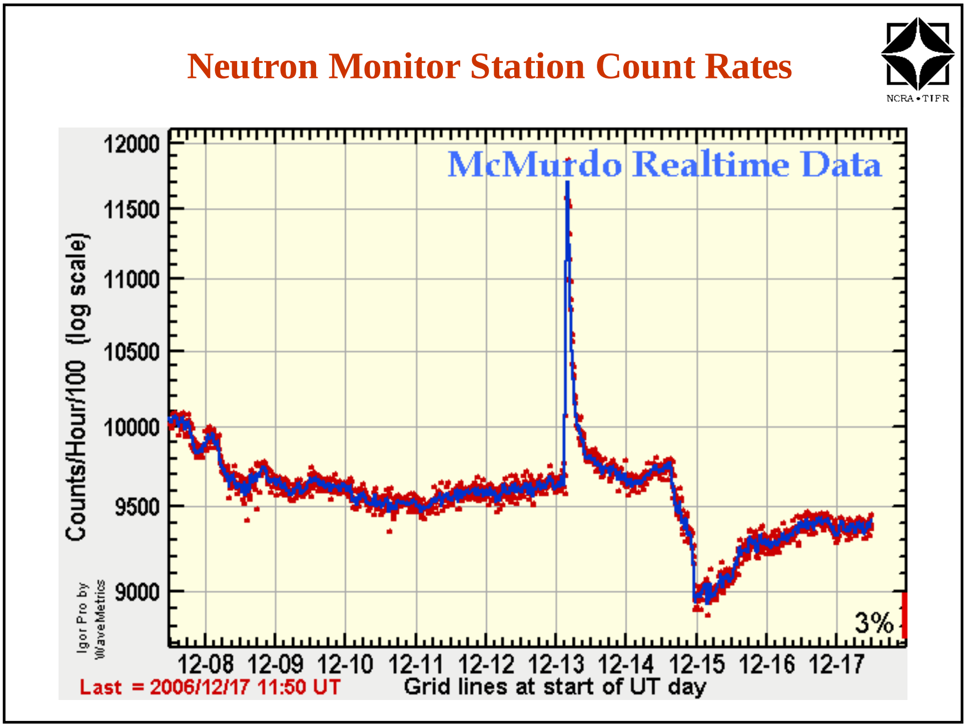


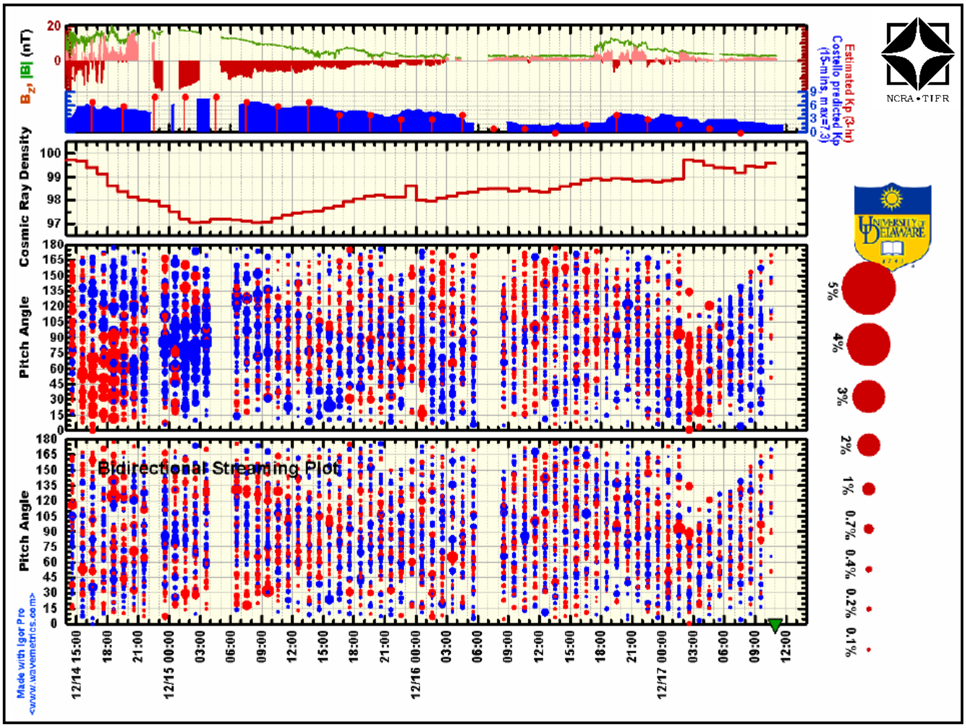
Line of sight fence
1453-109
R = 129 Ro; Lat = +1o
CME
1453-358
R = 120 Ro; Lat = -34o
Earth
NCRA • TIFR



|B| (nT)
Bz (nT)
V (km/s)
N
T (K)
Pressure
1AU IP Mag Avg B-vector nT
1AU IP Bz, GSE nT
flow speed, GSE km/s
Proton density n/cc
temperature K
Flow pressure nPa
TIME RANGE=2006/12/13 (347) to 2006/12/17 (351)


AE and Dst
10 11 12 13 14 15 16 17
December 2006


Neutron Monitor Station Count Rates
NCRA • TIFR
McMurdo Realtime Data
Counts/Hour/100 (log scale)
12000
11500
11000
10500
10000
9500
9000
3%
12-08 12-09 12-10 12-11 12-12 12-13 12-14 12-15 12-16 12-17
Last = 2006/12/17 11:50 UT
Grid lines at start of UT day
Igor Pro by WaveMetrics



Bz, |B| (nT)
Estimated Kp (3-hr)
Costello predicted Kp
(15-mins, max=7.3)
Cosmic Ray Density
Pitch Angle
Bidirectional Streaming Plot
Made with Igor Pro
<www.wavemetrics.com>
12/14 15:00
12/15 00:00
12/16 00:00
12/17 00:00
5%
4%
3%
2%
1%
0.7%
0.4%
0.2%
0.1%
NCRA • TIFR