

# 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...



# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting



*La pluralité des mondes habités*  
(C. Flammarion 1862)

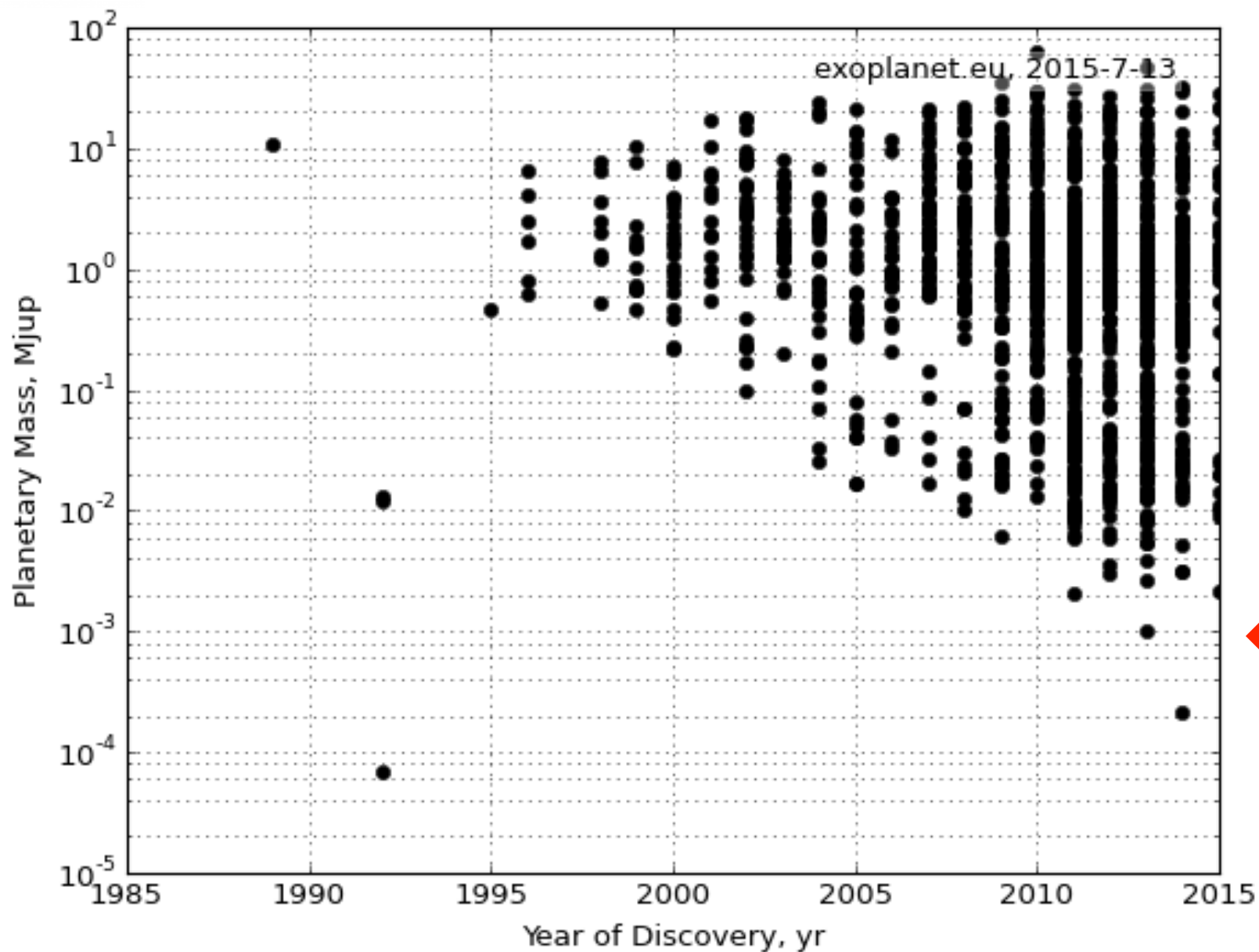


# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting





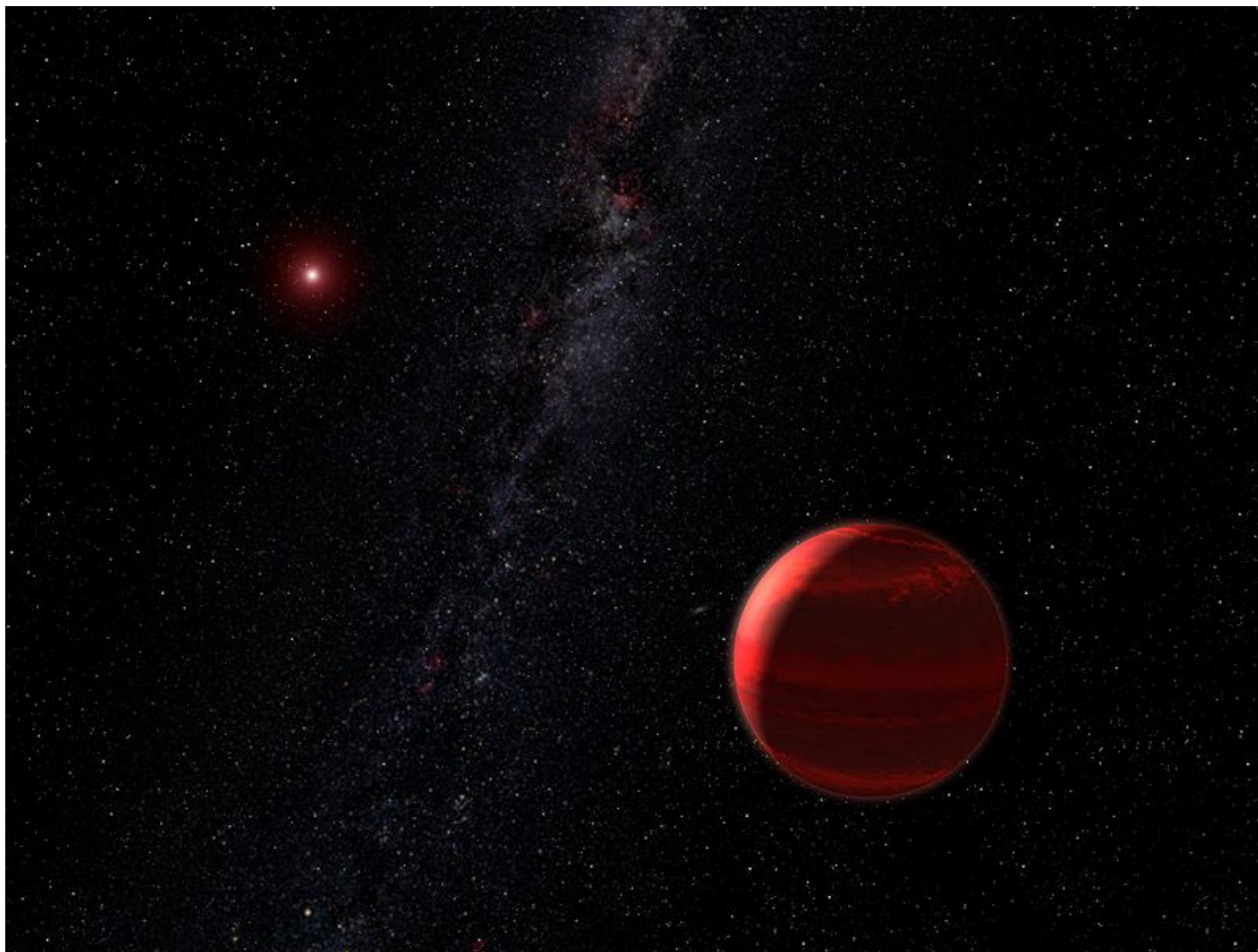


# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting



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



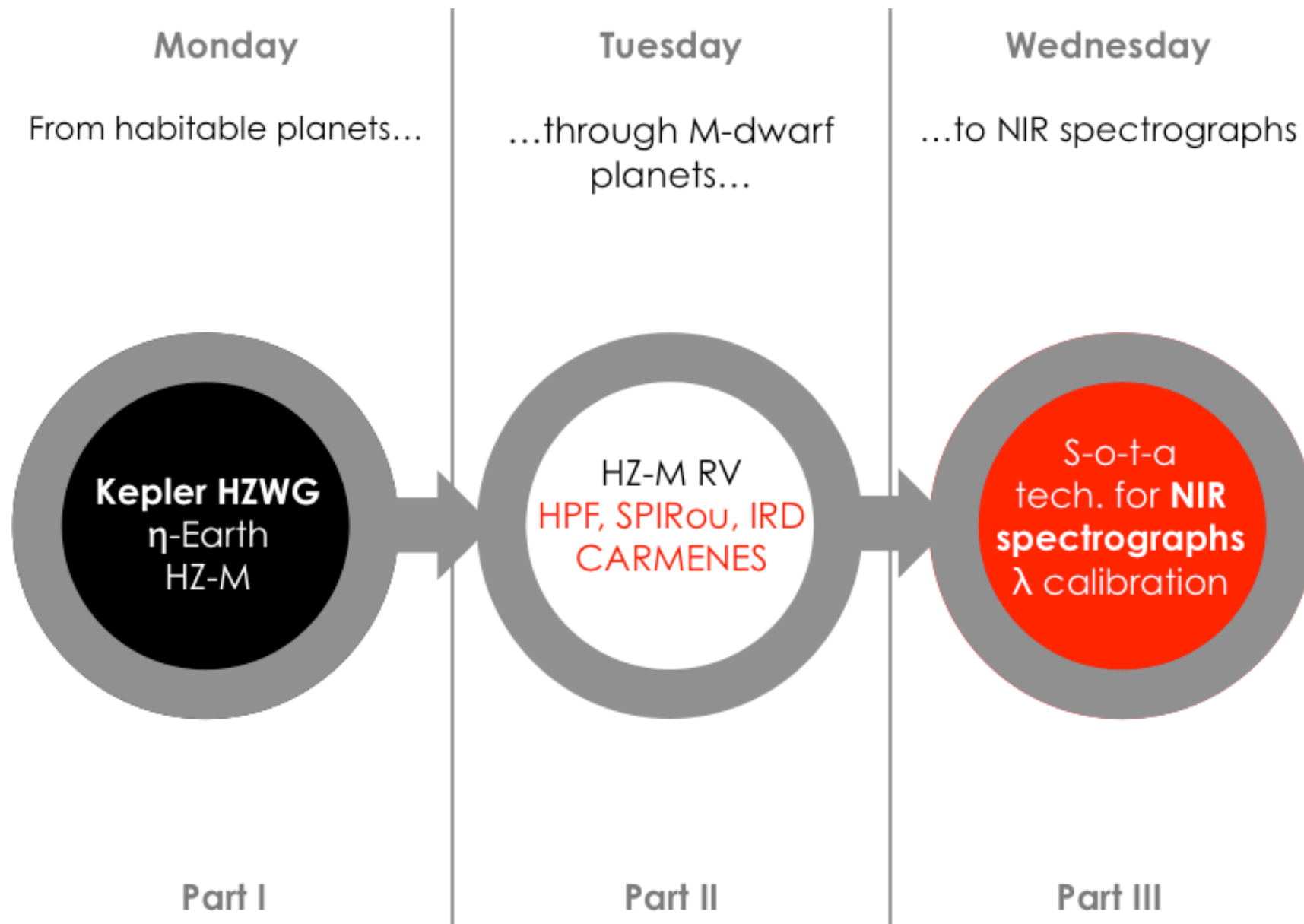


# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting



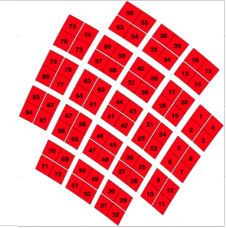


# Kepler's Habitable Zone Working Group

13 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

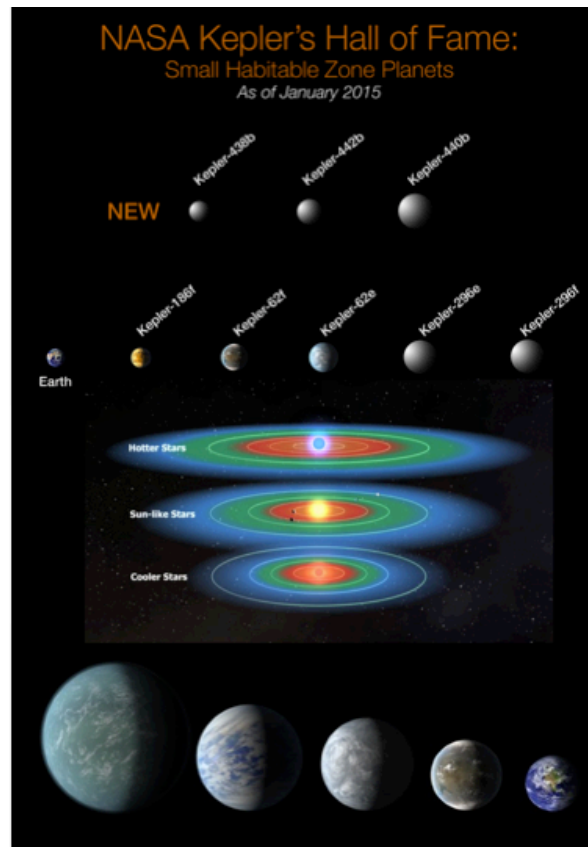
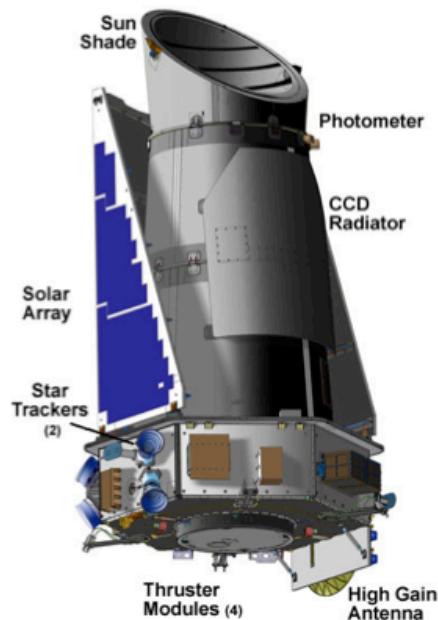
Satellite meeting



SatMeeting5 (Monday)

## Validation and compilation of *Kepler* habitable zone candidates

# Kepler



**Nader Haghighipour**  
**Stephen R. Kane**  
**Ravi K. Kopparapu**

(follow-up talk on  
Thursday afternoon)



# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

*(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)

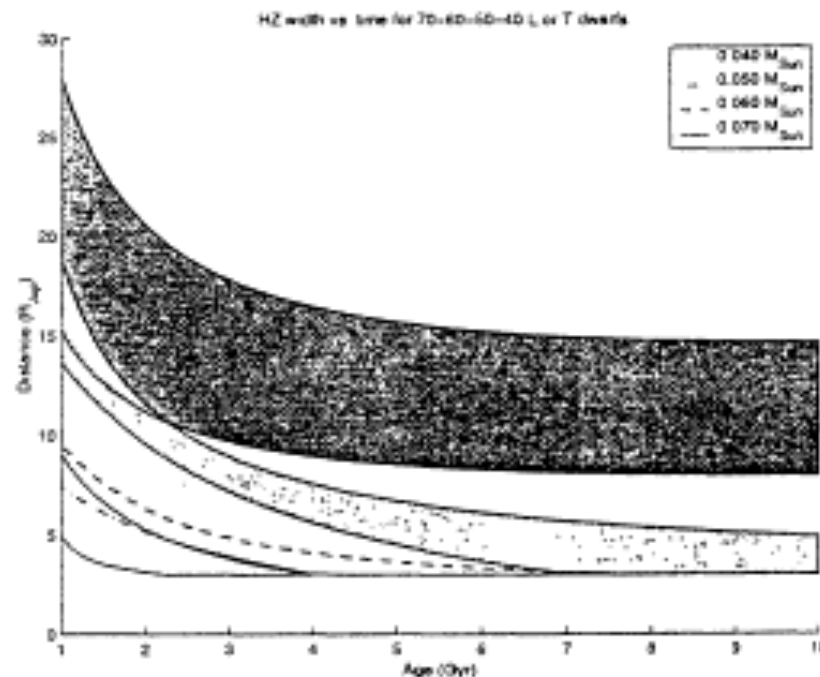


Figure 5. Habitable zones for an hypothetical Earth-like planet around a 0.070 (darkest grey), 0.060, 0.050 or 0.040  $M_{\odot}$  (lightest grey) brown dwarfs. Regions within curves indicate where and when liquid water can be found.

VARIABILITY IN BROWN DWARFS: ATMOSPHERES AND TRANSITS

J. A. Caballero<sup>1,2</sup> and R. Rebolo<sup>1,3</sup>

<sup>1</sup>Instituto de Astrofísica de Canarias

<sup>2</sup>Universidad Complutense de Madrid

<sup>3</sup>Consejo Superior de Investigaciones Científicas



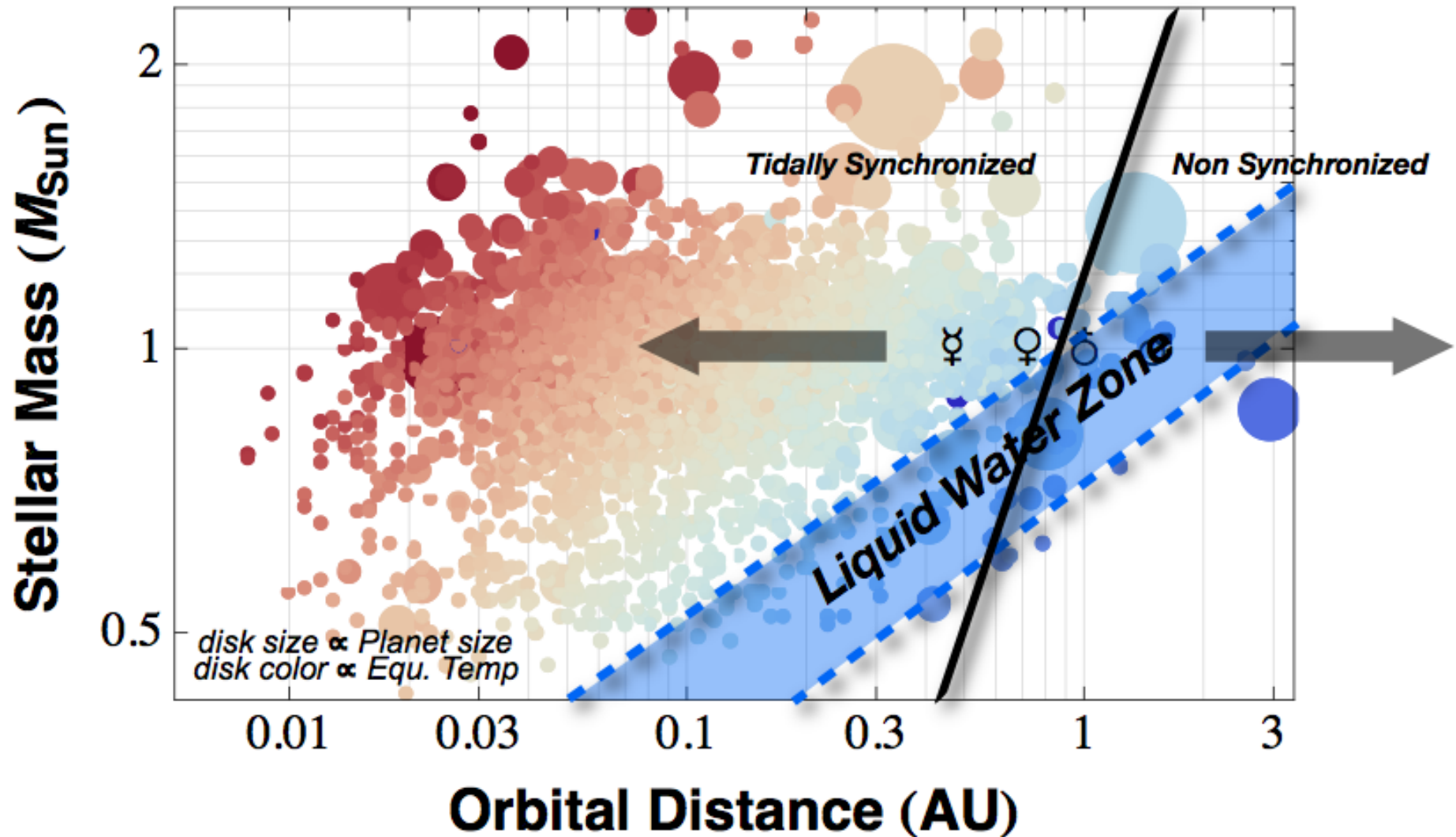


# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting





# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

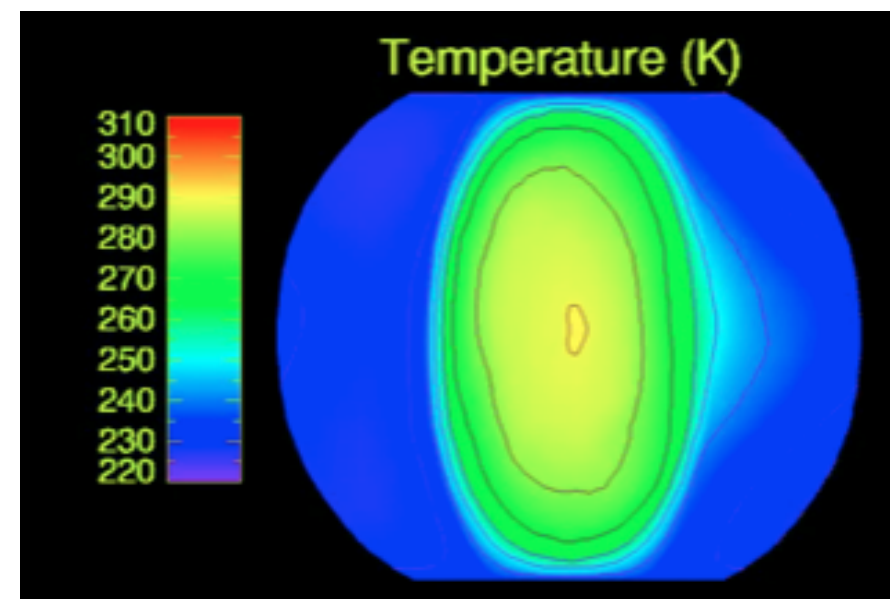
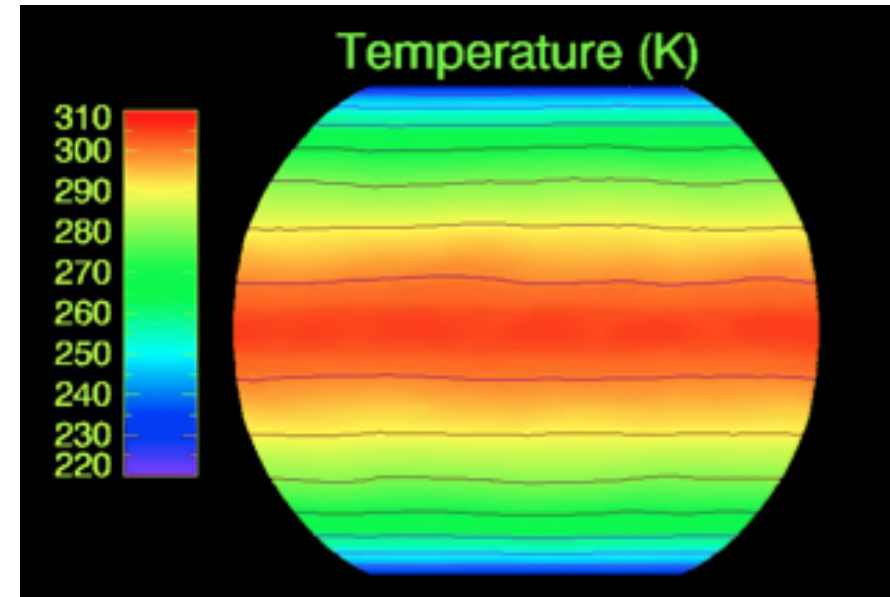
Triple satellite meeting

*First movement (Allegro ma non troppo)*

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

**Eric. T. Wolf**, U. Colorado, USA

**Jérémy Leconte**, CITA/CPS,  
CA





# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

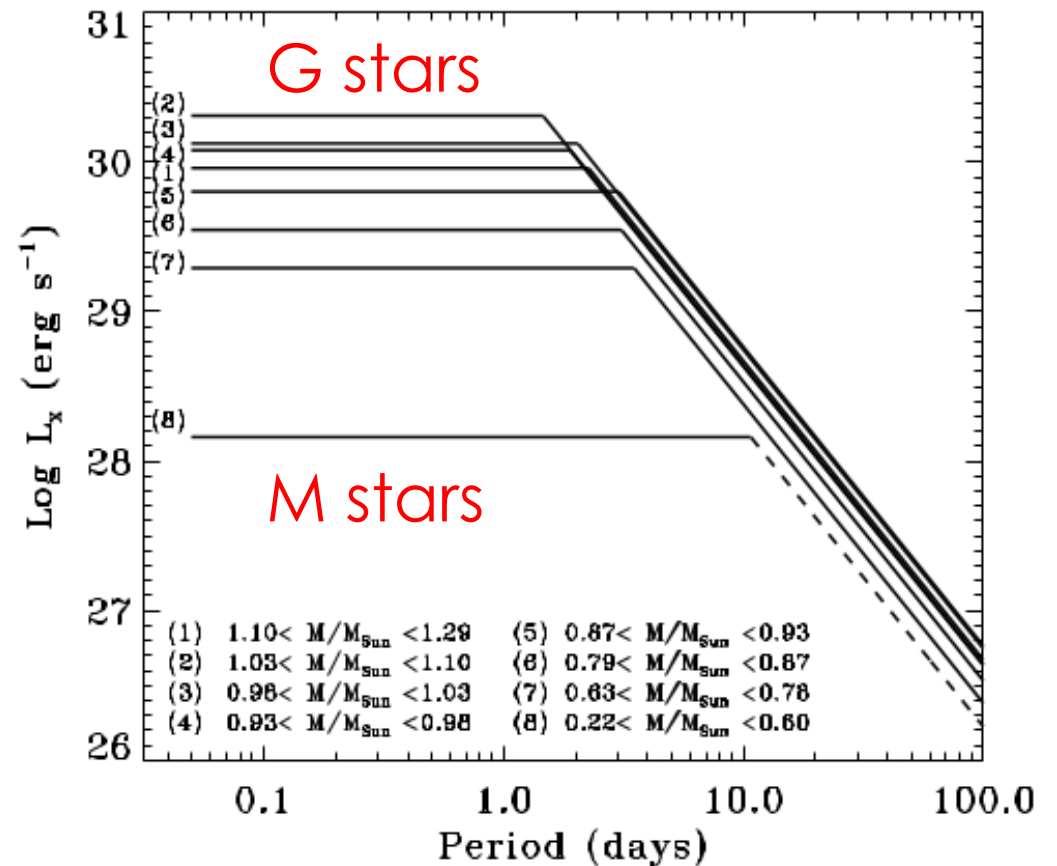
**Pathways towards habitable planets**

Triple satellite meeting

## Second movement (Andante molto mosso)

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

**Jorge Sanz-Forcada**, CAB,  
E







# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

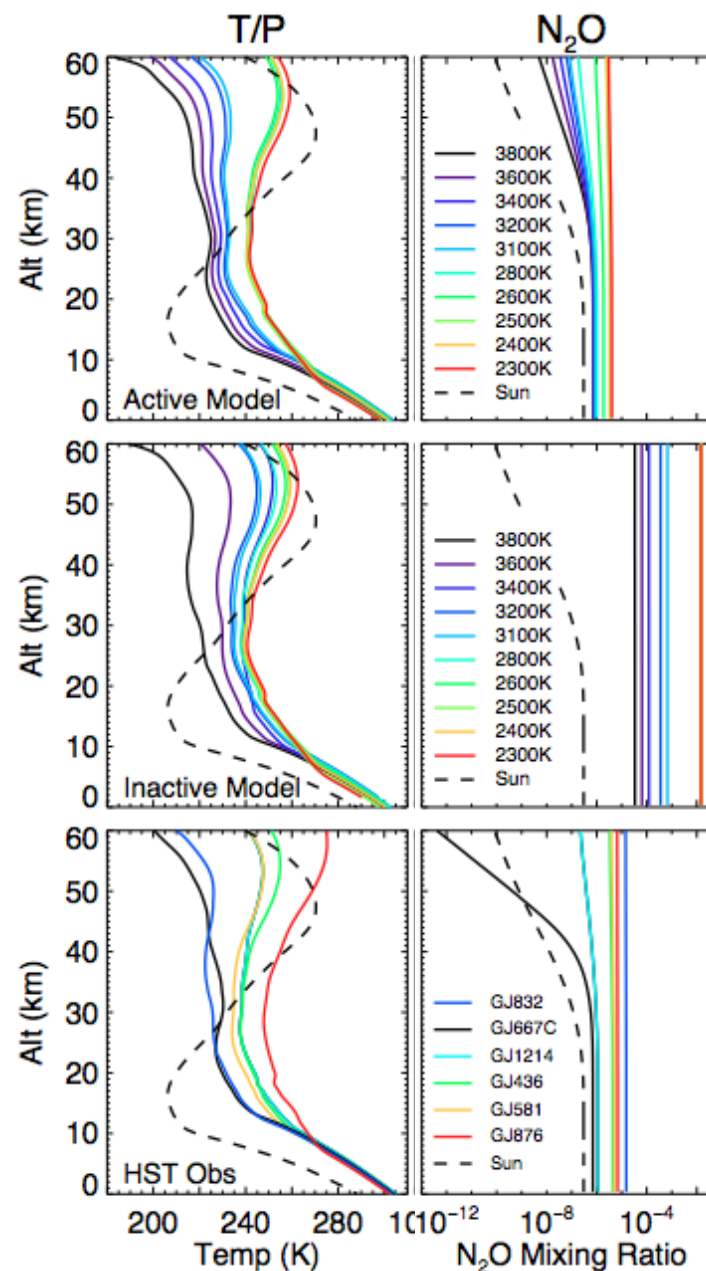
## *Third movement (Allegro)*

**Atmospheric chemistry:** H loss, haze layers and  $\text{CH}_4$ ,  $\text{H}_2\text{O}_2$ ,  $\text{O}_2$ ,  $\text{O}_3$ ,  $\text{H}_2\text{SO}_4$  abundances for Mars-, Titan-, Venus- and Earth-like planets

**False positive biosignatures:**  $\text{O}_2/\text{O}_3$ ,  $\text{O}_2/\text{O}_3 + \text{CH}_4/\text{N}_2\text{O} + \text{H}_2\text{O}$ , thermodynamic disequilibrium...

**Peter Gao**, Caltech, USA

**Sonny Harman**, PSU, USA





# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

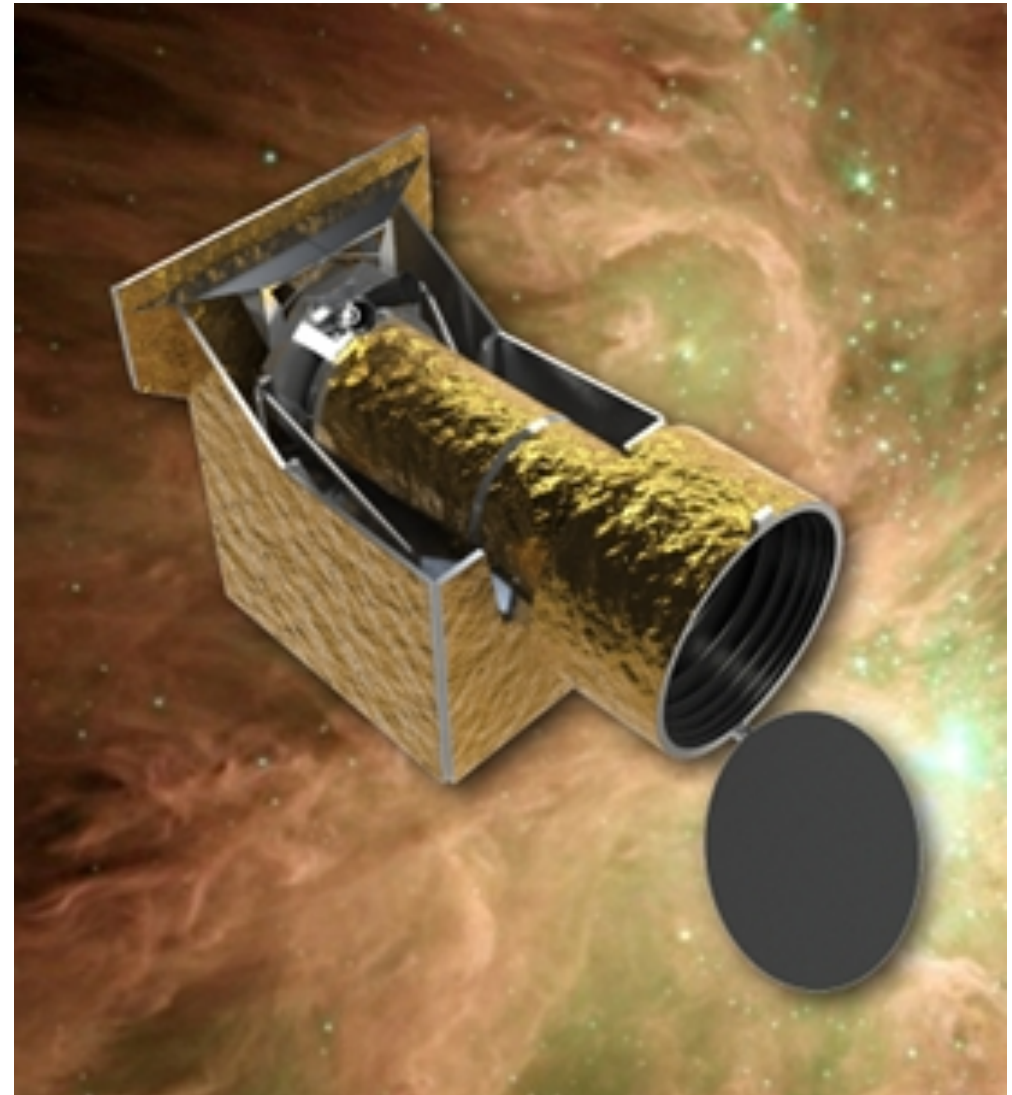
**Pathways towards habitable planets**

Triple satellite meeting

## *Fourth movement* (Allegro)

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

**Ravi K. Kopparapu**, PSU,  
USA



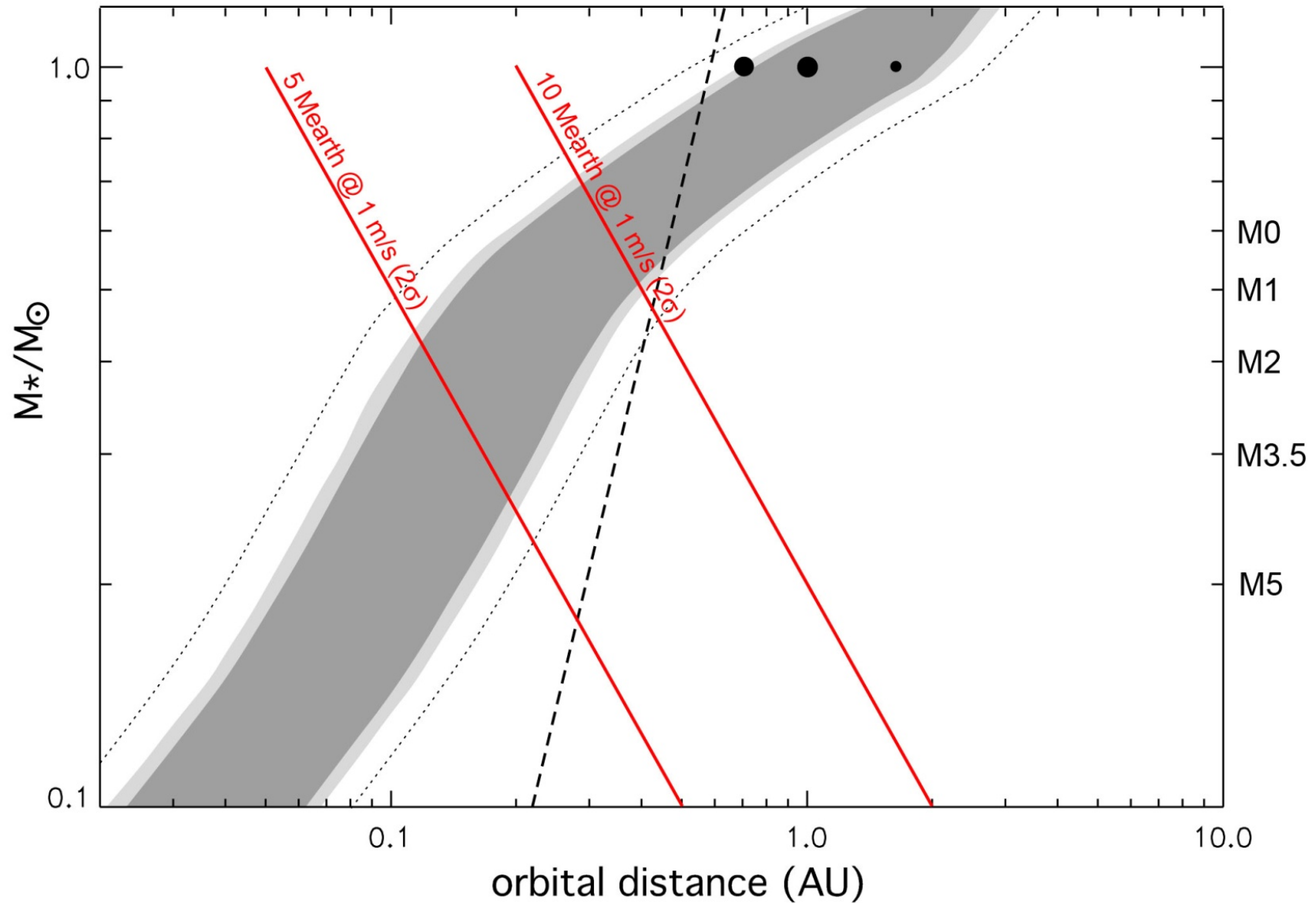


# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting







# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting



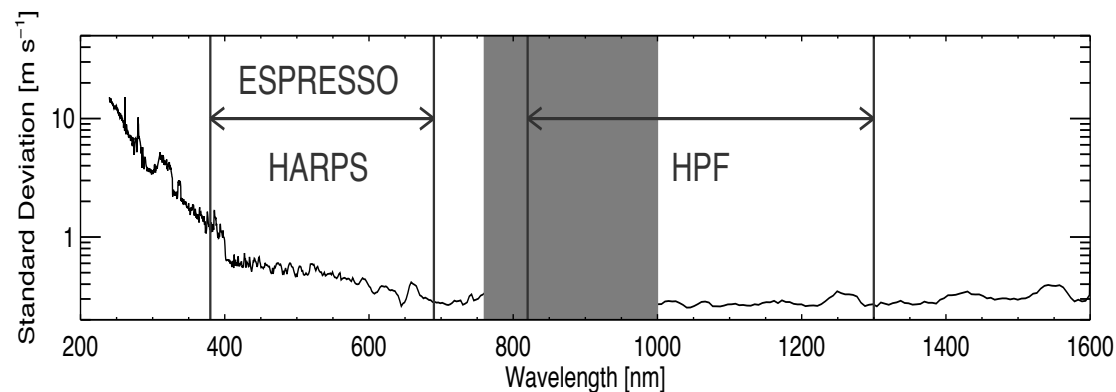


# Habitable planets, M dwarfs and NIR spectrographs

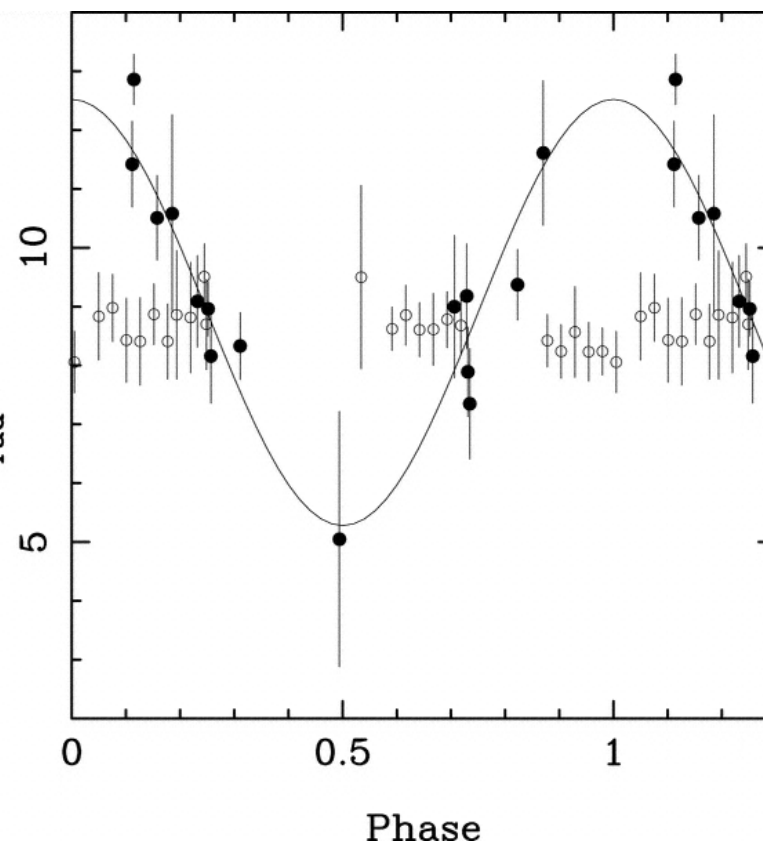
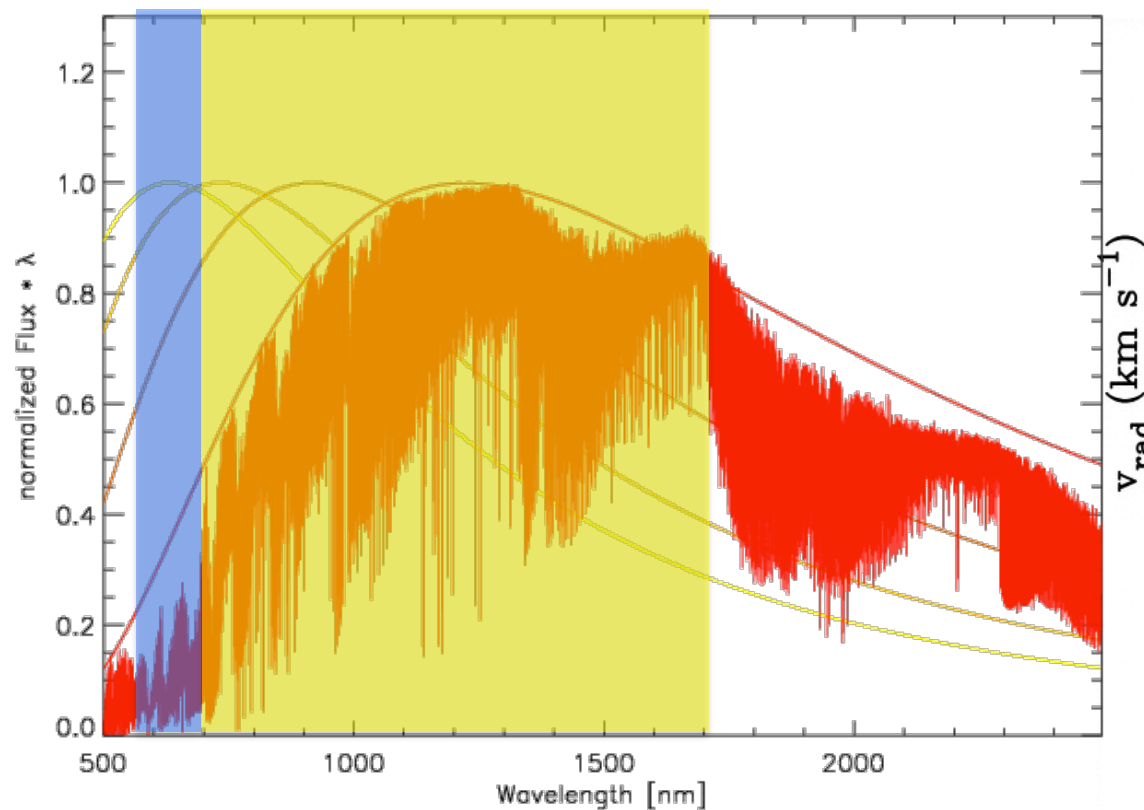
13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting



Need of... 



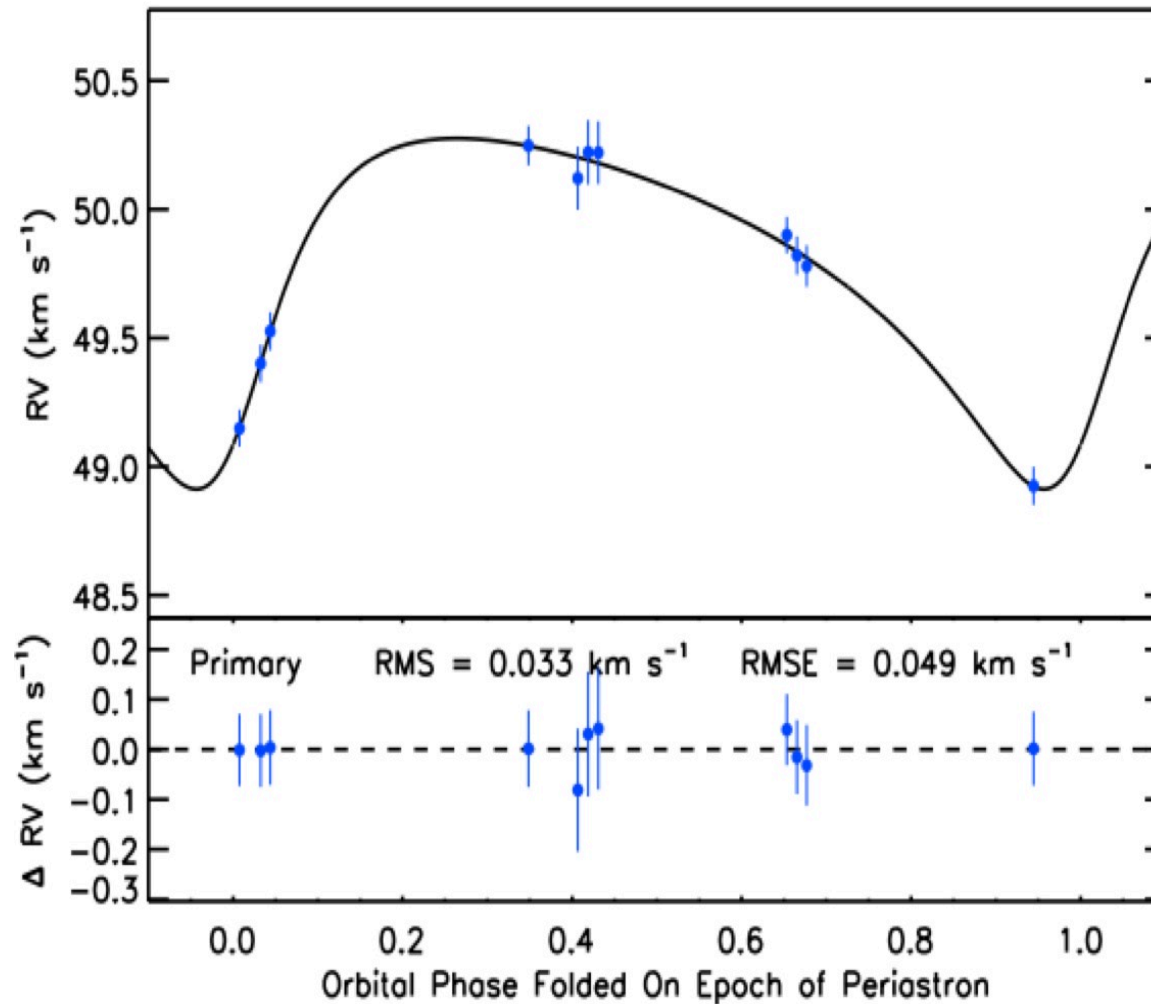


# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting



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

*First NIR RV planet discovery?*

**2MASS J13121982+1731016**



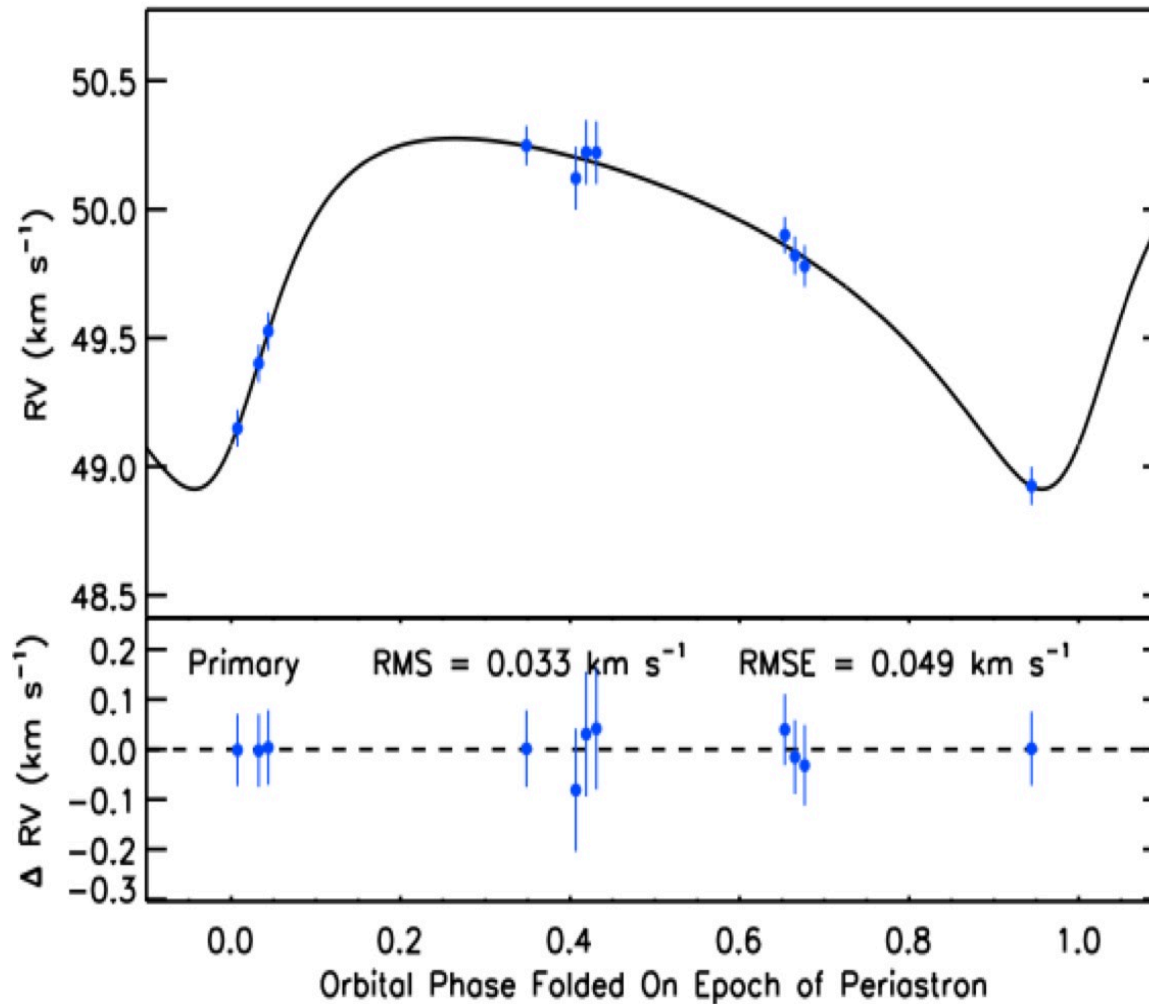


# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting



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

*First NIR RV planet **recovery***  
**HD 114762**



# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting



carmenes



TARDIS



SPiRou



# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

## *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*)



# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

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





# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

Coda

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

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

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





# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

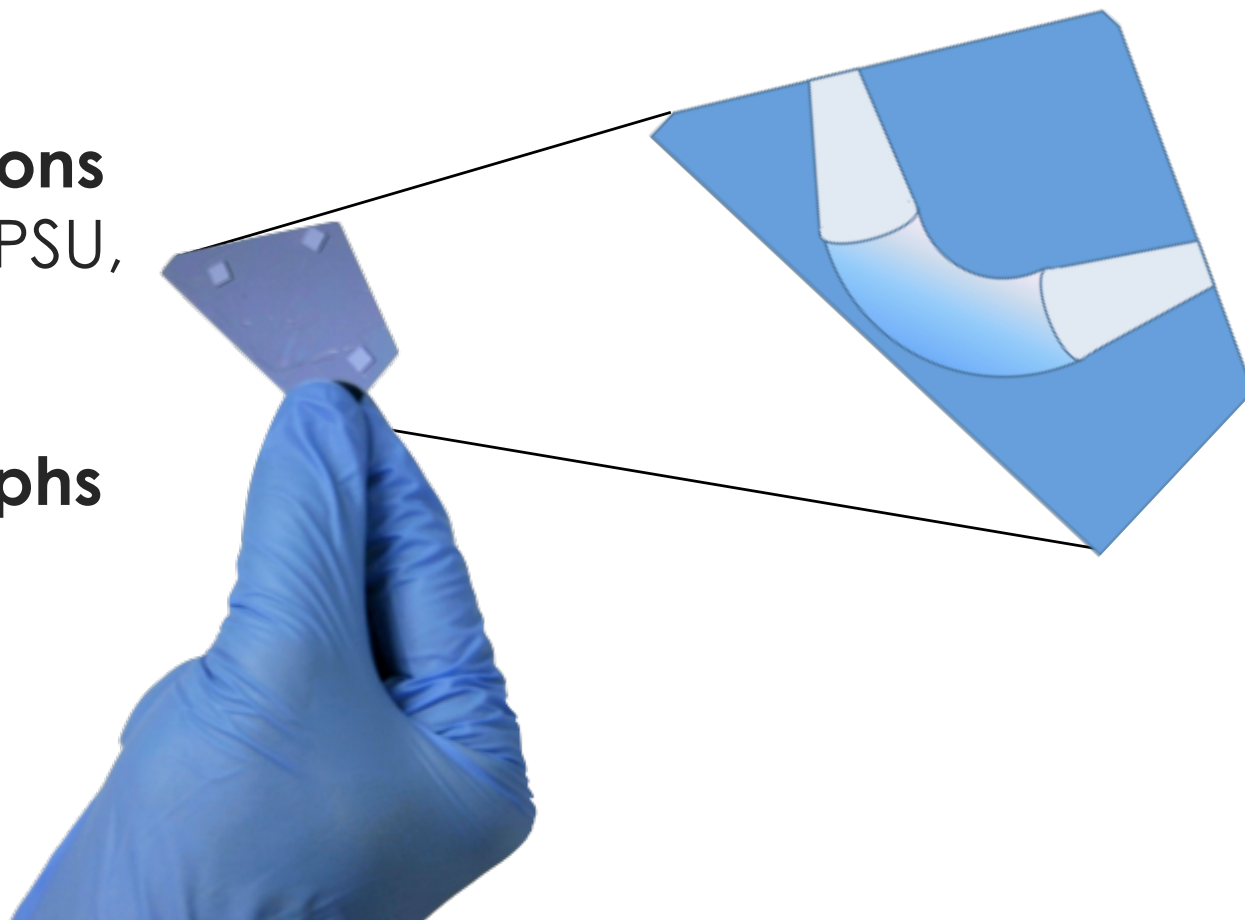
Triple satellite meeting

Coda

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

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

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





Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

*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
- d) *Mustafar* (Io): **lava** planet
- e) *Endor* (Kashyyyk, Yavin IV): **jungle** planet
- f) *Terra...*





# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting



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



# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

## 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*...



# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

## 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



# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

## 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)?





NASA's Exoplanet Exploration Program

Exoplanet Travel Bureau



Kepler-186f is the first Earth-size planet discovered in the potentially "habitable zone" around another star, where liquid water could exist on the planet's surface. Its star is much cooler and redder than our Sun. If plant life does exist on a planet like Kepler-186f, its photosynthesis could have been influenced by the star's red-wavelength photons, making for a color palette that's very different than the greens on Earth. This discovery was made by Kepler, NASA's planet-hunting space telescope.

[www.nasa.gov](http://www.nasa.gov)

NASA's Exoplanet Exploration Program, Jet Propulsion Laboratory, Pasadena, CA  
[keep.jpl.nasa.gov](http://keep.jpl.nasa.gov)





# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

## 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



# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

**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





# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

**Q2+Q4:** unclear spectral type for which NIR spectrographs are better than VIS ones: K7-M7V?  
Dependence 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  $\lambda$  coverage, the better”



# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

**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 or laser combs together with high opto-mechanical stability



# Habitable planets, M dwarfs and NIR spectrographs

13-15 July 2015 • Bern, Switzerland

**Pathways towards habitable planets**

Triple satellite meeting

**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