The SHINE exoplanet survey

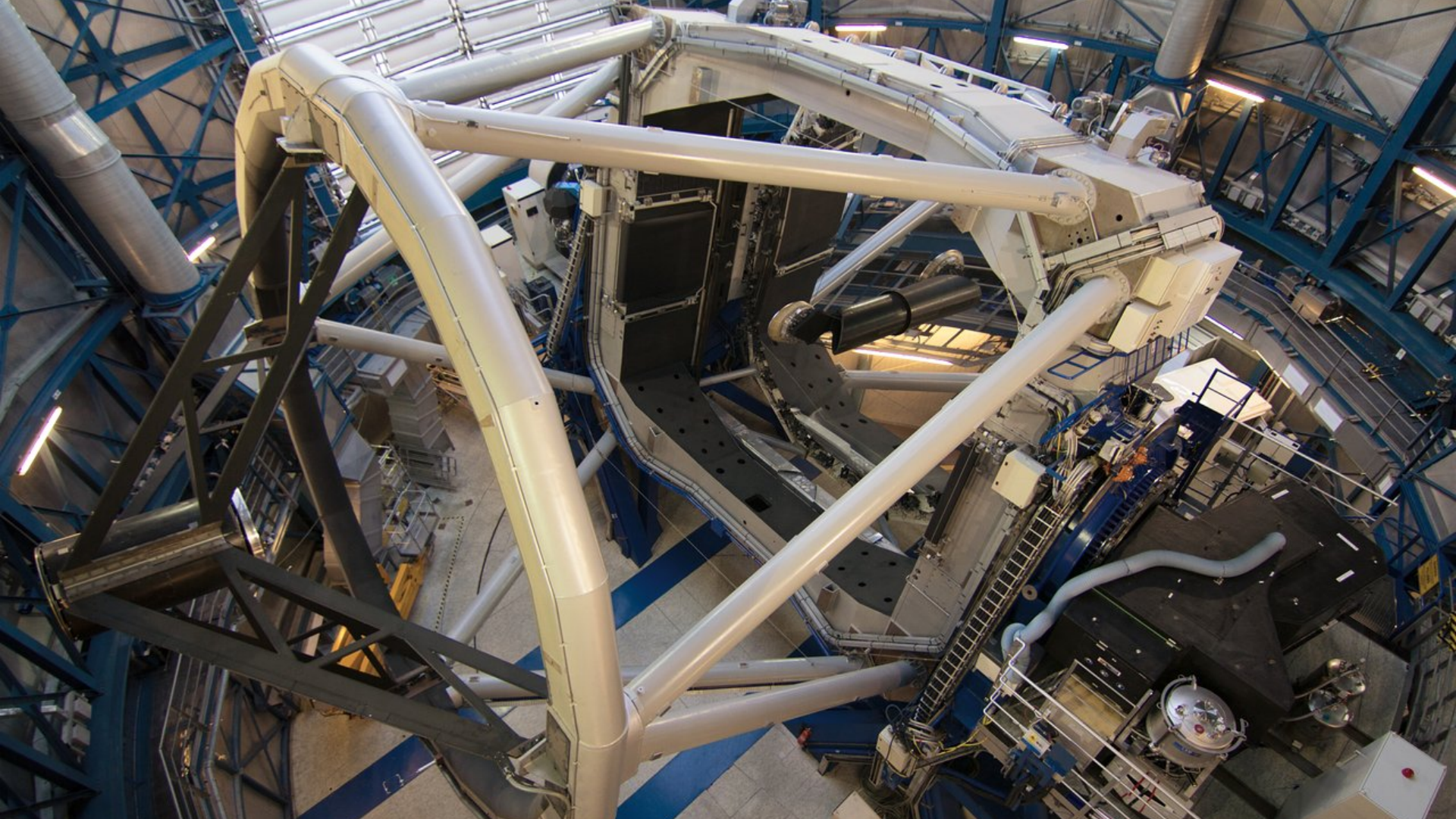
Anthony Cheetham

University of Geneva, Switzerland

SHINE Team: G. Chauvin, S. Desidera, M. Bonnefoy, A. Cheetham, M. Feldt, R. Gratton, A.-M. Lagrange, M. Langlois, M. Meyer, A. Vigan, B. Biller, A. Boccaletti, M. Bonavita, F. Cantalloube, S. Daemgen, P. Delorme, V. D'Orazi, R. Galicher, J. Hagelberg, M. Janson, H. Le Coroller, R. Ligi, A.-L. Maire, S. Messina, A. Mueller, S. Peretti, M. Samland, E. Sissa, C, A. Zurlo + the SPHERE consortium

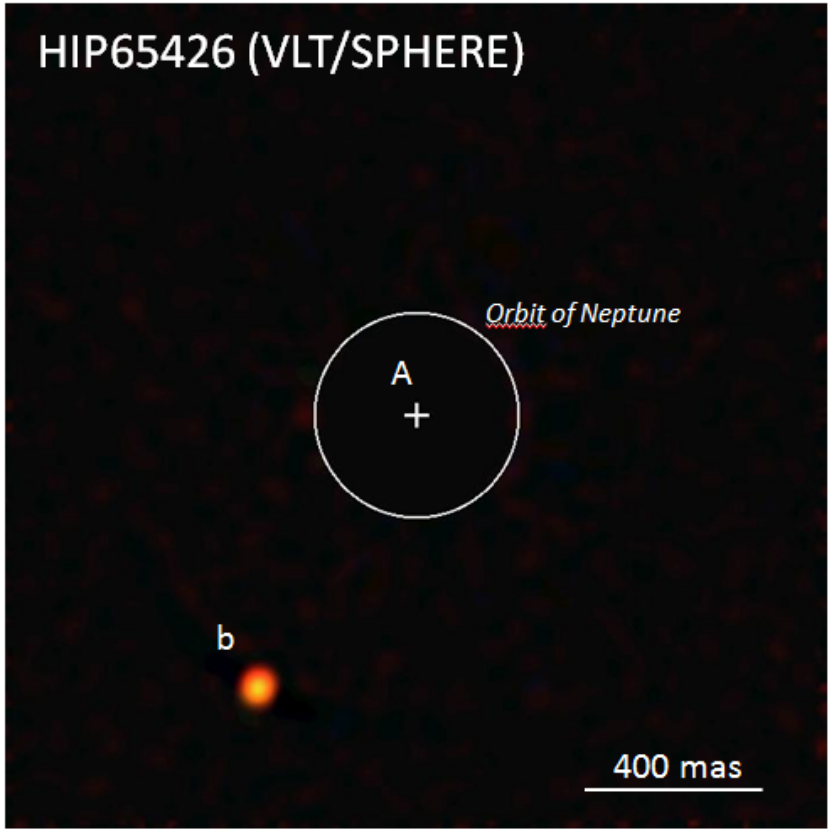
SPHERE PI, Co-PI & CoIs: J.L. Beuzit, M. Feldt, A. Boccaletti, C. Dominik; T. Henning, E. Lagadec, H. Le Coroller, F. Ménard, H.-M. Schmidt, M. Turatto , S. Udry

SHINE



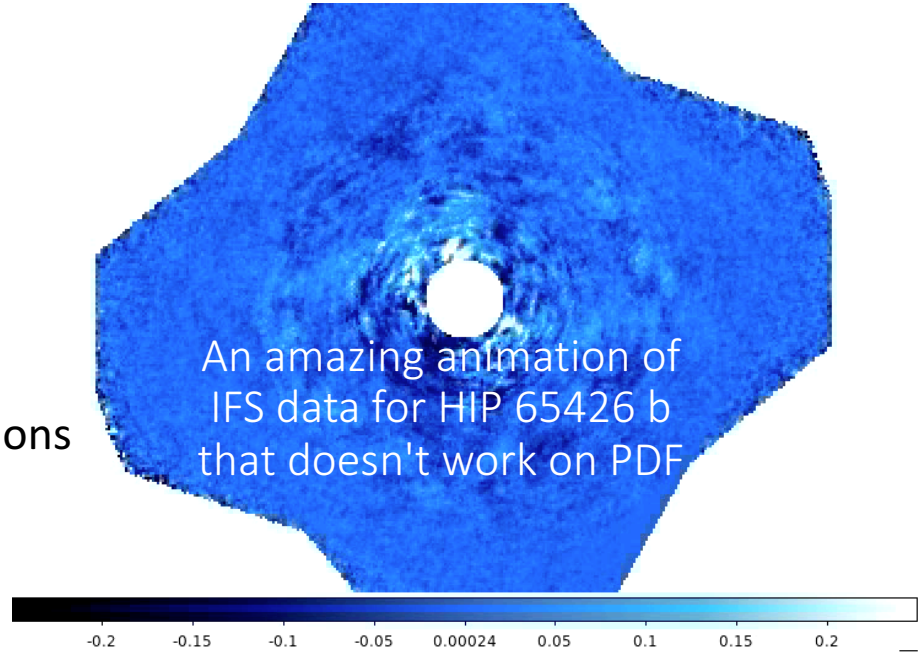
The SHINE survey

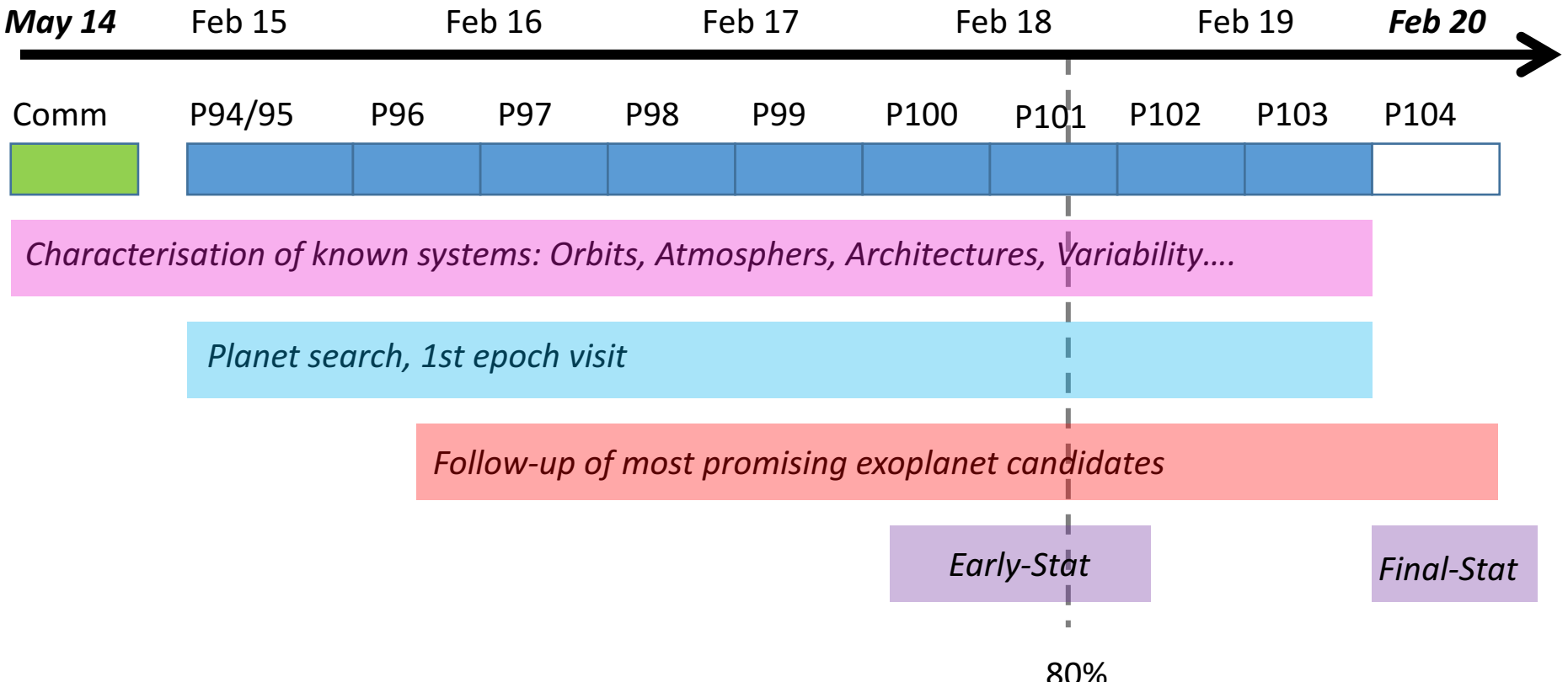
- Near-IR imaging survey of exoplanets
- 200 nights
- SPHERE instrument at VLT
  - IRDIS (1.6um, 12” FoV)
  - IFS (0.9-1.4um, 1.7” FoV)
- Statistical sample: 400-600 targets
- Special targets: 50 targets (disks, known companions etc)



Science with SHINE

- New planet discoveries
- Physics of giant planets
  - Young L, T, Y objects
  - Atmospheres
  - Mass-luminosity
  - Accretion and evolution
- System architectures
  - Planet-disk and planet-planet interactions
- Giant planet occurrence and formation




May 14
Feb 15
Feb 16
Feb 17
Feb 18
Feb 19
Feb 20
Comm
P94/95
P96
P97
P98
P99
P100
P101
P102
P103
P104
Characterisation of known systems: Orbits, Atmosphers, Architectures, Variability….
Planet search, 1st epoch visit
Follow-up of most promising exoplanet candidates
Early-Stat
Final-Stat
80%

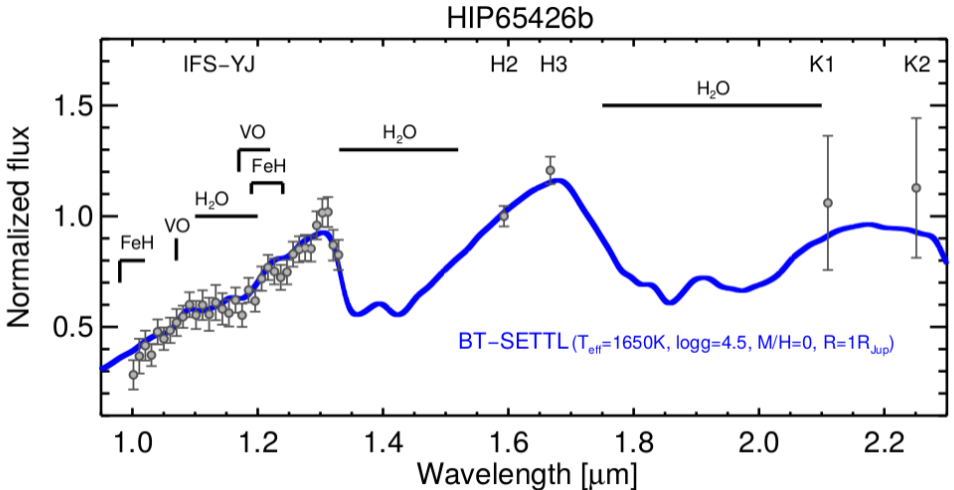
New discoveries

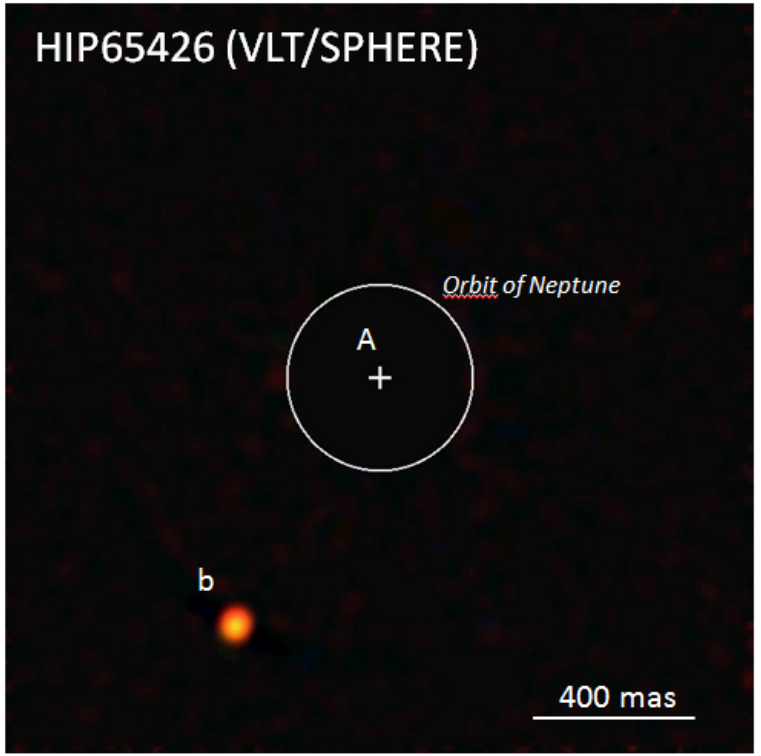
HIP 65426 b

- Host: A2, 1.96$M_{\odot}$
- LCC member (14Myr)

- 92 AU
- L5-L7
- 6-12 M_{Jup}

- 1300-1600K
- log(g) = 4-5 dex
- R = 1.5 R_{Jup}

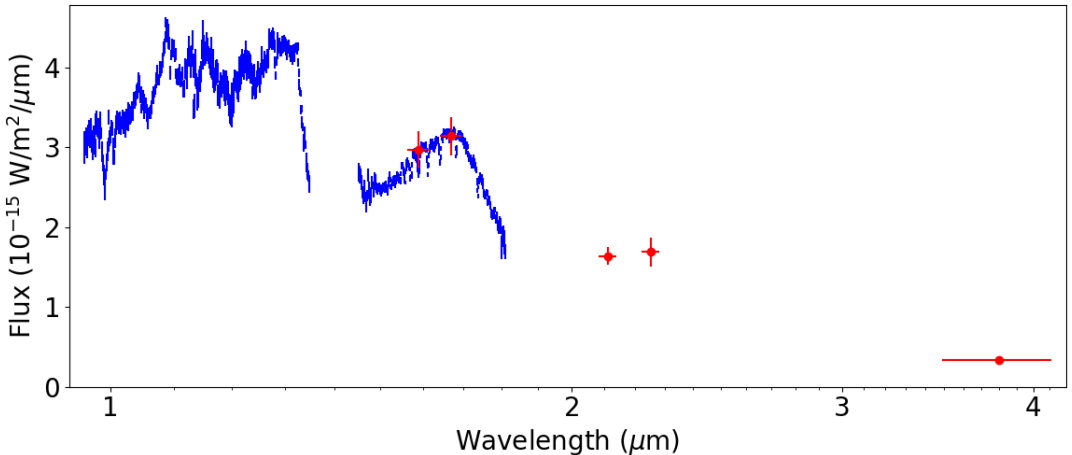


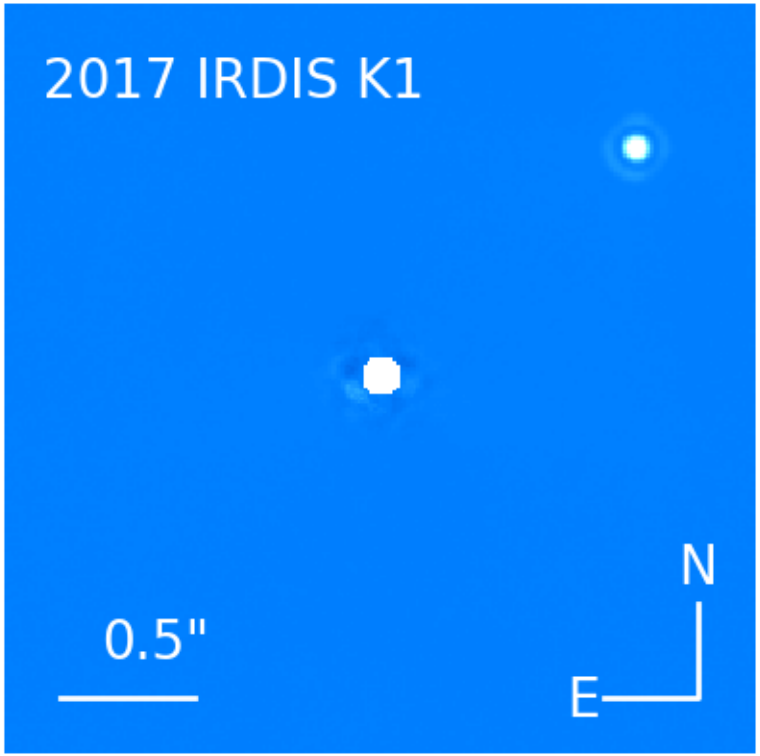


First new planet discovery
Chauvin et al. 2017, A&A

HIP 64892 B

- Host: B9, 2.35$M_{\odot}$
- LCC member (16Myr)
- 159 AU
- M8-L0
- 29-37 M_{Jup}
- 2500-2700K
- log(g) = 3.5-4.5 dex
- R = 2.3 R_{Jup}





First new brown dwarf discovery
Cheetham et al. 2018, A&A (accepted)

and the newest addition…

PDS 70 b

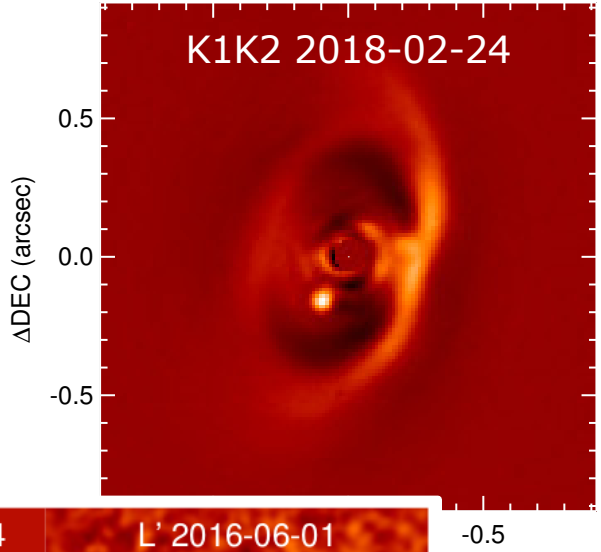
- Host: K7, 0.76$M_{\odot}$
- UCL member (5.4 Myr)

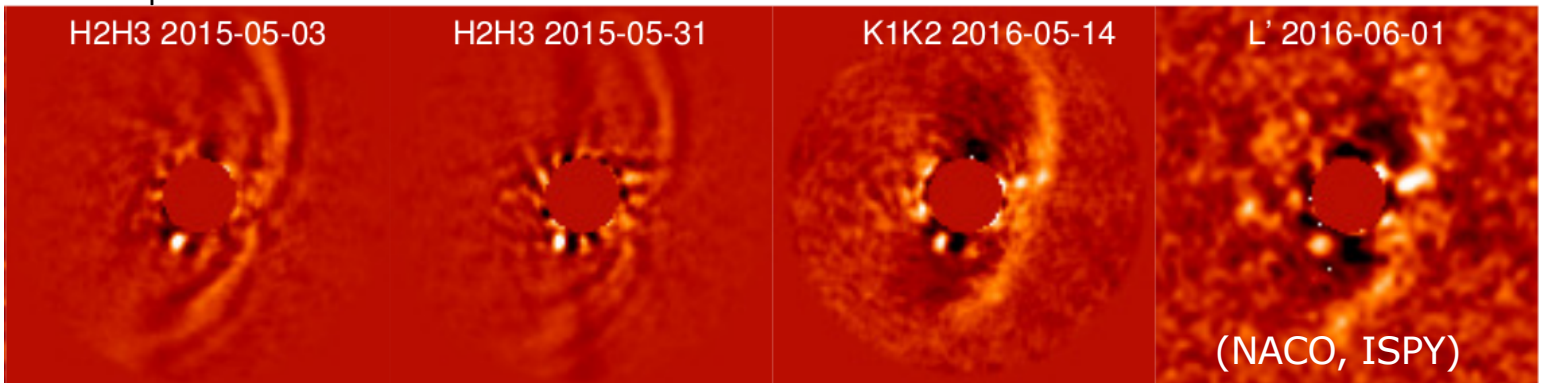
- 22 AU
- mid-late L
- 6-12 M_{Jup}
- 1050-1600K
- log(g) < 3.5 dex
- R = 1.4-3.3 R_{Jup}

Keppler, Benisty, Mueller, Henning et al. 2018

Mueller, Keppler, Henning et al. 2018

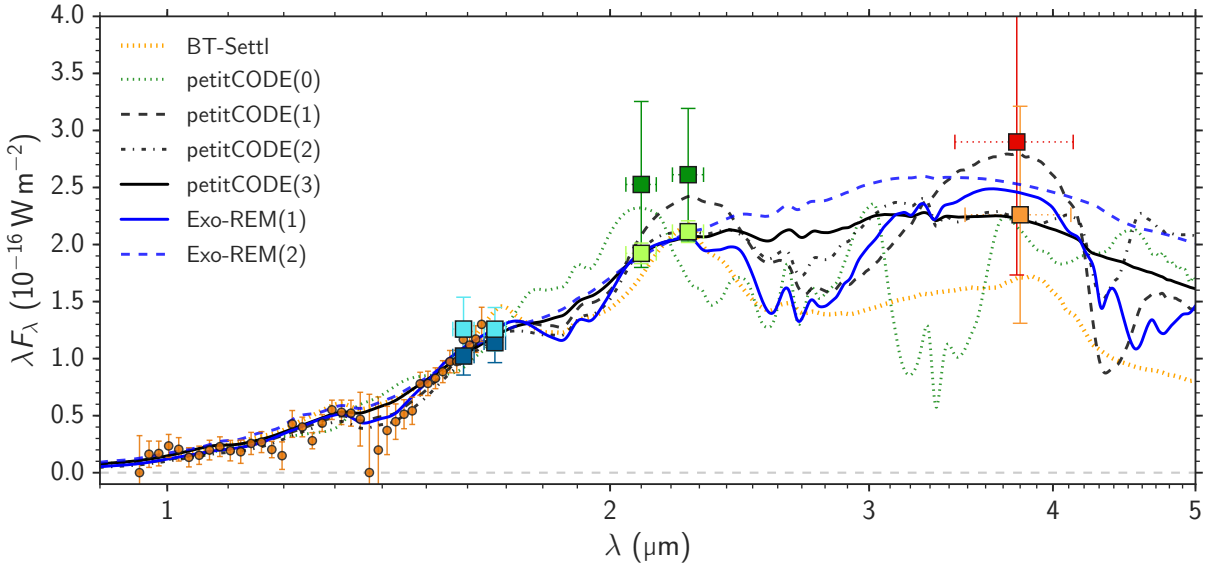
and ESO press release

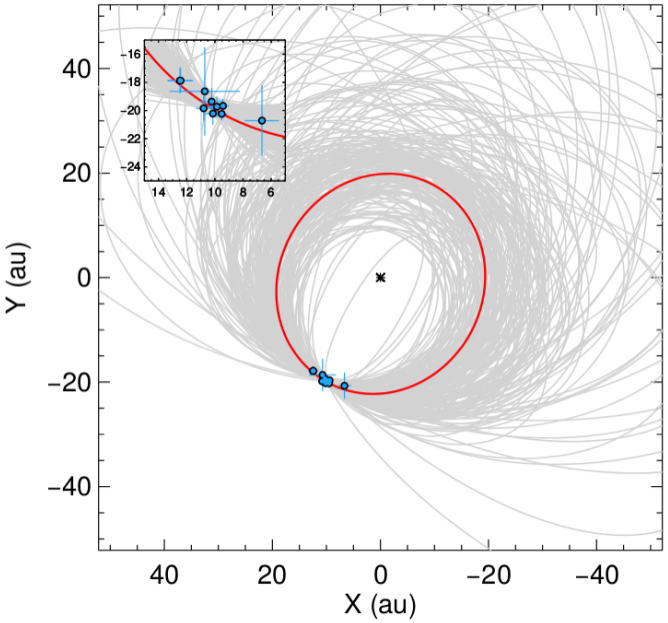




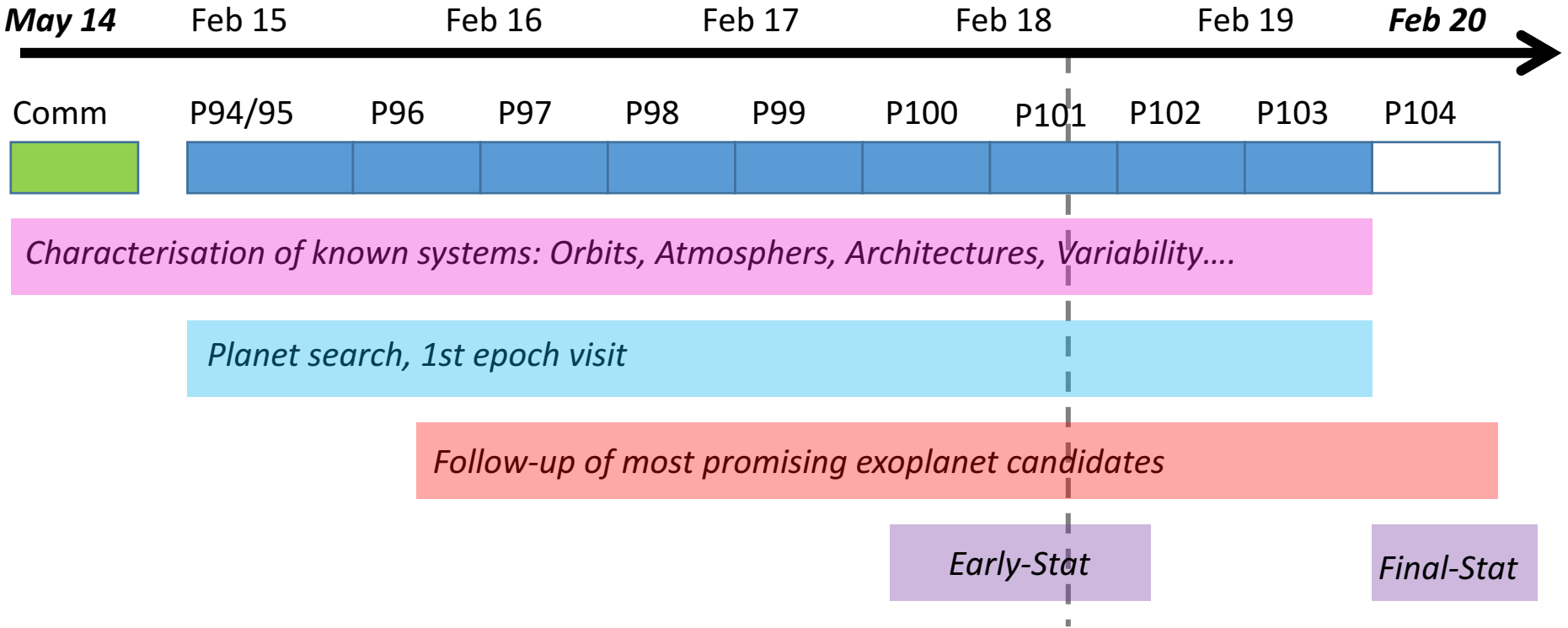
PDS 70 b

See poster 36 by M. Samland for more details!





Early Statistical Analysis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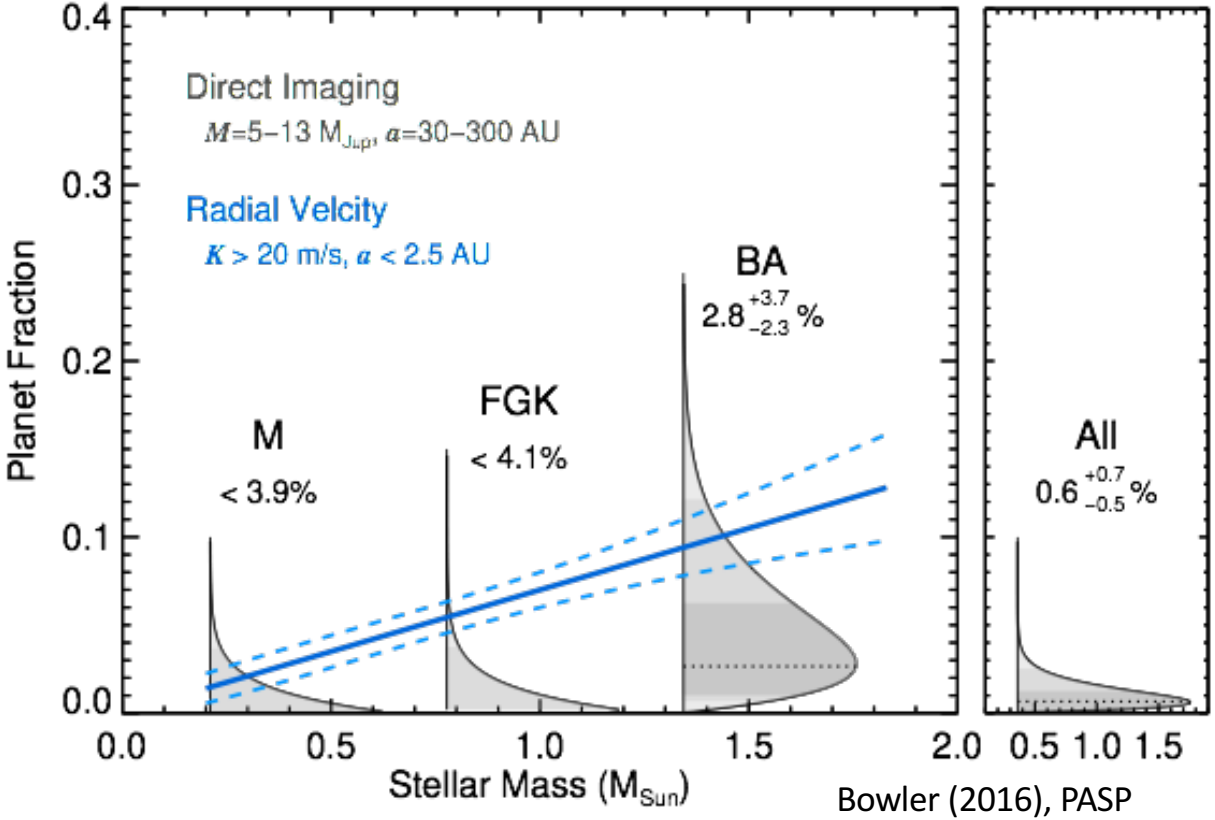
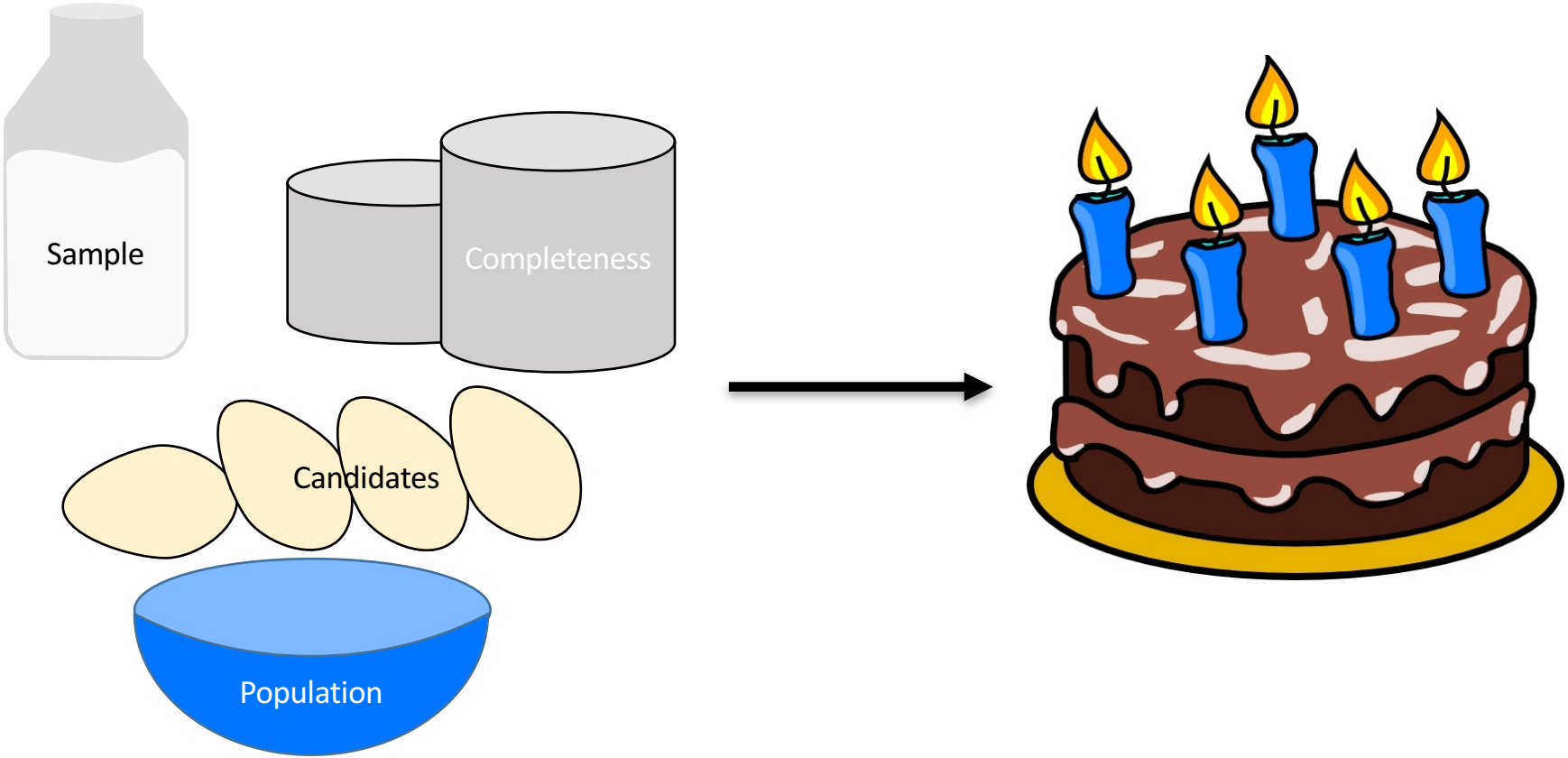
Follow-up of most promising exoplanet candidates
Early-Stat
Final-Stat

Statistical Constraints

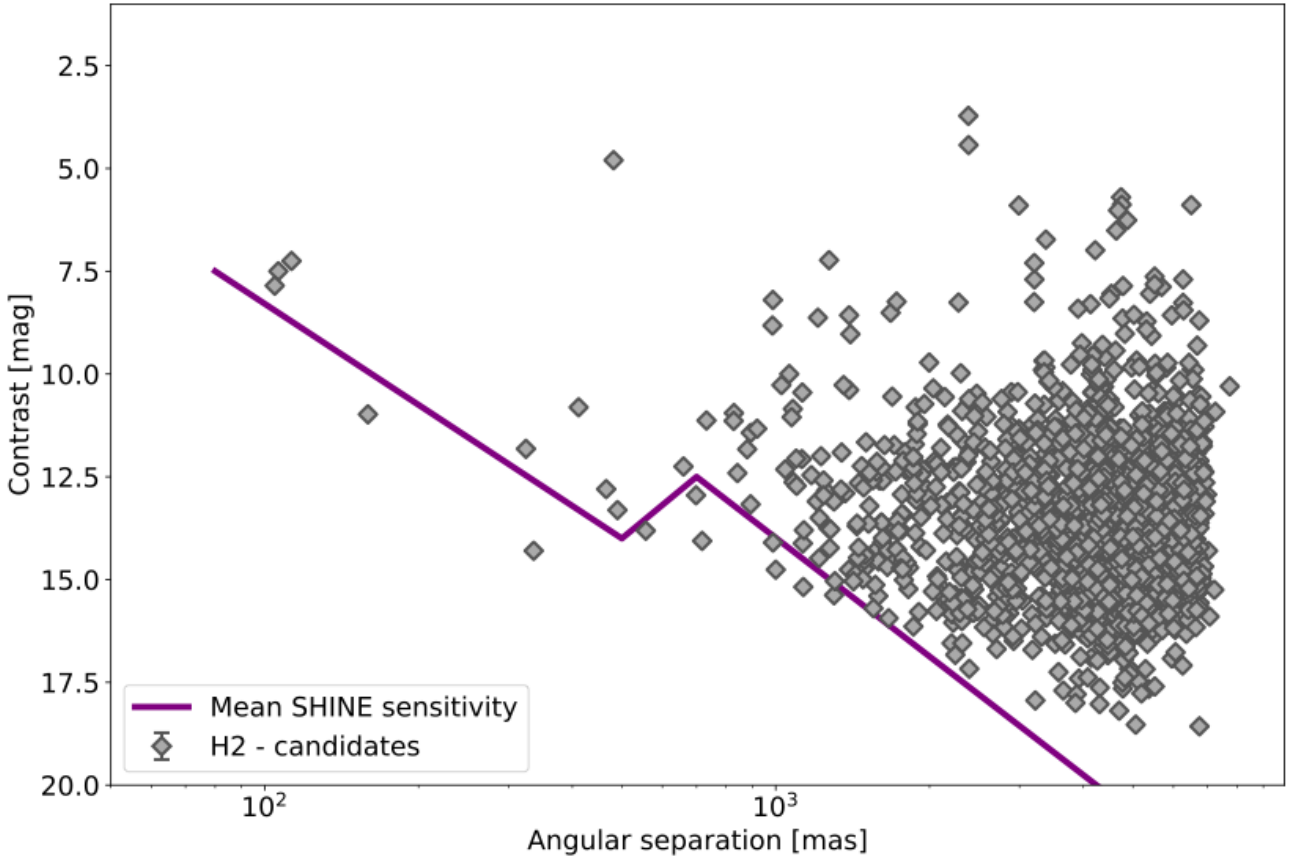


Bowler (2016), PASP

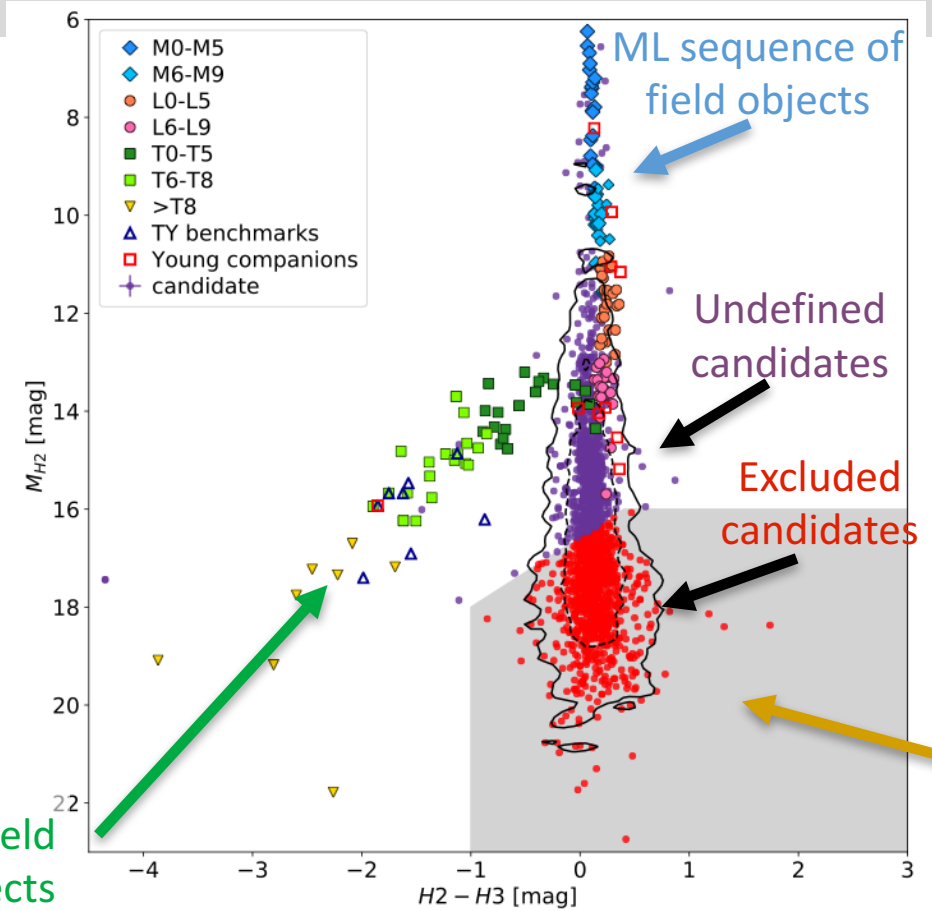
Statistical Constraints



Candidates

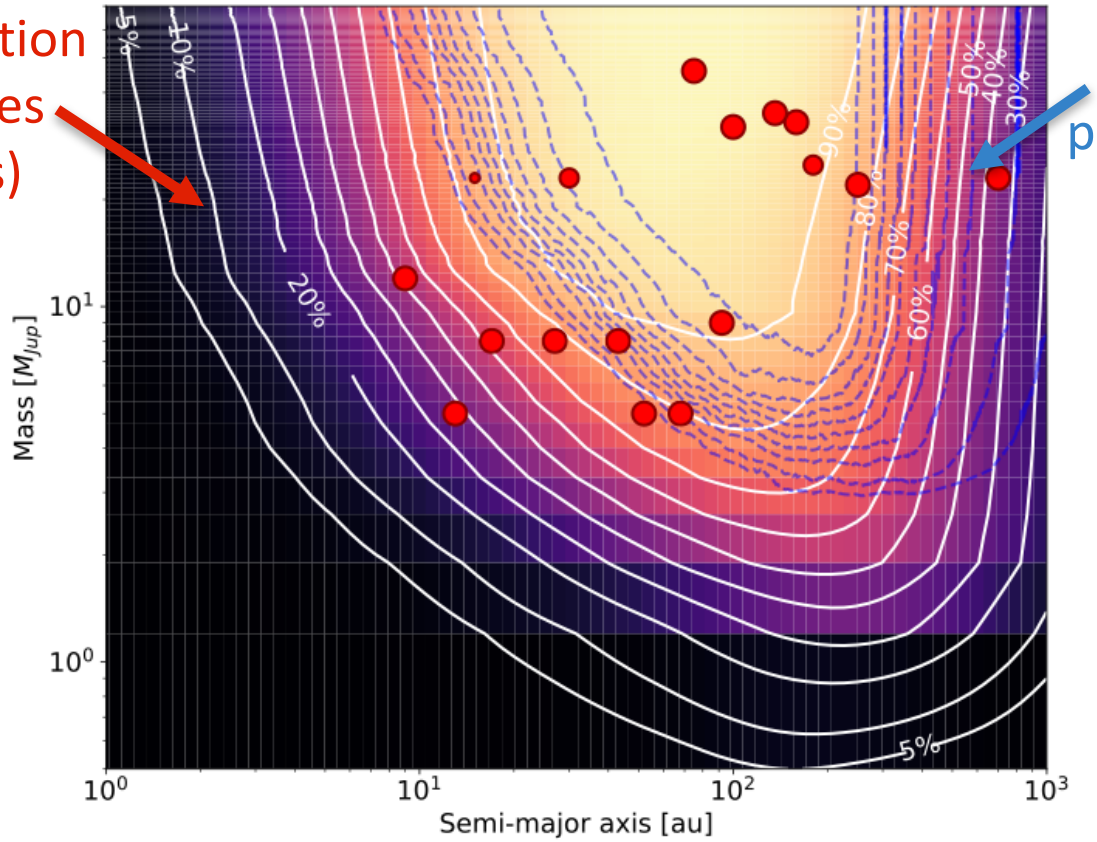

2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Contrast [mag]
10^2
10^3
Angular separation [mas]
Mean SHINE sensitivity
H2 - candidates

Candidates


M0-M5
M6-M9
L0-L5
L6-L9
T0-T5
T6-T8
>T8
TY benchmarks
Young companions
candidate
ML sequence of field objects
Undefined candidates
Excluded candidates
Exclusion region
TY sequence of field objects
M_{H2} [mag]
$H2 - H3$ [mag]
6
8
10
12
14
16
18
20
22
−4
−3
−2
−1
0
1
2
3

Completeness

SHINE detection probabilities (180 stars)



Naco-LP detection probabilities (200 stars)

Mass conversion with Baraffe et al. models **(Baraffe+ 2003, 2015)**

+ Monte-Carlo analysis with MESS tool **(Bonavita+ 2013)**

Occurrence Rates

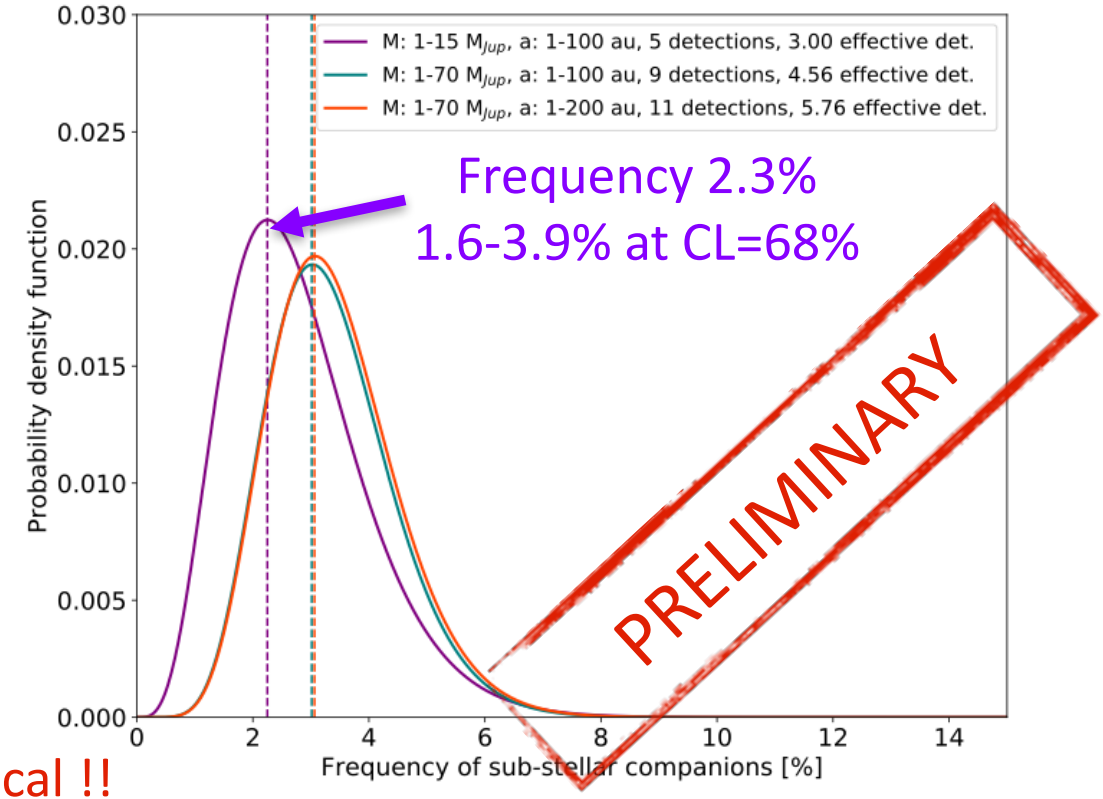
Bayesian estimation of the likelihood
(Lafrenière+ 2007; Vigan+ 2012)

Frequency estimation in several bins of mass and semi-majors axis

Hypotheses:

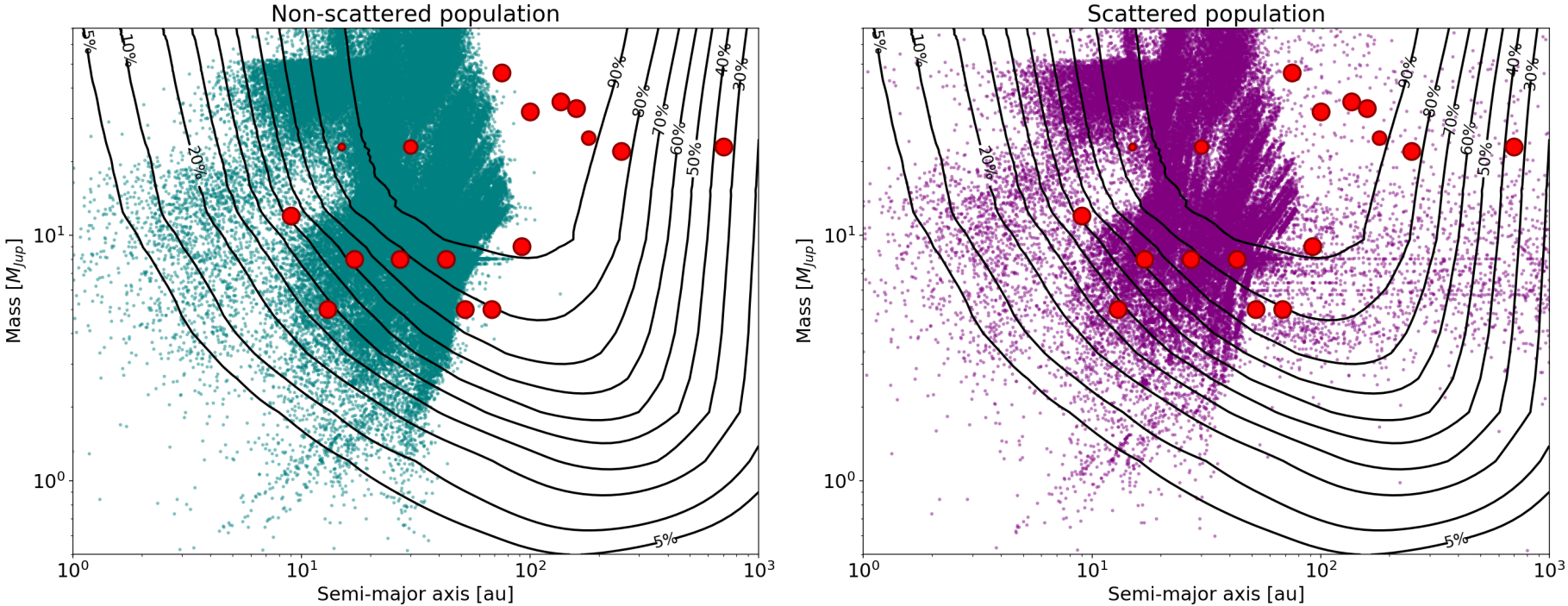
- all spectral types
- nominal age for stars
- undefined candidates ignored → background
- companions distribution:
  - flat in mass
  - flat in semi-major axis

Not physical !!



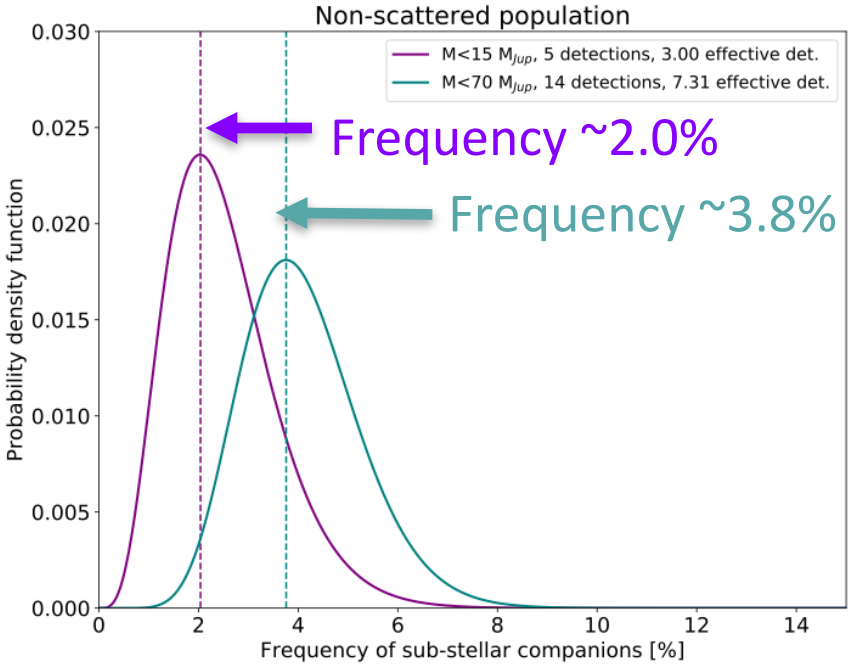
Comparison with Models

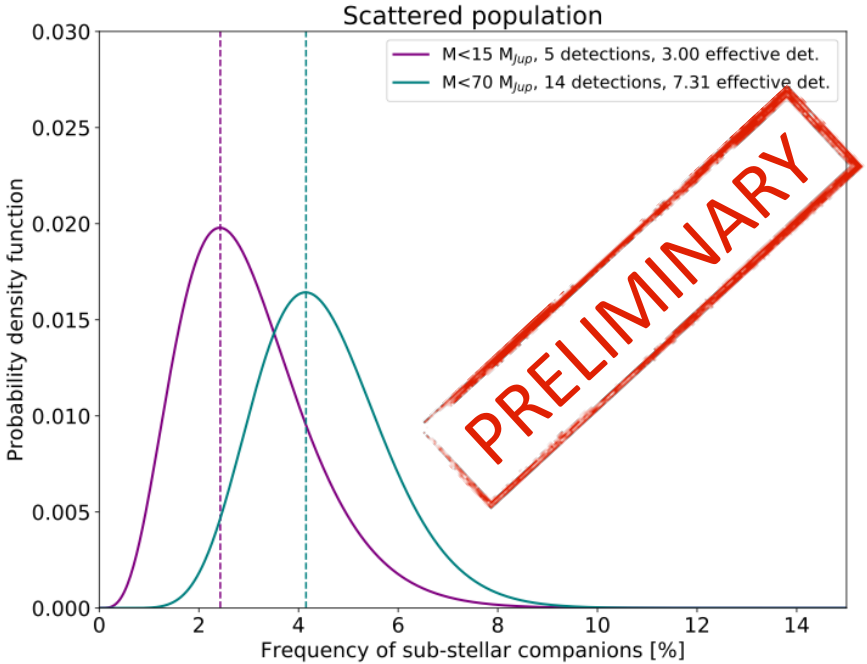
- Population synthesis models of Forgan et al. (2013, 2015)
- Gravitational Instability + scattering



Comparison with Models

- Frequency estimation compatible with NaCo-LP results **(Vigan et al. 2017)**
- Similar results without and with scattering

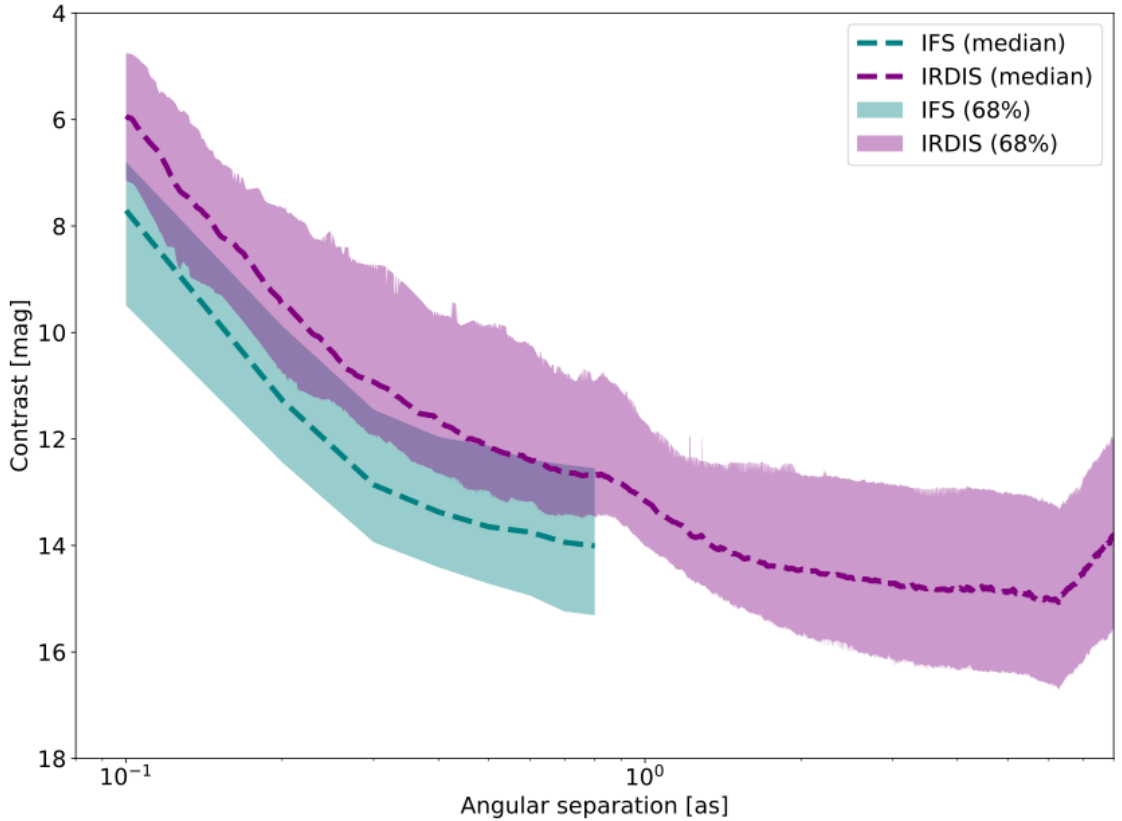




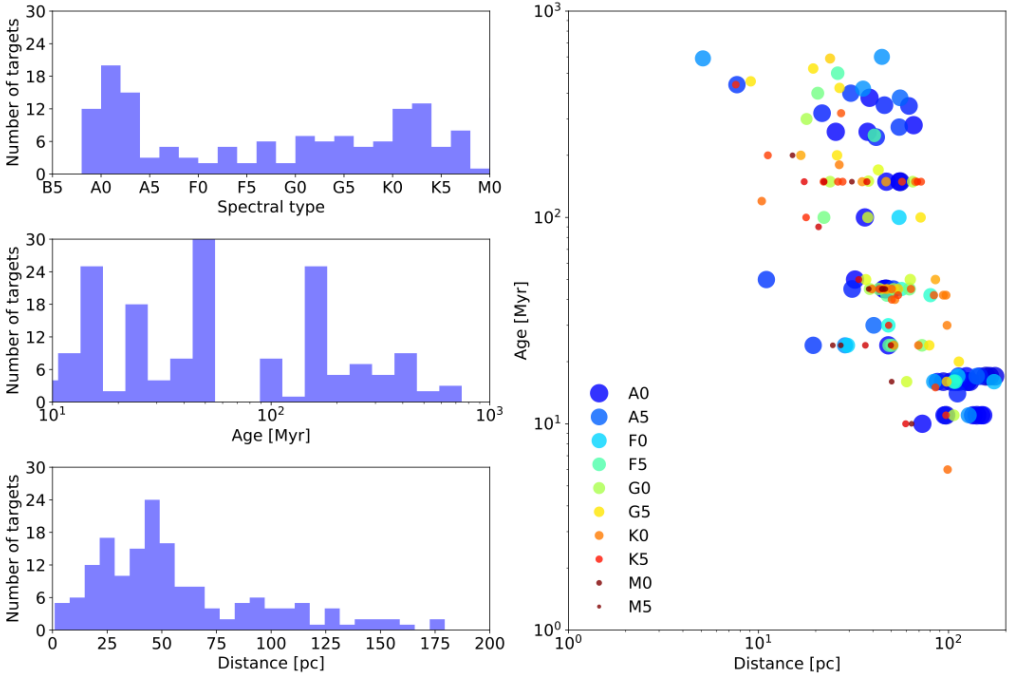
→ Next step: comparison to CA models (Mordasini et al.)

SHINE

- 3.5 / 5 years
- >50 peer-reviewed publications (Nature, A&A, ApJ, MNRAS, …)
- 7 Press releases (ESO, CNRS, MPIA, INAF, …)
- Lots of interesting results from known objects
- Many newly imaged disks
- Several new detected planets and brown dwarfs
- More interesting candidates
- Early Statistical analysis in progress (Desidera+ 2018, Langlois+ 2018, Vigan+ 2018)
- Final statistical analysis ~2021


IFS (median)
IRDIS (median)
IFS (68%)
IRDIS (68%)
Contrast [mag]
4
6
8
10
12
14
16
18
10^{-1}
10^{0}
Angular separation [as]

Intermediate SHINE sample



- 167 targets
- 4+1 priority bins:
  - P4 to P1 for standard targets
  - P0 for special targets
- observed by order of priority + external parameters (date, obs. conditions, etc)

Desidera et al. in prep.

- intermediate sample representative of the full SHINE sample
- no significant bias in spectral type/distance/age
- ***but*** bias towards P0 targets because of known companions

Known detections in the sample

2 new 12 known 14 detections

Star	Spectral type	Semi-major axis [au]	Mass [M_{Jup}]	q M_p/M^*	Original priority	Updated priority	Effective detection
ß Pictoris	A3	8-10	12-13	0.7 %	P1	P0	0.60
HR8799	A5	17, 27, 43, 68	4-6, 5-9, 5-9, 5-9	0.2-0.6%	P1	P0	0.60
HD95086	A8	52	3-7	0.4 %	P1	P0	0.60
HIP65426	A2	92	6-12	0.3-0.6%	P1		0.60
GJ504	G0	>27	12-33	0.9-2.5%	P2	P0	0.35
51 Eri	F0	13	2-10	0.1-0.7%	P1	P0	0.60
HIP64892	B9	147-171	29-37	1.3-1.7%	P1		0.60
HIP107412	F5	10-20	15-30	1.1-2.2%	P4	P0	0.01
PZ Tel	G9	70-80	38-54	3.3-4.7%	P1	P0	0.60
η Tel	A0	136	20-50	1.0-2.4%	P1	P0	0.60
GSC 8047-0232	K2	280	15-35	1.6-3.8%	P2	P0	0.35
CD -35 2722	M1	50-152	23-39	4.0-6.8%	P1	P0	0.60
AB Pic	K1	250	13-30	1.3-3.0%	P1	P0	0.60
HIP78530	B9	700	23	1.0 %	P1	P0	0.60

Priority P1: 60% probability of observation (P_{obs})

Priority P2: 35% probability of observation

Priority P4: 1% probability of observation

Change to **P0** creates a real bias

→ count "effective detections" for the analysis

$$N_{det}^{eff} = \sum_{i=1}^{N_\star} P_{obs,i} N_{det,i} \quad = 7.31$$

Exoplanetary Atmospheres

Investigating temperature/gravity/clouds

Today: most imaged exoplanets are young L and early-T types,

Peculiar properties:
- Redder at L/T transition,
- CH4 absorption inhibited
- Underluminous for various cases,
- Enhanced photometric variability?

  > Clouds/Gravity & Temperature

Exploring atmospheric diversity:
- Buiding an homogeneous spectral sequence with SHINE,
- Testing predictions of models (Teff, log(g), Fe/H), cloud modelling, non-equil. processes,
- Comparison with young BD properties; Formation processes footprint?