Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

Pathways towards habitable planets

Triple satellite meeting 4

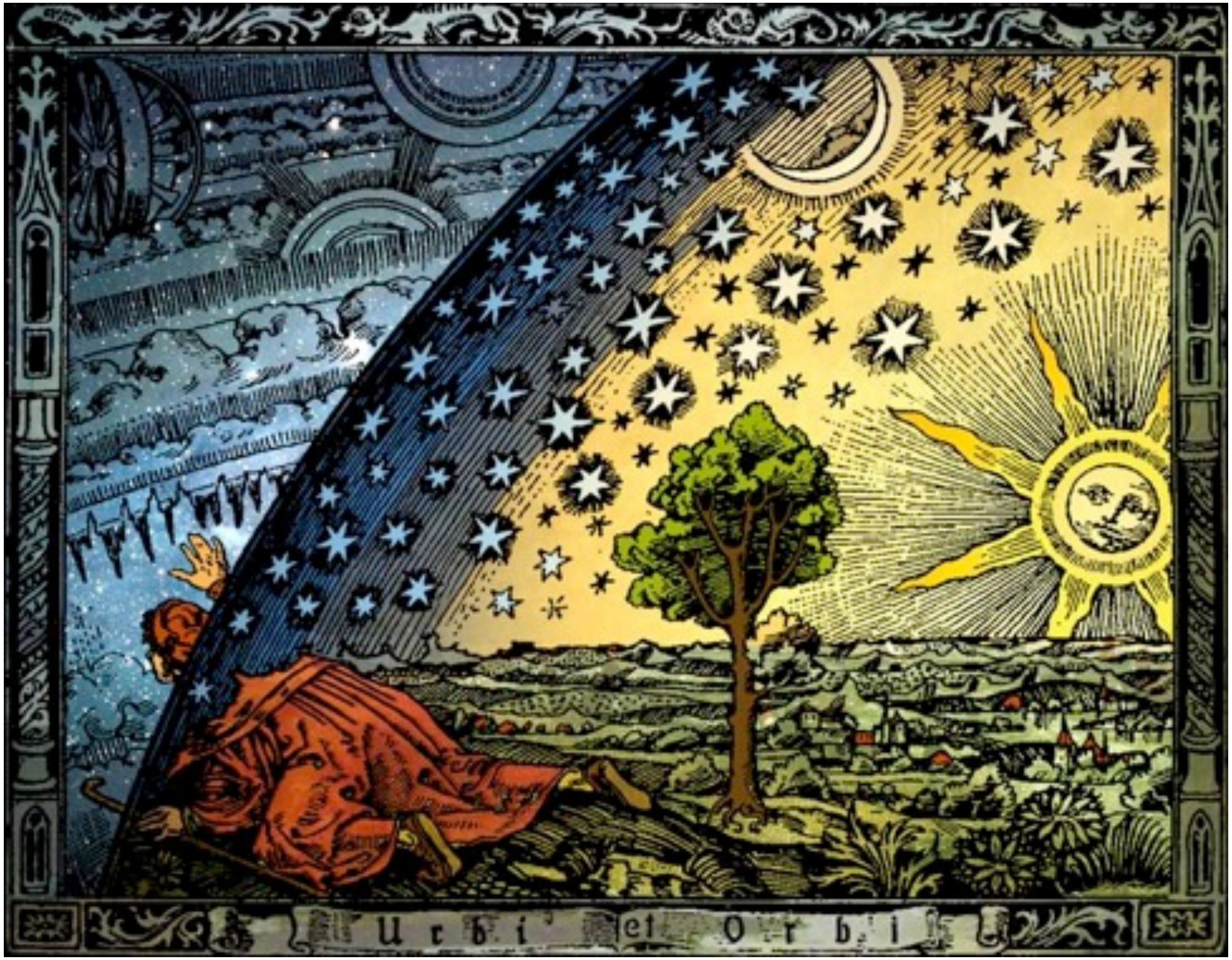
José A. Caballero

Suvrath Mahadevan, Ravi K. Kopparapu

Samuel Halverson, Christian Schwab

Eric T. Wolf, Jérémy Leconte, Jorge Sanz-Forcada, Peter Gao, Sonny Harman, Isabelle Boisse, Takayuki Kotani, Andreas Quirrenbach, Riccardo Claudi, Carlos del Burgo, Leonardo Vanzi, Peter Plavchan, Livia Origlia, Scott Diddams

Ulf Seemann, Cullen H. Blake…



La pluralité des mondes habités
(C. Flammarion 1862)

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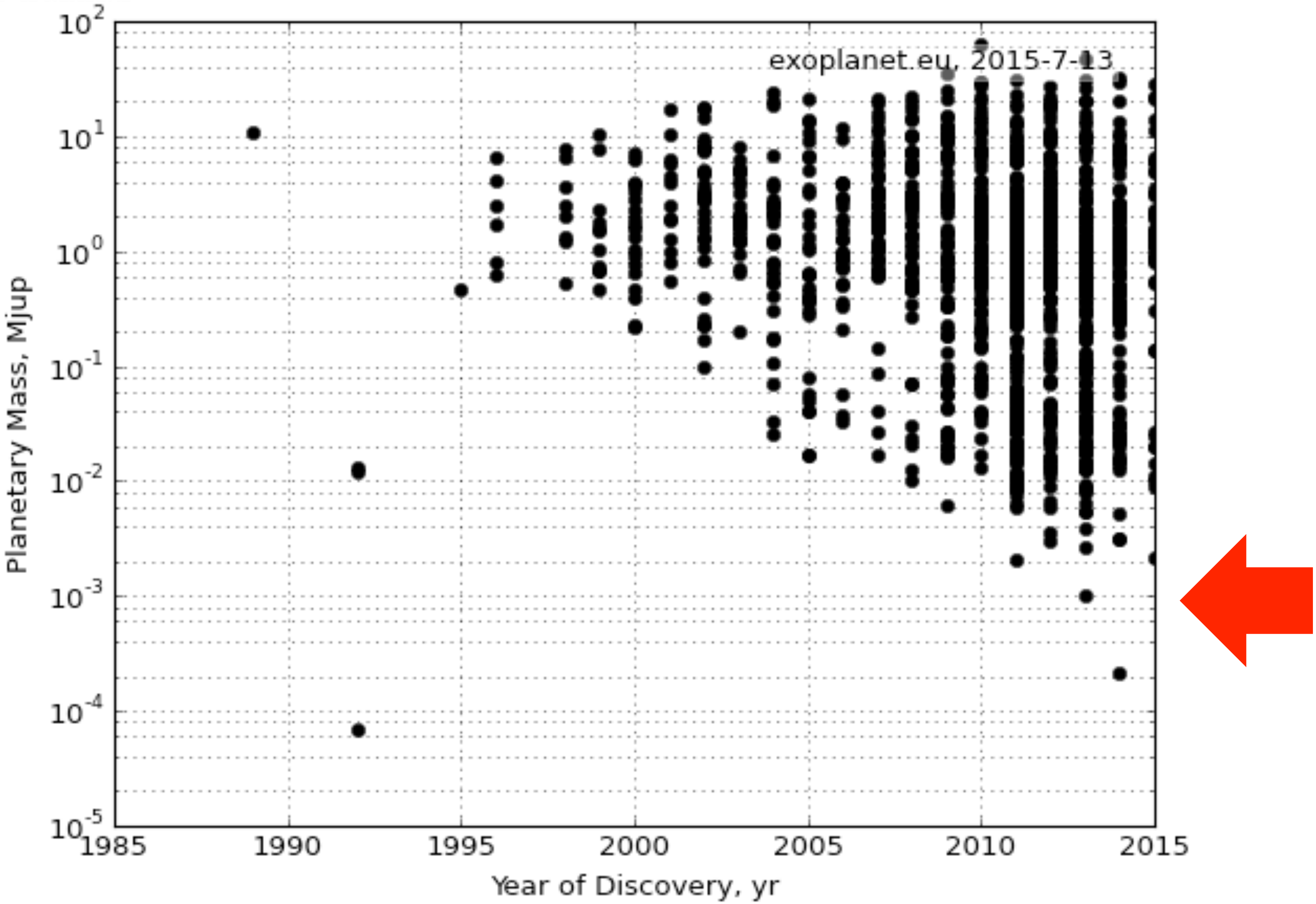

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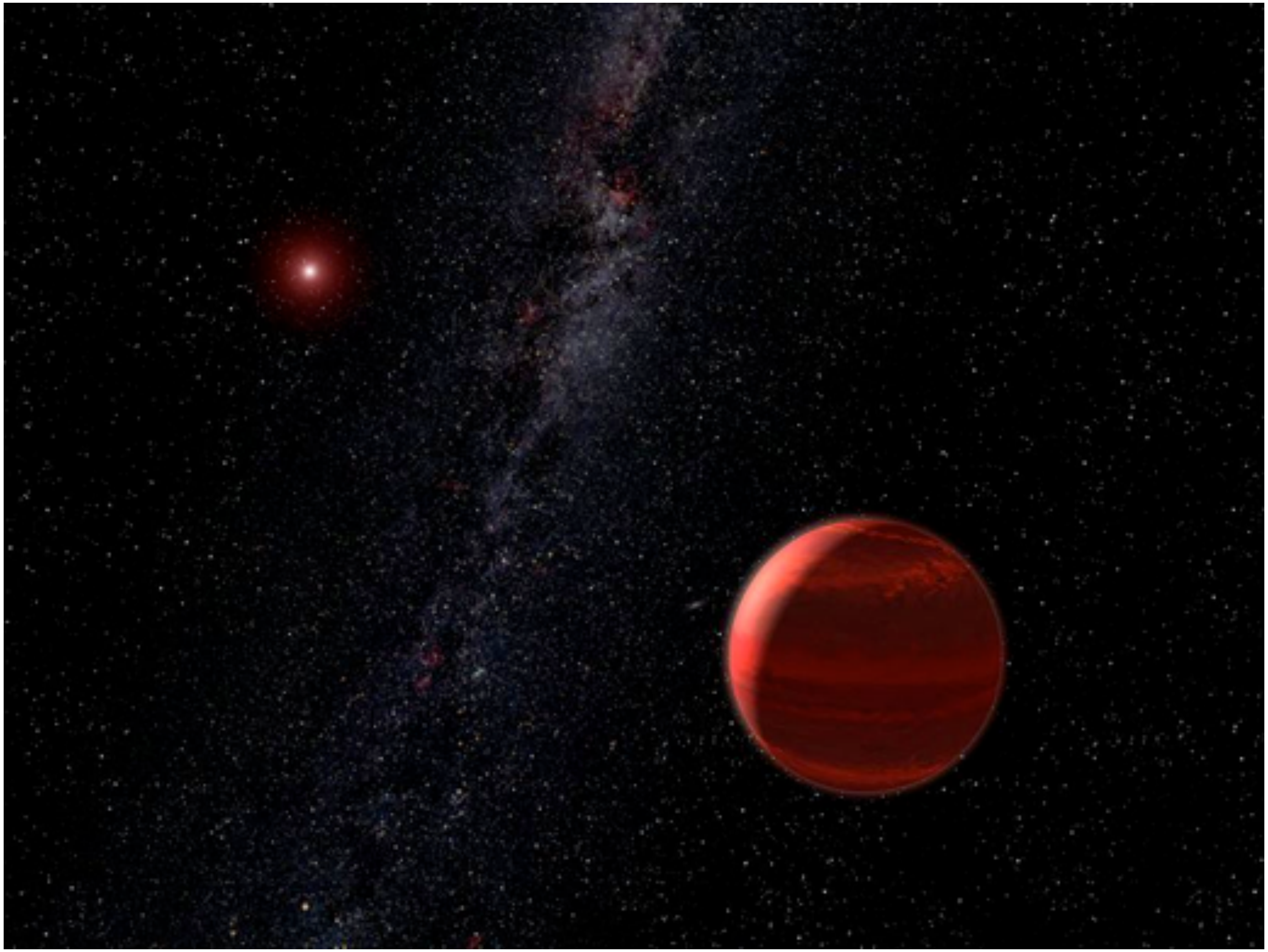

Open session: François Forget, Dániel Apai, **Eric Gaidos**, Jorge Sanz-Forcada, **Feng Tian**, Stephen R. Kane, Jérémy Leconte…

Habitable planets, M dwarfs and NIR spectrographs

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Monday	Tuesday	Wednesday
From habitable planets…	…through M-dwarf planets…	…to NIR spectrographs

Part I	Part II	Part III

Kepler's Habitable Zone Working Group
13 July 2015 • Bern, Switzerland
Pathways towards habitable planets
Satellite meeting

SatMeeting5 (Monday)

Validation and compilation of *Kepler* habitable zone candidates

Nader Haghighipour
Stephen R. Kane
Ravi K. Kopparapu

(follow-up talk on Thursday afternoon)

(Hard sci-fi) Prelude

Planets in HZs around ultracool dwarfs (M6-9V and early L stars, mid and late L brown dwarfs): detectable with current technology!

Franck Selsis, U. Bordeaux, F

Nota bene: L-type stars will harbour the only HZs in the Universe in 10^{14} yr (100 Ta)

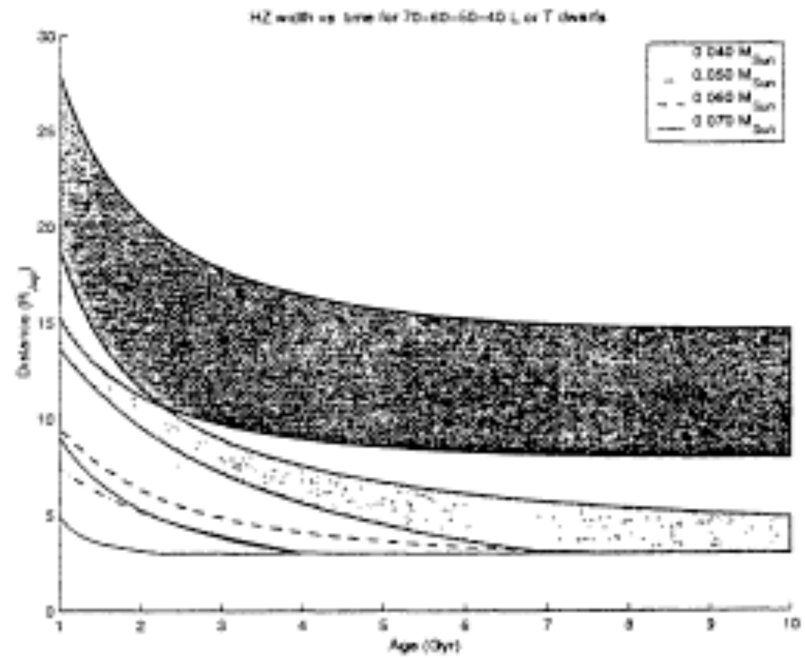
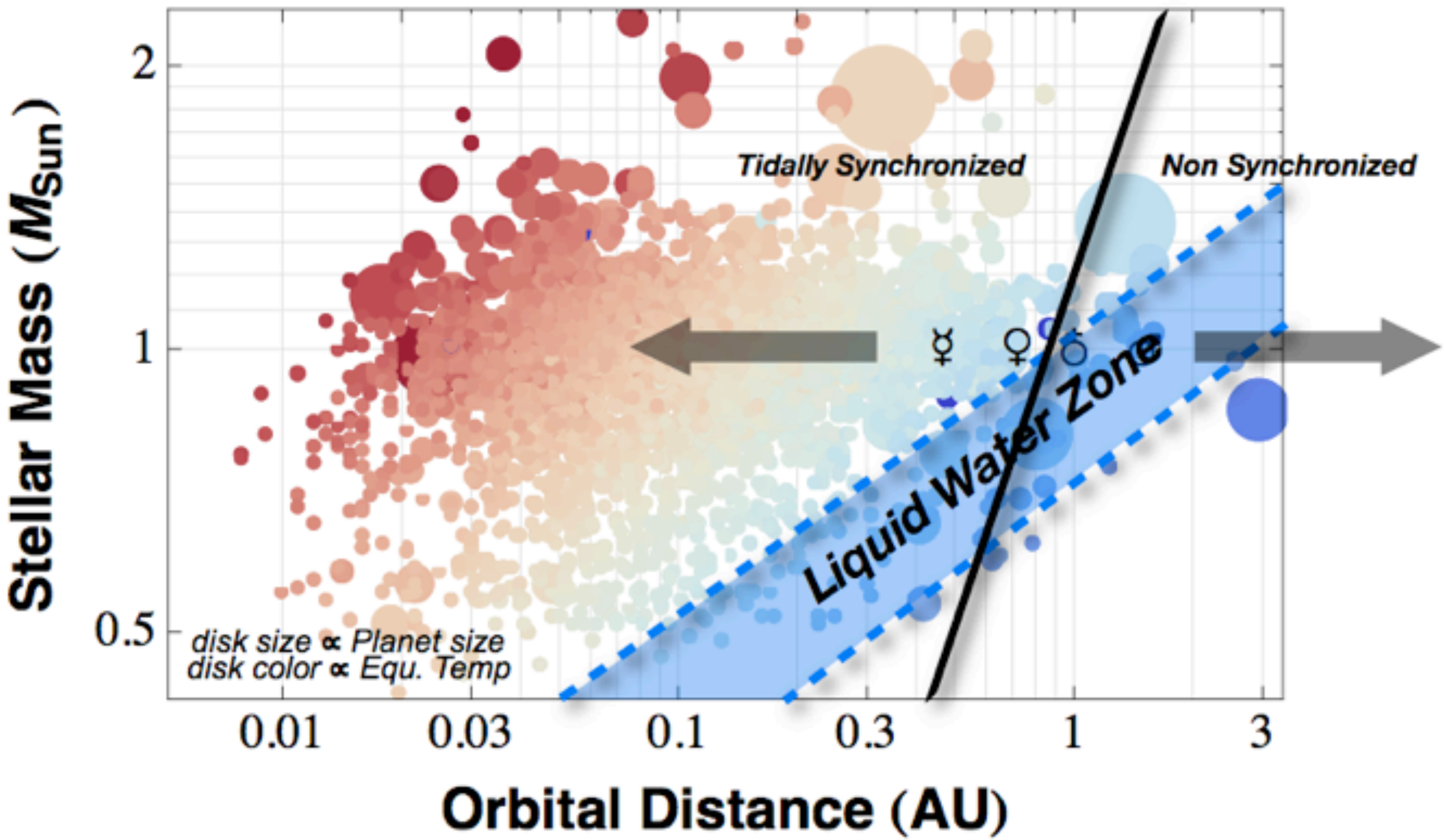


Figure 5. Habitable zones for an hypothetical Earth-like planet around a 0.070 (darkest grey), 0.060, 0.050 or 0.040 $M_\odot$ (lightest grey) brown dwarfs. Regions within curves indicate where and when liquid water can be found.

VARIABILITY IN BROWN DWARFS: ATMOSPHERES AND TRANSITS

J. A. Caballero[1,2] and R. Rebolo[1,3]

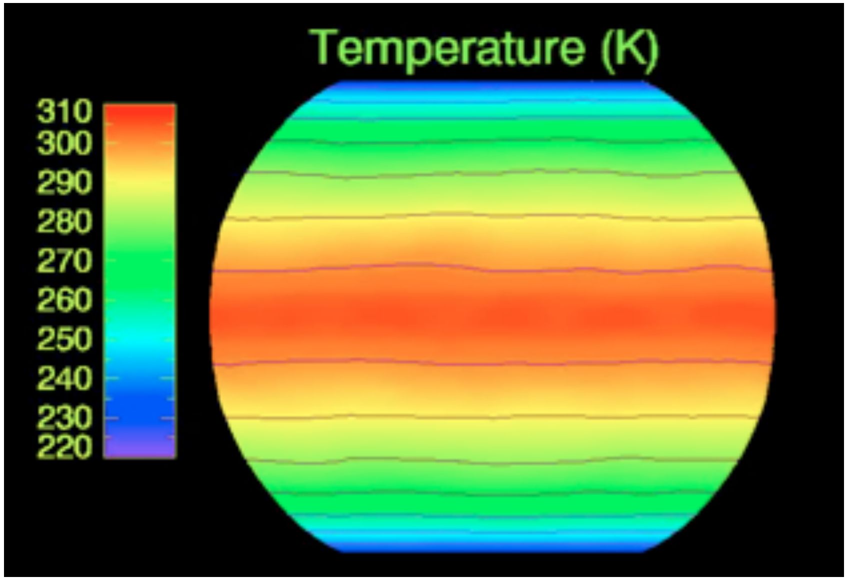
[1]Instituto de Astrofísica de Canarias
[2]Universidad Complutense de Madrid
[3]Consejo Superior de Investigaciones Científicas

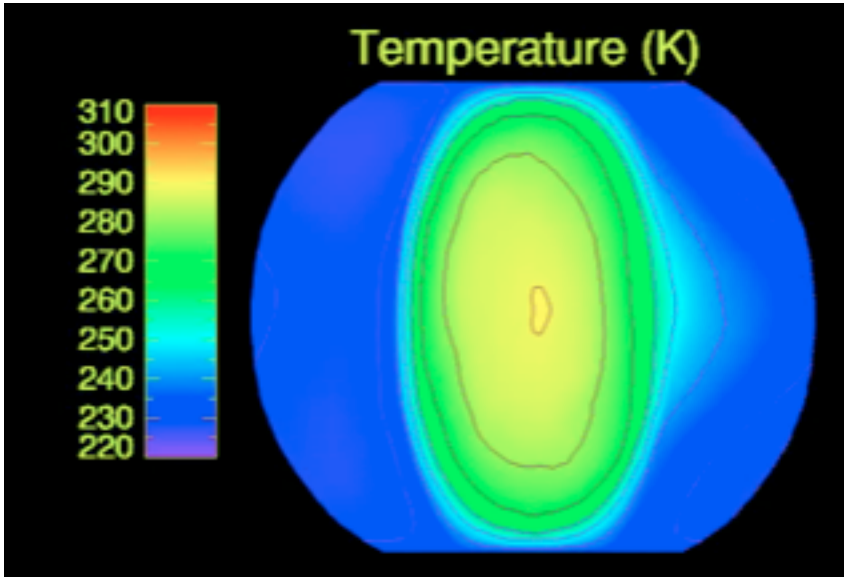

Stellar Mass (M_{Sun})
2
1
0.5
Tidally Synchronized
Non Synchronized
Liquid Water Zone
disk size ∝ Planet size
disk color ∝ Equ. Temp
0.01
0.03
0.1
0.3
1
3
Orbital Distance (AU)

First movement (Allegro ma non troppo)

M dwarfs low *L* → Short a_{HZ} → Tidal locking → Slow and synchronous rotators (e.g. 24 h vs. 60 d) → **3D general circulation models** + surface pressure-dependent **thermal atmospheric tides**

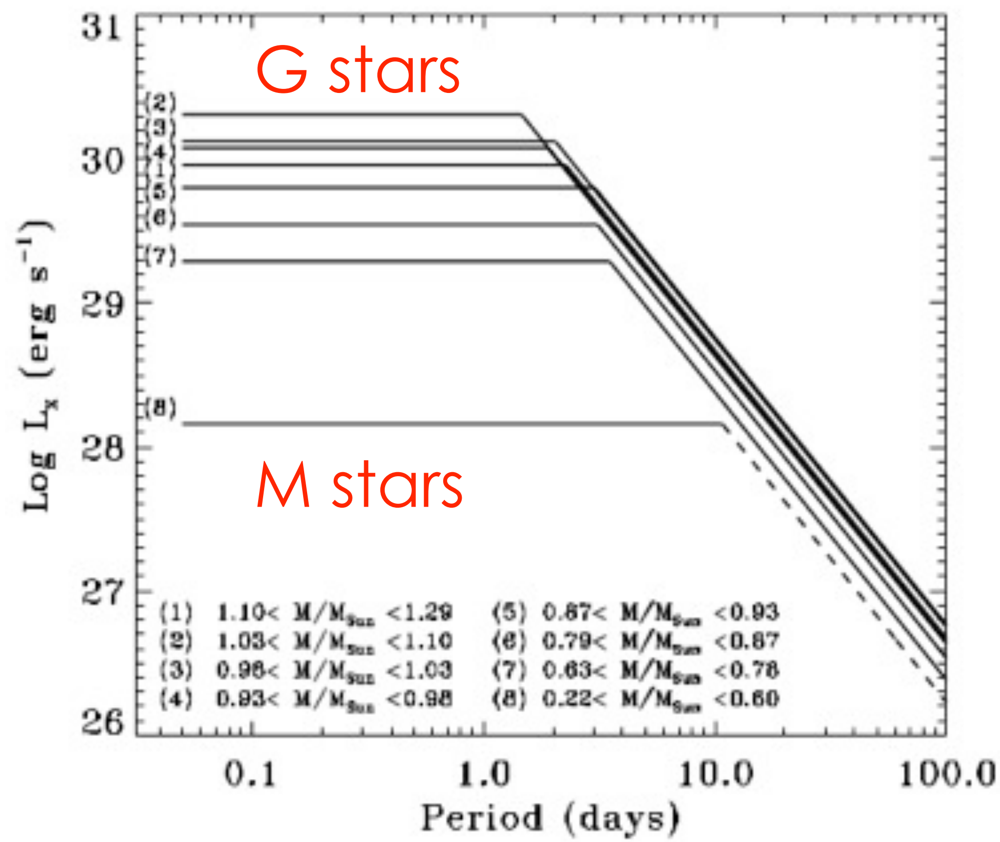
Eric. T. Wolf, U. Colorado, USA
Jérémy Leconte, CITA/CPS, CA





Second movement
(Andante molto mosso)

M dwarfs have deep convective envelopes → **stellar activity** + longer saturation regime → frequent flaring and coronal mass ejections + short a_{HZ} → atmosphere erosion



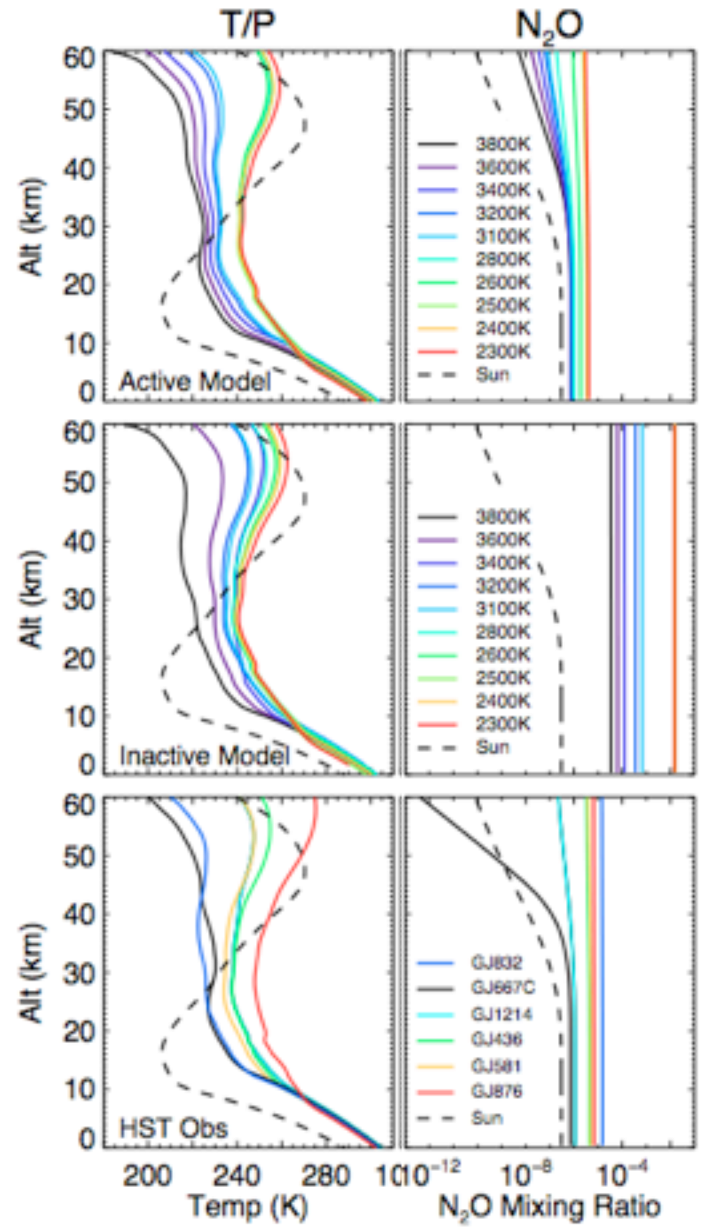
Jorge Sanz-Forcada, CAB, E

Third movement (Allegro)

Atmospheric chemistry: H loss, haze layers and CH_4, H_2O_2, O_2, O_3, H_2SO_4 abundances for Mars-, Titan-, Venus- and Earth-like planets

False positive biosignatures: O_2/O_3, O_2/O_3+CH_4/N_2O+H_2O, thermodynamic disequilibrium…

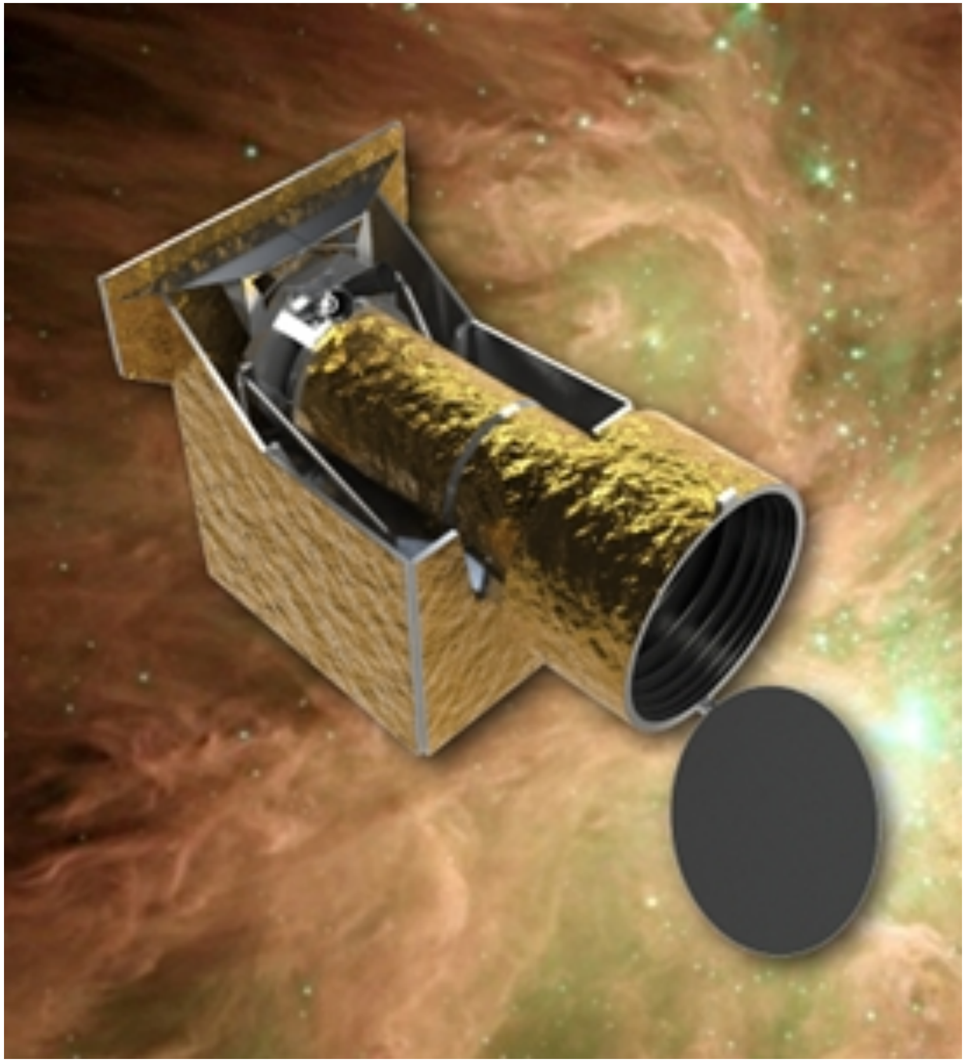
Peter Gao, Caltech, USA
Sonny Harman, PSU, USA

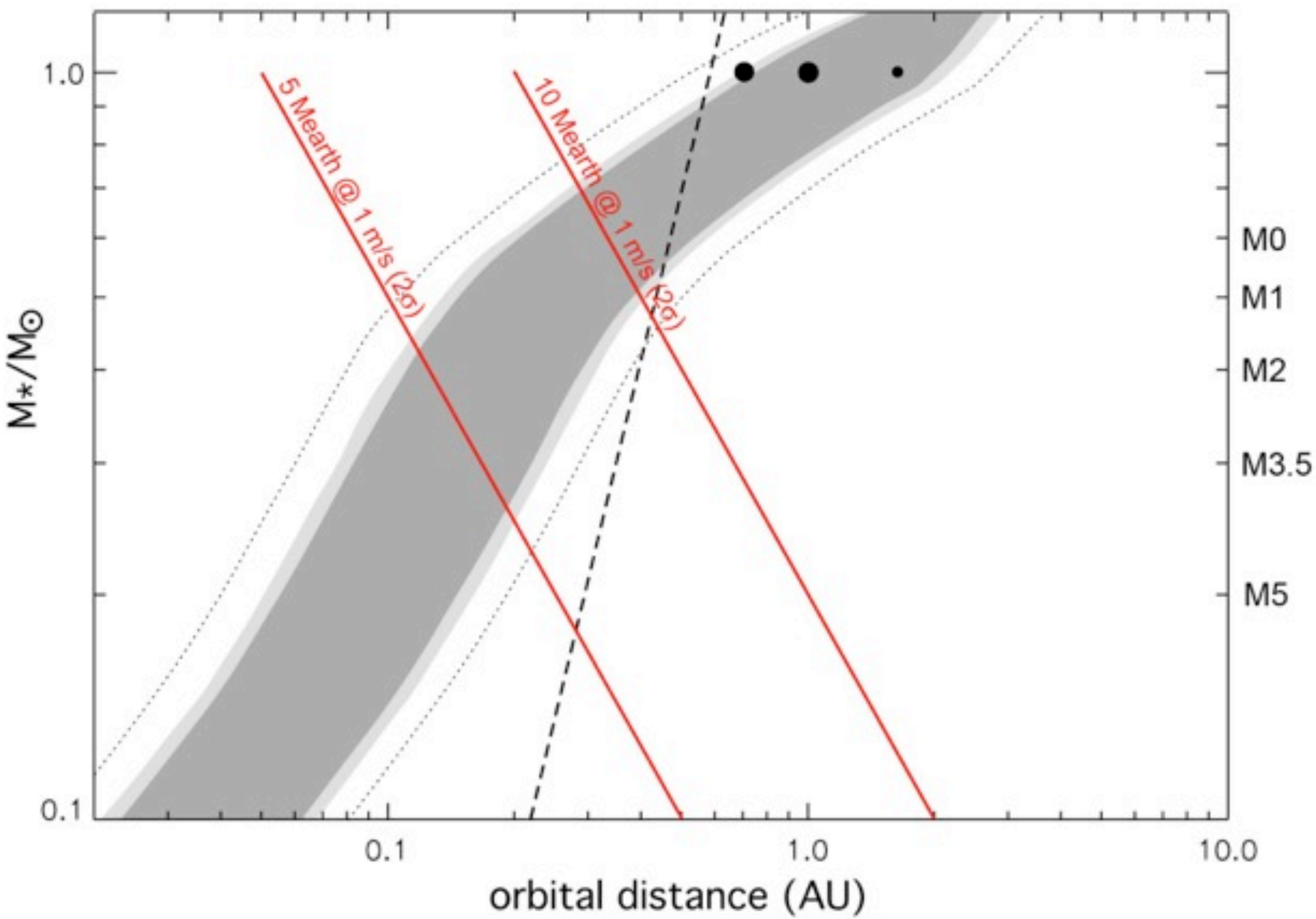


Fourth movement
(Allegro)

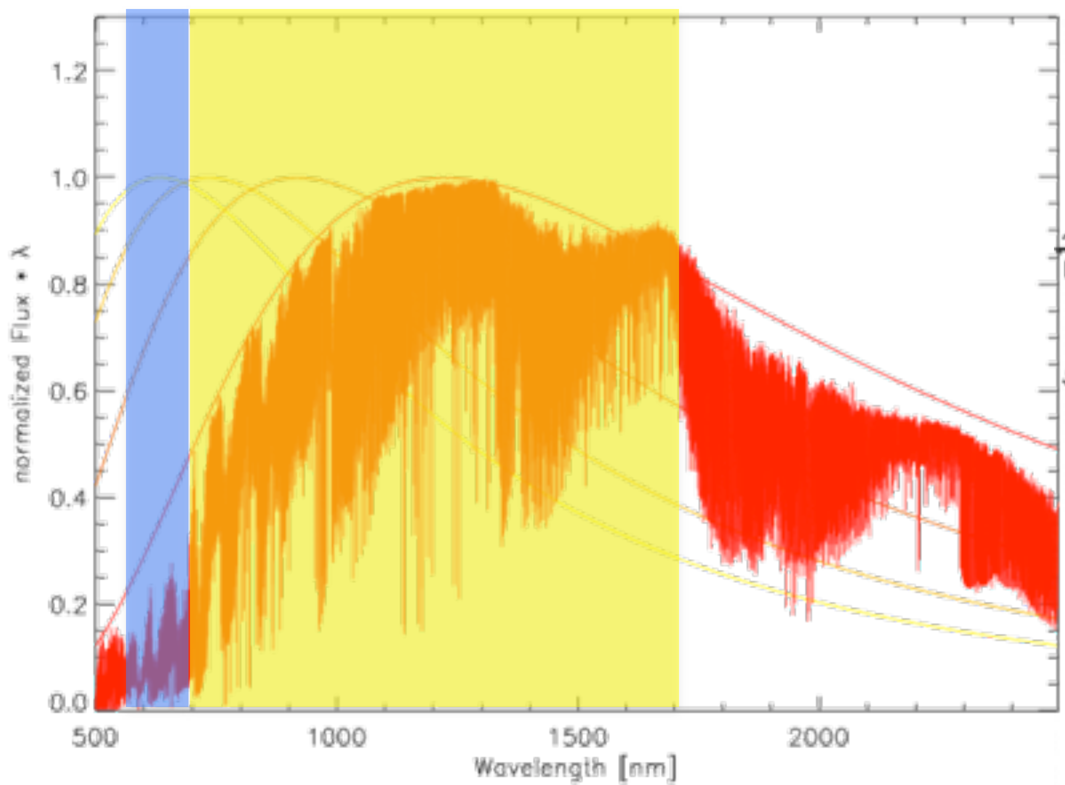
Detection, occurrence and characterisation: from ***Kepler*** to ***TESS***, ***PLATO*** and ***JWST*** (and beyond)

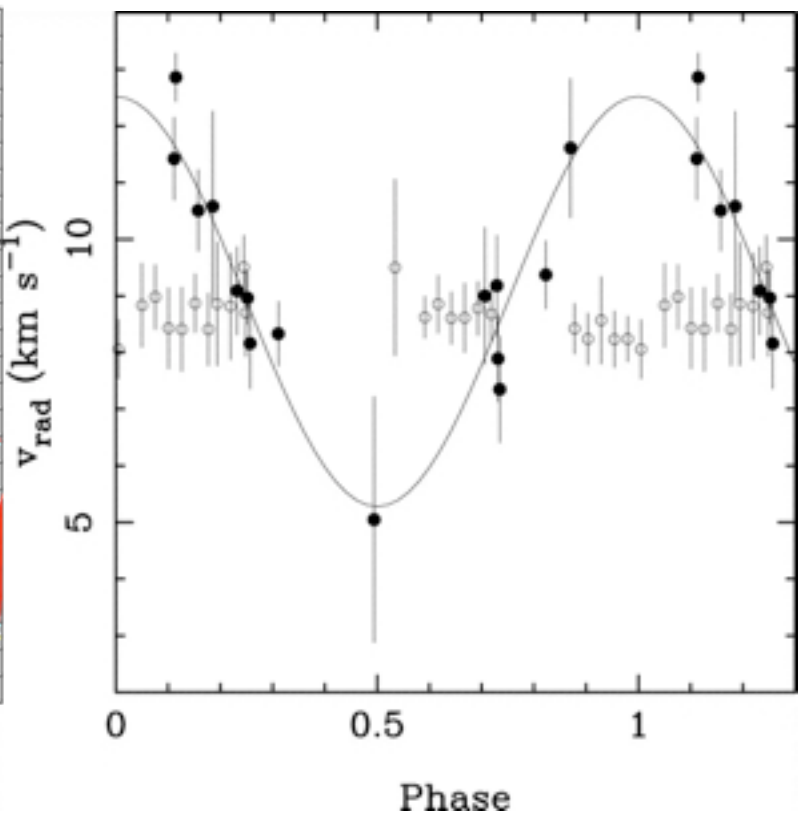
Ravi K. Kopparapu, PSU, USA

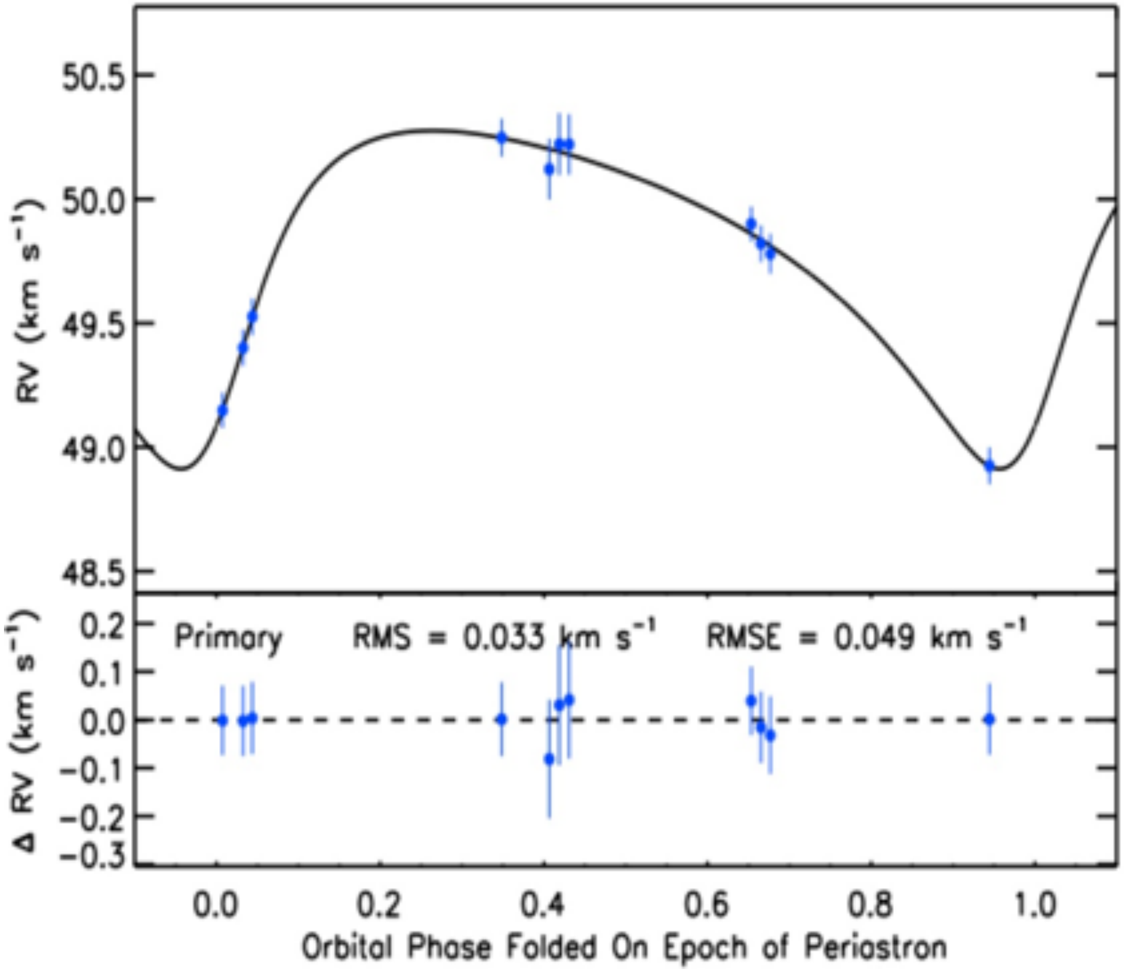



5 Mearth @ 1 m/s (2σ)
10 Mearth @ 1 m/s (2σ)
M∗/M⊙
1.0
0.1
M0
M1
M2
M3.5
M5
0.1
1.0
10.0
orbital distance (AU)

Need of... ↑


normalized Flux * λ
0.0
0.2
0.4
0.6
0.8
1.0
1.2
500
1000
1500
2000
Wavelength [nm]

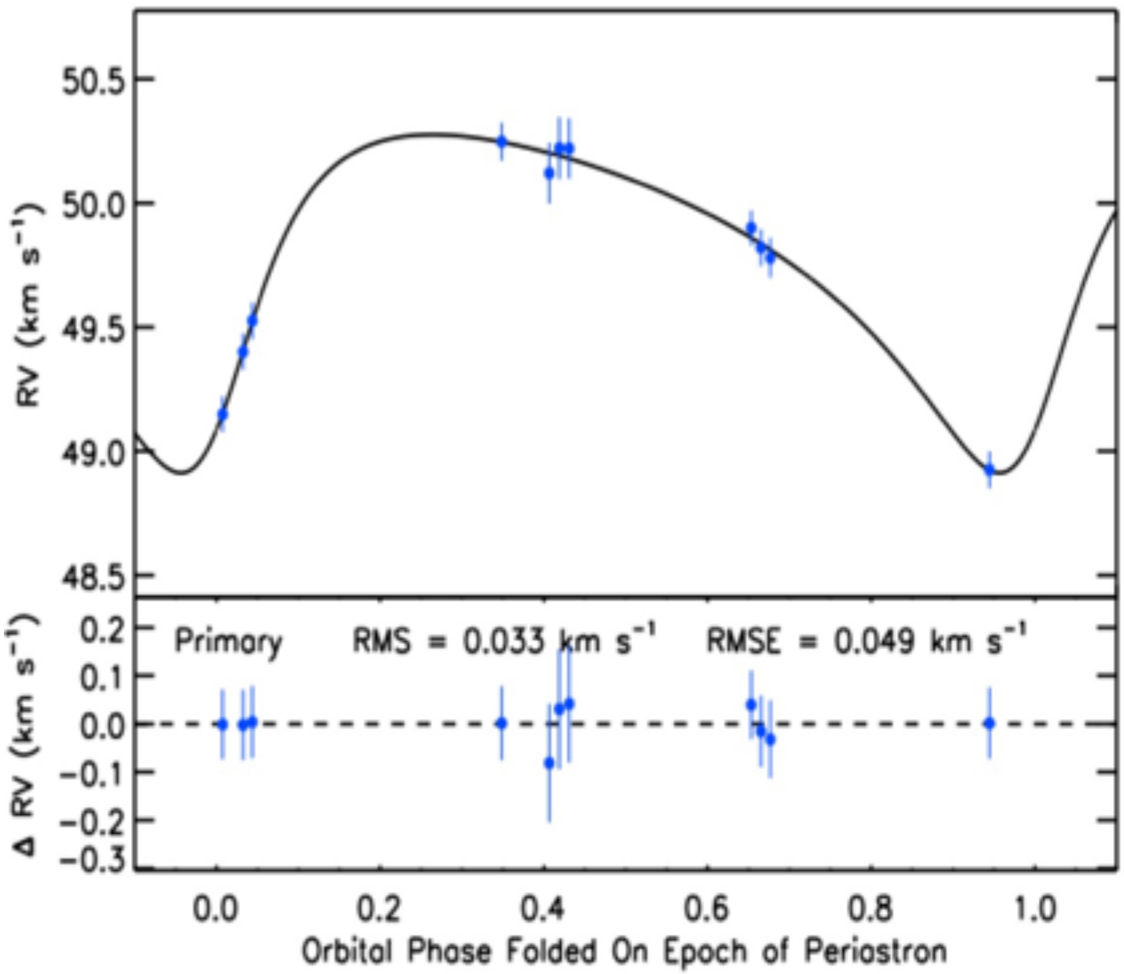

v_{rad} (km s^{-1})
5
10
0
0.5
1
Phase



SDSS APOGEE (H band, R~20k) DETECTS RV SIGNAL OF SUBSTELLAR COMPANION AROUND A TELLURIC STANDARD

First NIR RV planet discovery?

2MASS J13121982+1731016



SDSS APOGEE independently DETECTS RV SIGNAL OF known PLANET AROUND HD114762 (Latham et al. 1989)

*First NIR RV planet **re**covery*

HD 114762

HPF

NAHUAL

IRD
InfraRed Doppler

iSHELL

CRIRES+

HIRES

carmenes

TARDIS

SPIRou

Fifth movement (Allegretto)

- **HPF**/HET (*Suvrath Mahadevan*)
- **SPIRou**/CFHT (Isabel Boisse)
- **IRD**/Subaru (Takayuki Kotani)
- **CARMENES**/3.5m Calar Alto (Andreas Quirrenbach)
- **Giano**/TNG (Riccardo Claudi)
- **NAHUAL**/GTC (Carlos del Burgo)
- **TARdYS**/6.5m TAO (Leonardo Vanzi)
- CSHELL-**iSHELL**/IRTF & **MINERVA-Red** (Peter Plavchan)
- **CRIRES+**/VLT (Ulf Seemann)
- **HIRES**/E-ELT (Livia Origlia)

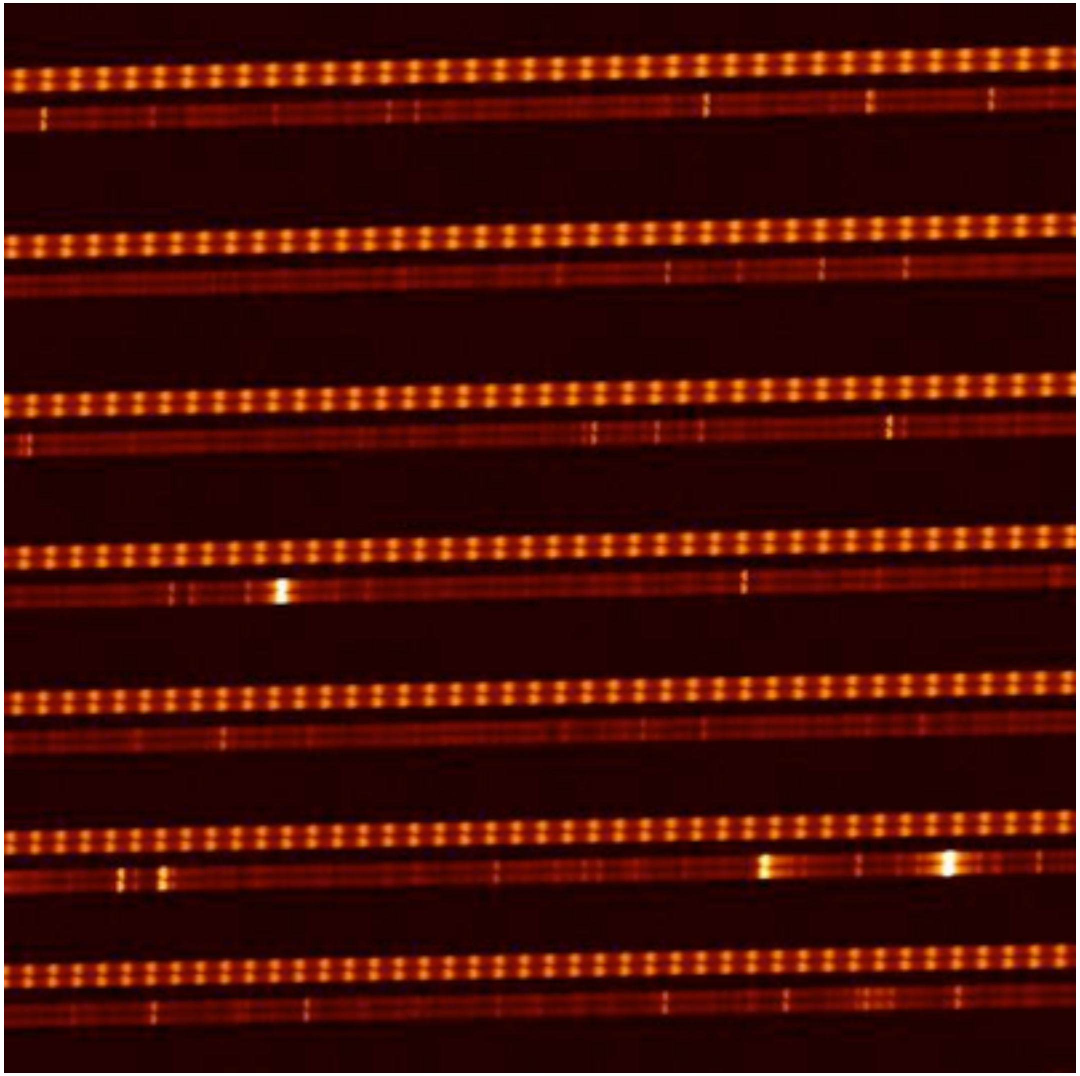
Instrument	Telescope	1st light	R (=Δλ/λ)	λ [μm]	Budget	Remark
CSHELL	3.0 m IRTF	1990s	46,000	(1-5):0.005	Mid	To be decomm.
GIANO	3.6 m TNG	**2012**	50,000	**0.95-2.45**	Mid	On sky
NAHUAL	10.4 m GTC	-	70,000	0.9-2.4	High	Cancelled
CARMENES	3.5 m Calar Alto	**Oct. 2015**	**82,000**	**0.55-1.70**	Mid	VIS & NIR channels
MINERVA-Red	2 x 0.7 m Mt. Hopkins	**Fall 2015**	50,000	0.84-0.89	**Low**	On site
iSHELL	3.0 m IRTF	Apr. 2016	70,000	(1-5):0.25	**Low**	Gas cell
IRD	**8.2 Subaru**	Early 2016	70,000	0.97-1.75	Mid	Laser comb, ceramics, AO
HPF	**9.2 HET**	Fall 2016	50,000	0.8-1.3	Mid	Laser comb
CRIRES+	**8.2 VLT UT**	2017	**100,000**	(0.95-5.30):0.40	**Low**	Polarimetry
SPIRou	3.6 CFHT	Mid 2017	75,000	**0.98-2.35**	Mid	Polarimetry
TARdYS	6.5 m TAO	201?	54,000	0.84-1-11	**Low**	5640 m
HIRES	**39 m E-ELT**	>2022	**100,000**	**0.31-2.50**	High	2-4 channels

Coda

NIR **laser combs** (Scott Diddams, NIST, USA)

NIR **Fabry-Pérot etalons** (Samuel Halverson, PSU, USA)

NIR **bulk spectrographs** (Christian Schwab, Macquarie U., AU)



Coda

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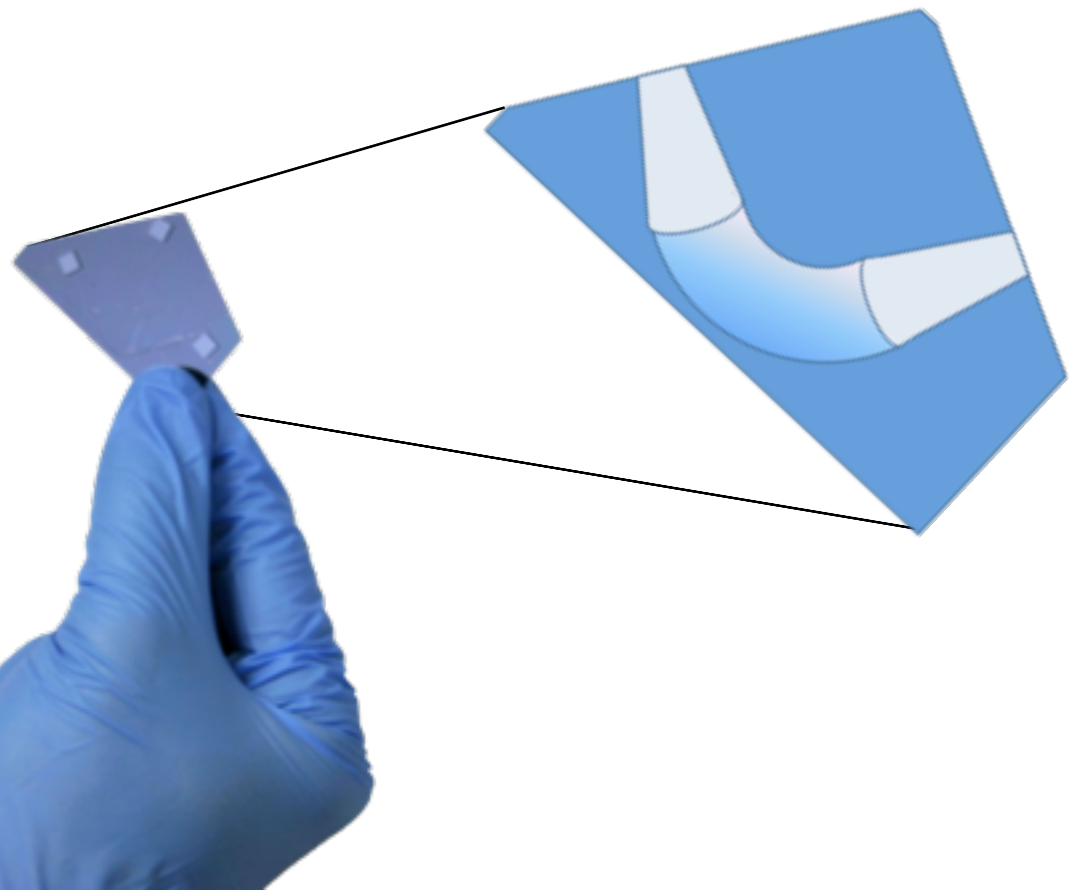

Postlude

Game/
Poll/
Exam

Q9: most probable habitable planet example?

a) *Tatooine* (Mars, Arrakis): **desert** planet
b) *Kamino* (Caladan, Solaris): **ocean** planet
c) *Hoth* (Europa, Snowball Earth): **ice** planet
• *Mustafar* (Io): **lava** planet
a) *Endor* (Kashyyyk, Yavin IV): **jungle** planet
b) *Terra*…

(See answers of game/poll/exam at the end of this presentation, in the Pathways 2015 web site)

Last song… (I)

- Still a lot to do on planets in HZs around M dwarfs: 3D atmosphere models of synchronised planets, atmosphere erosion by stellar radiation, chemistry and potential biosignatures…

- "Future is bright*(er from the space)*": *Gaia, TESS, PLATO*…

Last song… (II)

• The biggest issues in NIR radial-velocity surveys are **stellar activity** and, especially, **NIR detectors** (interpixel capacitance, persistence, read noise, availability and cost – avoid monopoly vendors?)

• Other issues are wavelength calibration, telluric absorption, fibres (modal noise, scrambling), *T* and *P* ultra-stability in cryogenics, adaptive optics, data reduction

Last song… (III and last**)**

• NIR-spectrograph community has got a critical mass – generally collegial and sharing already

• Enhance cross-pollination: sharing portions of targets lists? – white paper for funding search? – next dedicated meeting(s)?


Kepler-186f
WHERE THE GRASS IS ALWAYS REDDER ON THE OTHER SIDE

Part II game/poll/exam results:

Q1: M dwarfs have planets (from microlensing, radial velocity, transit and proto-planetary discs)

Q3+Q5: tidal locking and stellar activity do not rule out habitability

Q7: except for tidal locking and stellar activity, atmospheric composition and pressure are the most important parameter for habitability of M-dwarf planets

Q9: the most probable habitable planet examples are desert (*Tatooine*) and ocean (*Kamino*) planets

Q11: photosynthesis can be possible on M-dwarf planets in HZ

Q2+Q4: unclear spectral type for which NIR spectrographs are better than VIS ones: K7-M7V? Dependance on telescope size, instrument efficiency and stellar activity

Q6: no agreement on what is the best individual passband for RV monitoring of intermediate M dwarfs: *ZYJH*; agreement on "the wider λ coverage, the better"

Q8: spectral resolutions R > 100,000 are preferred, but lower values at 70,000-90,000 can be sufficient given the high M-dwarfs rotational velocities

Q13: the best wavelength calibration procedure is using simultaneous spectra of Fabry-Pérot etalons o laser combs together with high opto-mechanical stability

Q10+Q12: the best realistic monitoring approach is with a 4 m-class telescope for >80% time; however, there is no consensus whether making few visits (<50) on a large star sample (>500), many visits (>500) on a small star sample (<50) or a compromise between number of visits and star sample size