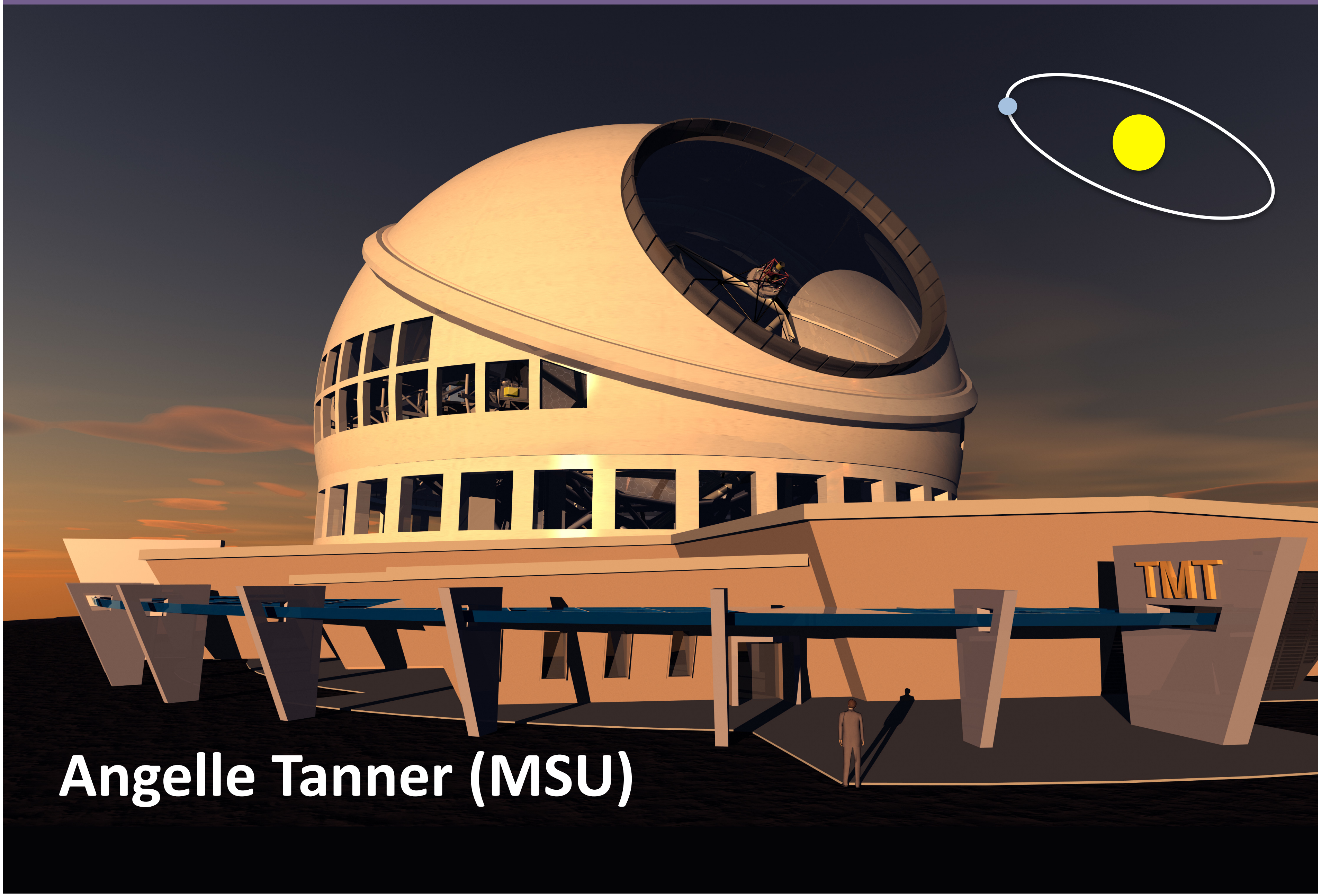
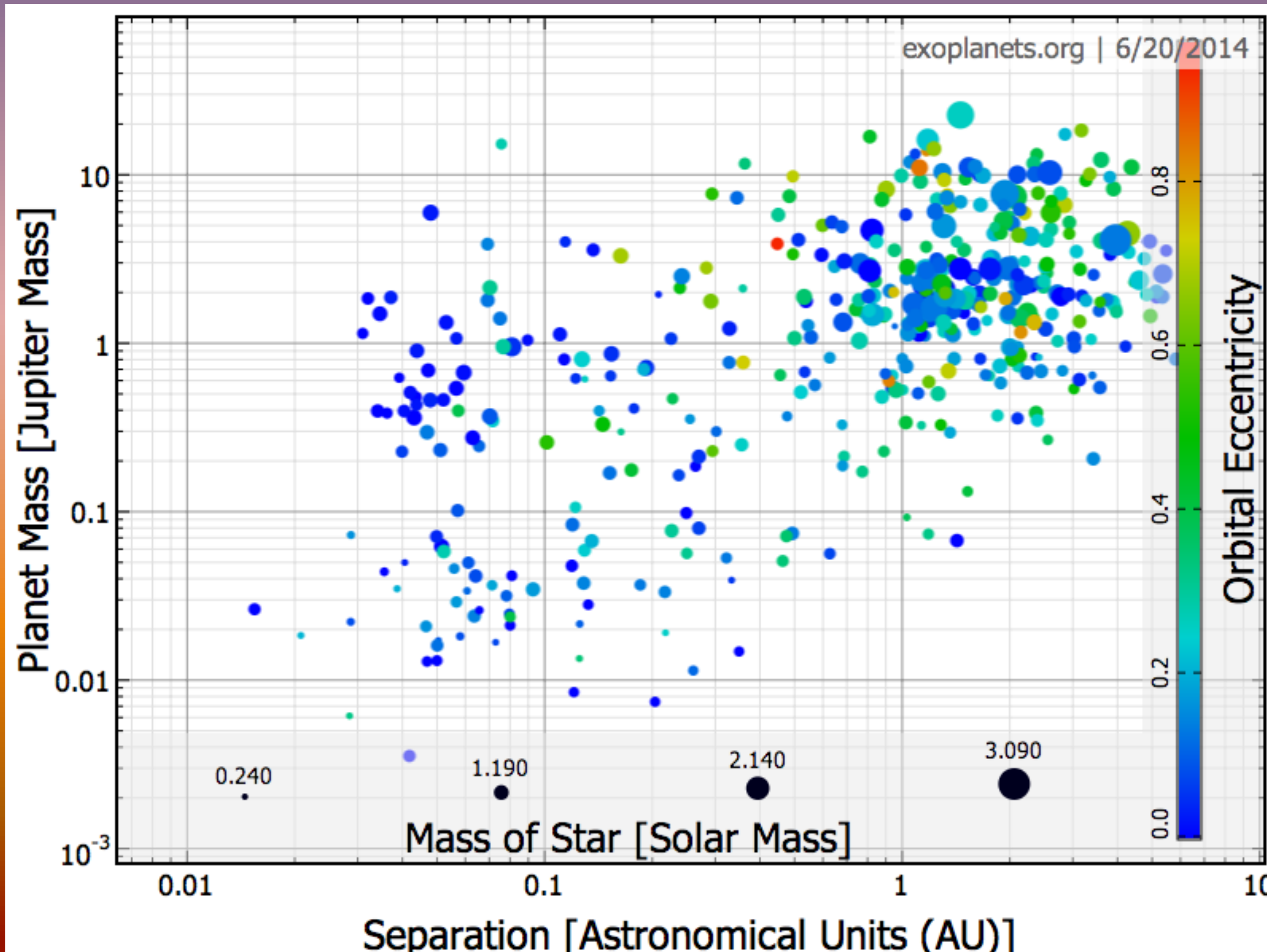
The TMT and Exoplanet Radial Velocities

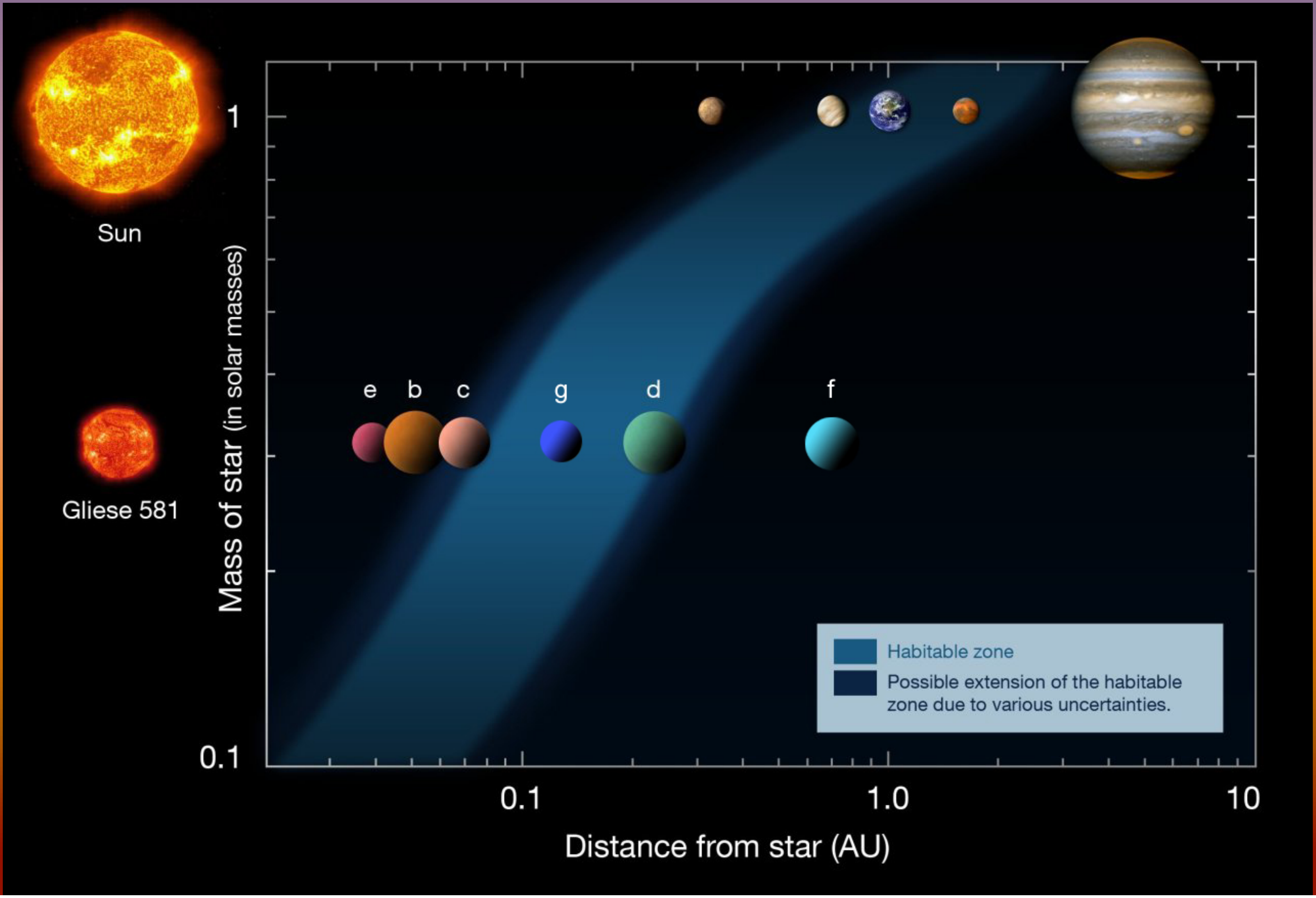


Angelle Tanner (MSU)

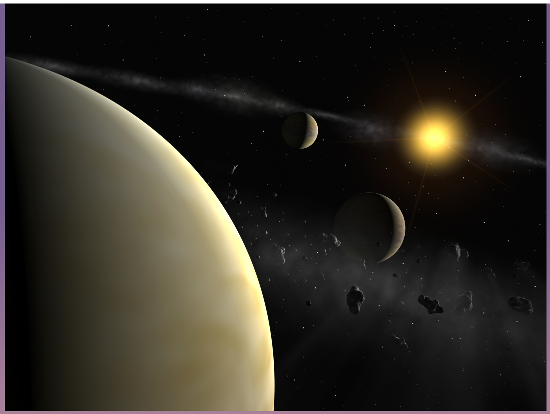
RV surveys have discovered ~440 planetary systems thus far.

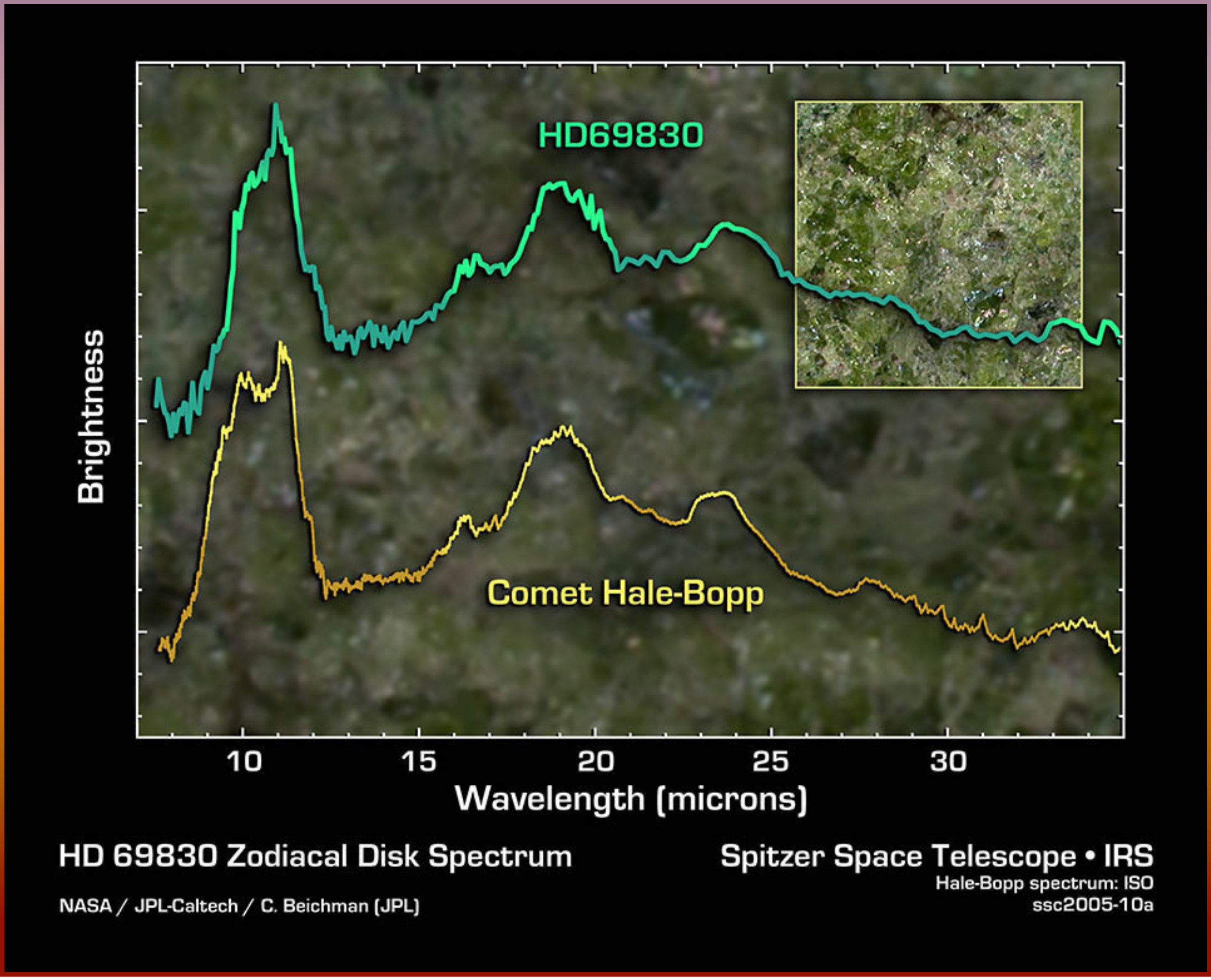


Notable Systems: GJ 581 – an M3 dwarf with three (or five planets) and a debris disk

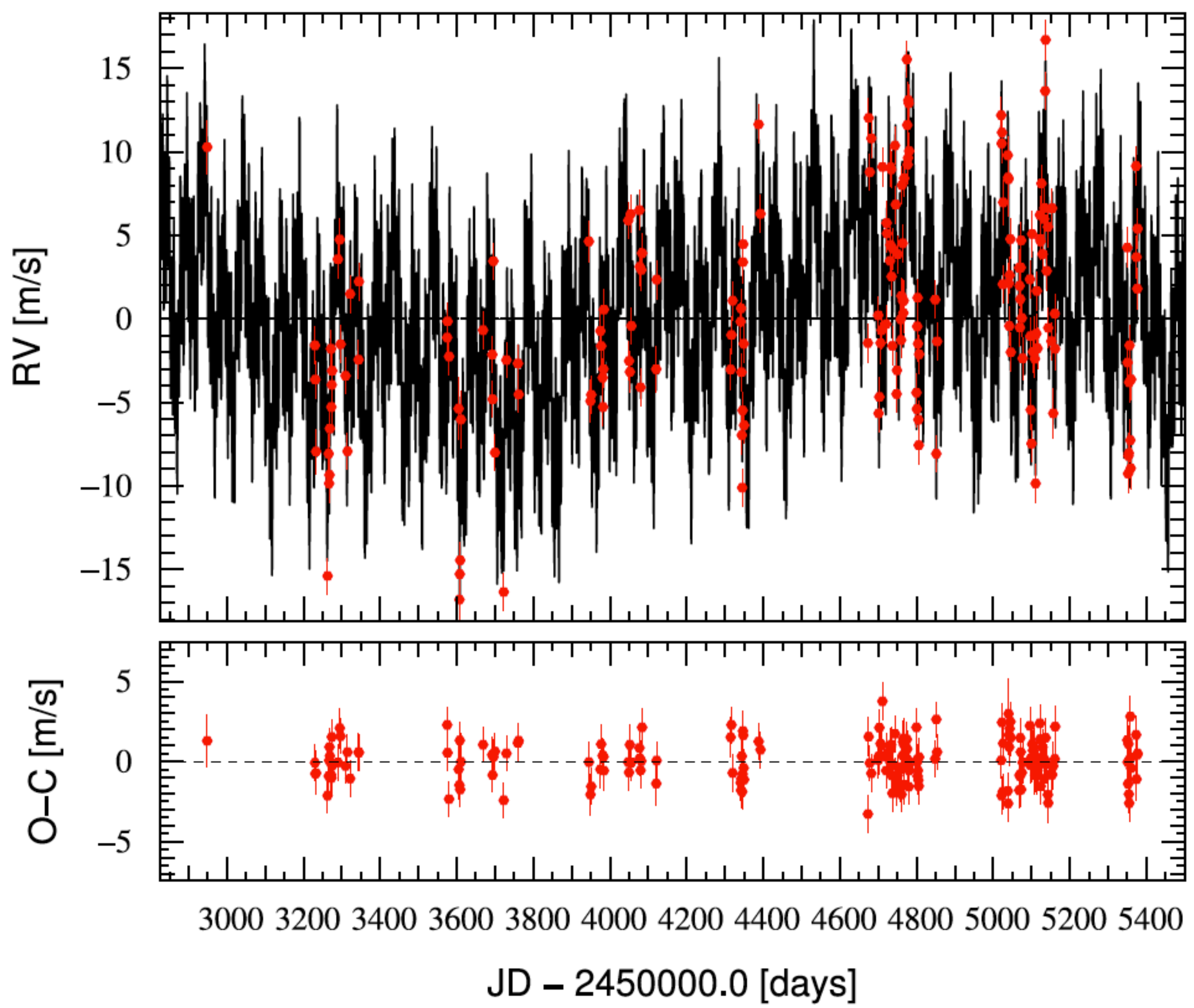


Notable Systems: HD 69830 has three Neptune mass planets and an asteroid belt



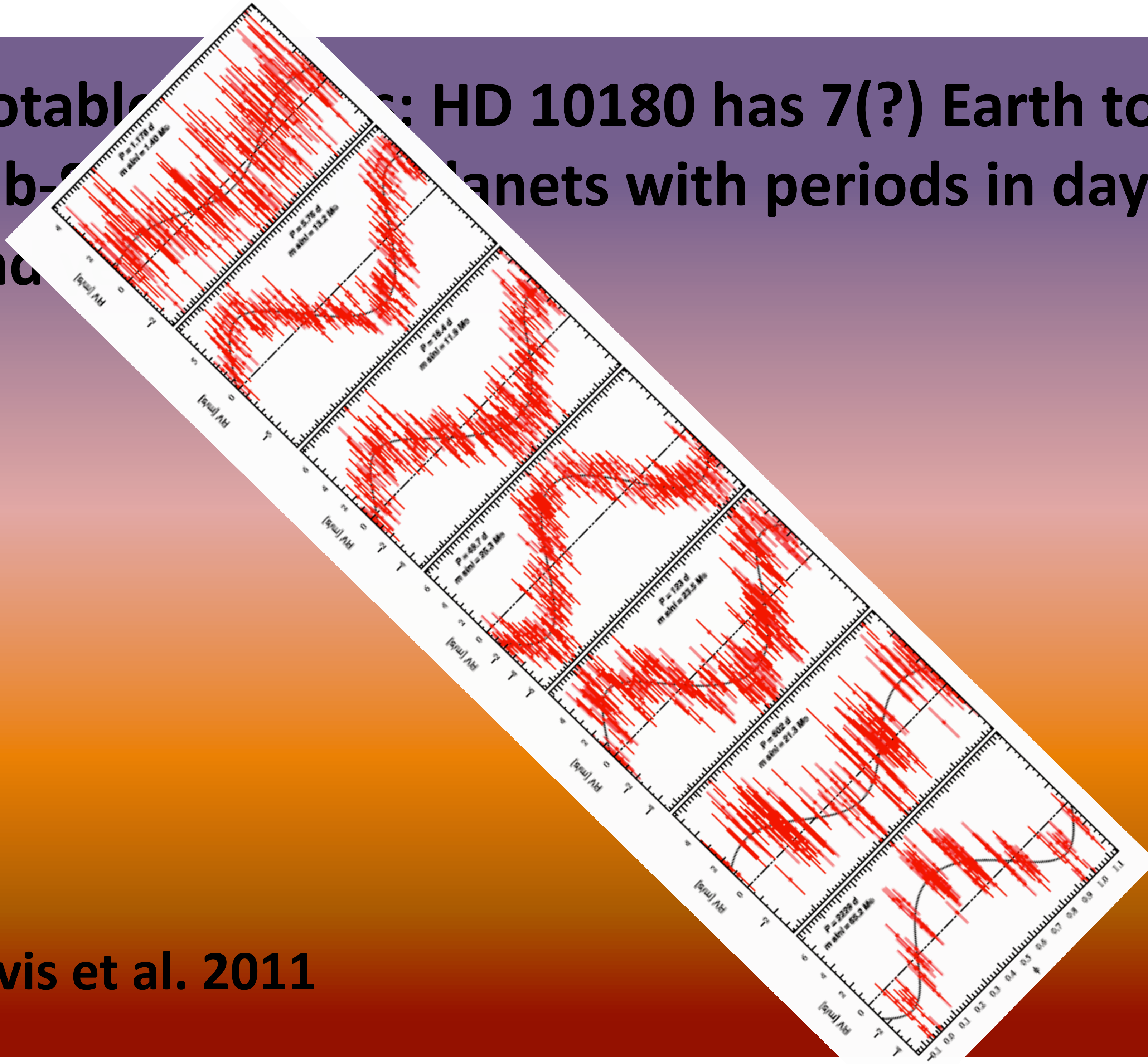


Notable Systems: HD 10180 has 7(?) Earth to sub-Saturn mass planets with periods in days and years



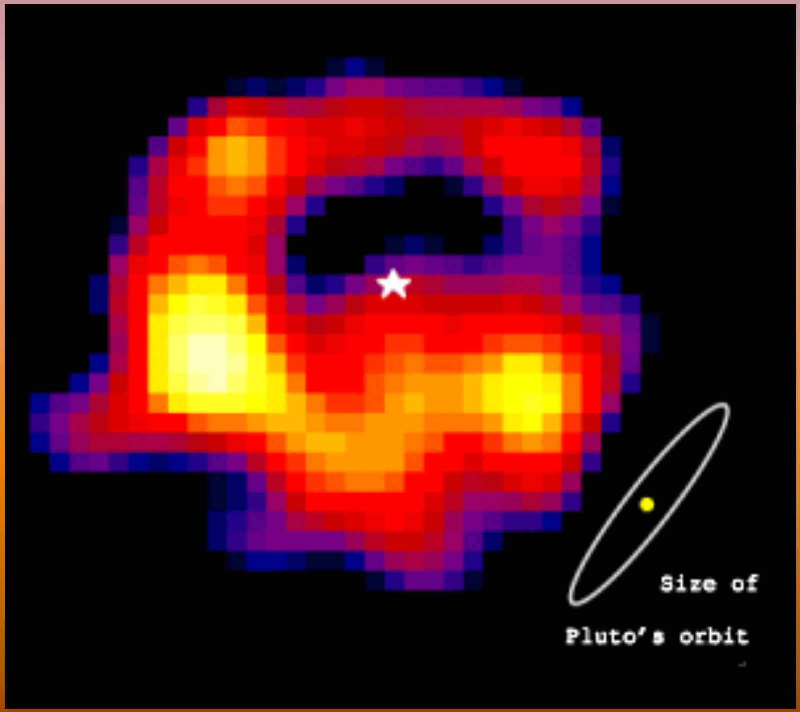
Lovis et al. 2011

Notabl... s: HD 10180 has 7(?) Earth to sub-S... lanets with periods in days and...

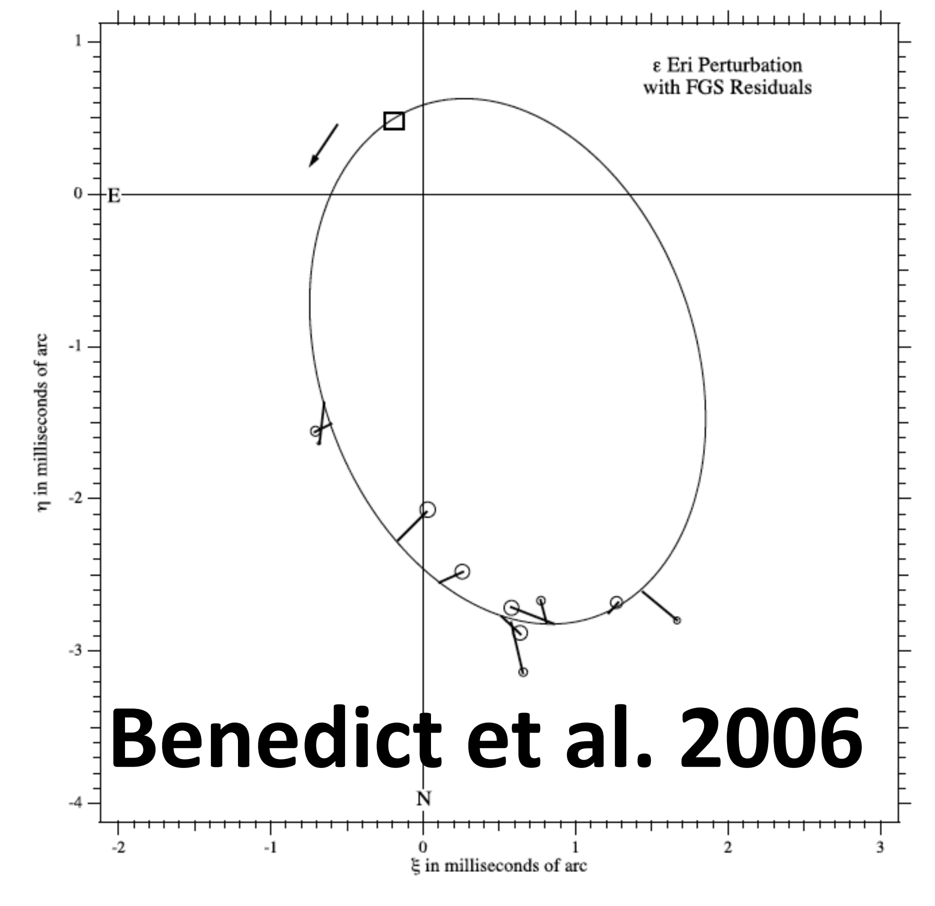


Lovis et al. 2011

Notable Systems: Eps Eridani – a nearby K2 dwarf with a 1.5 M_J planet at 3.4 AU with a known orbit through astrometry AND a debris disk

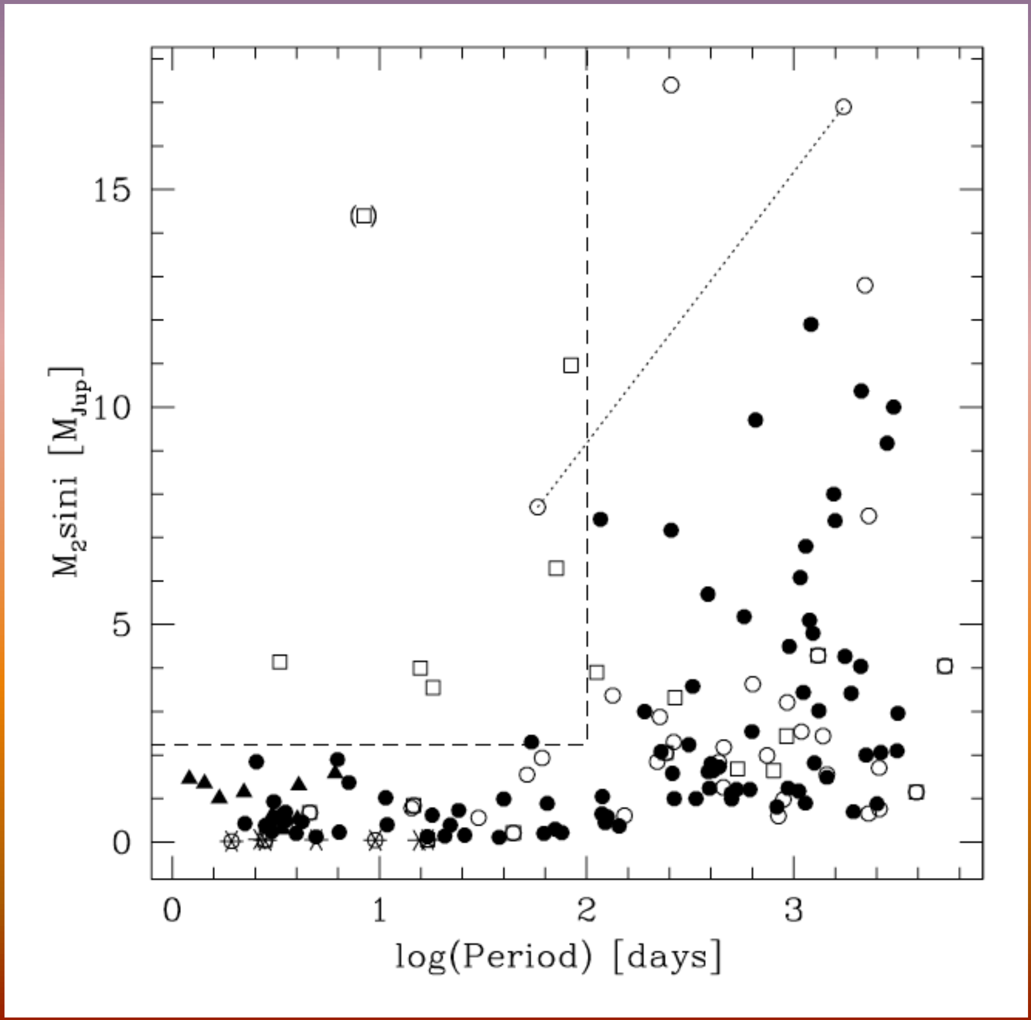


Greaves et al.

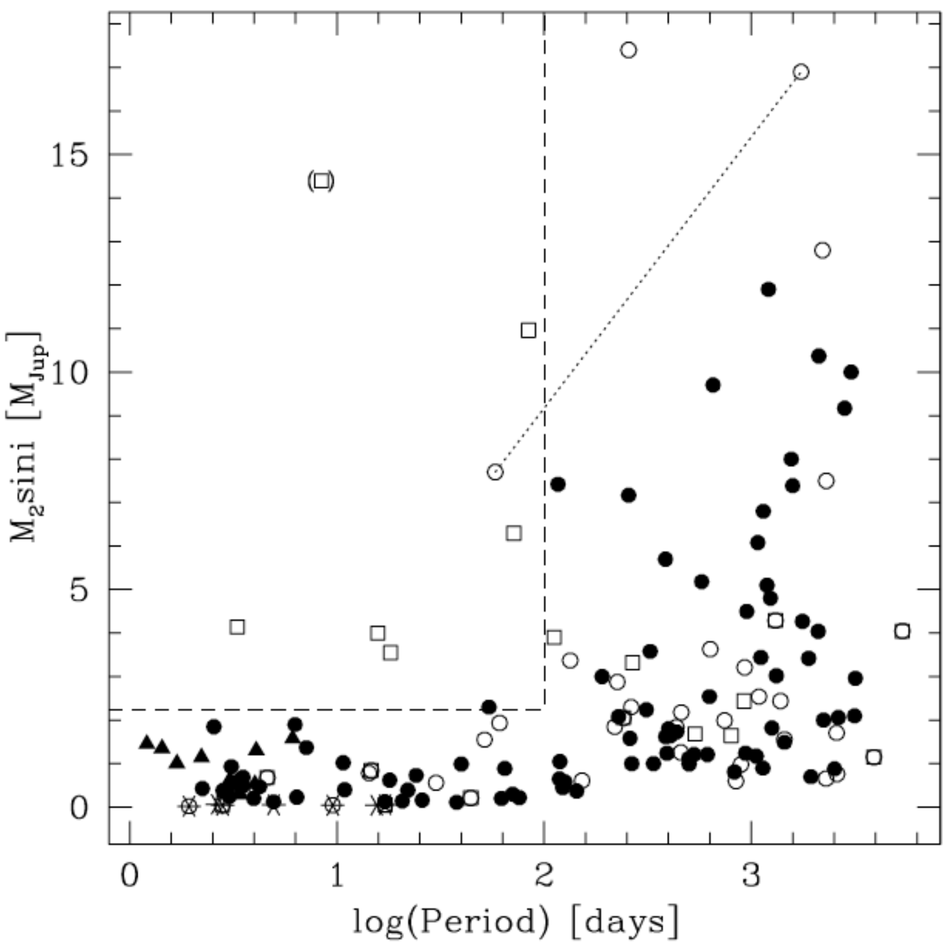


Benedict et al. 2006

There is a pile up of hot Jupiters at a period of 3 days believed to be a result of migration



There is a lack of massive planets at short periods which could also be due to migration, planet plunging or mass transfer



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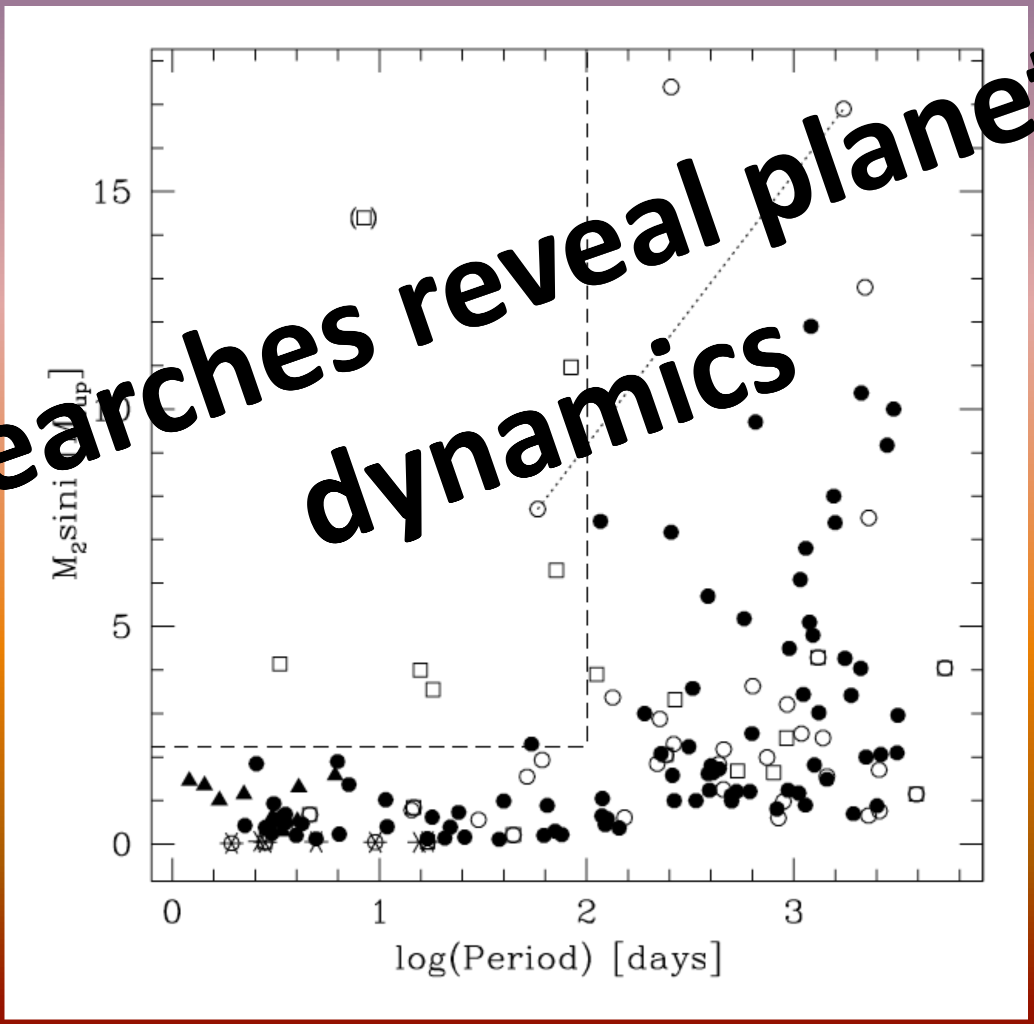
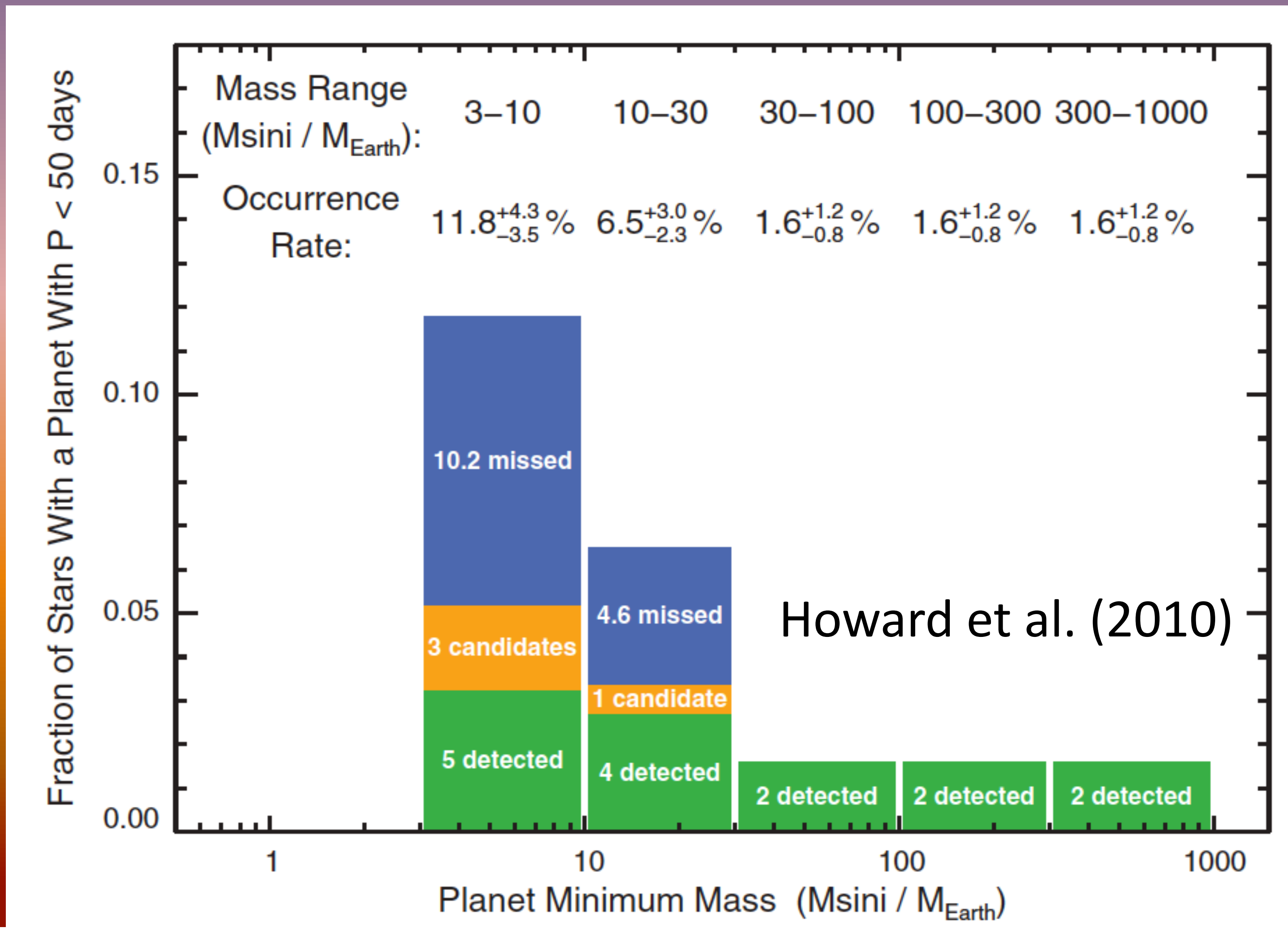


RV surveys predict the fraction of stars with planets in different period and mass ranges



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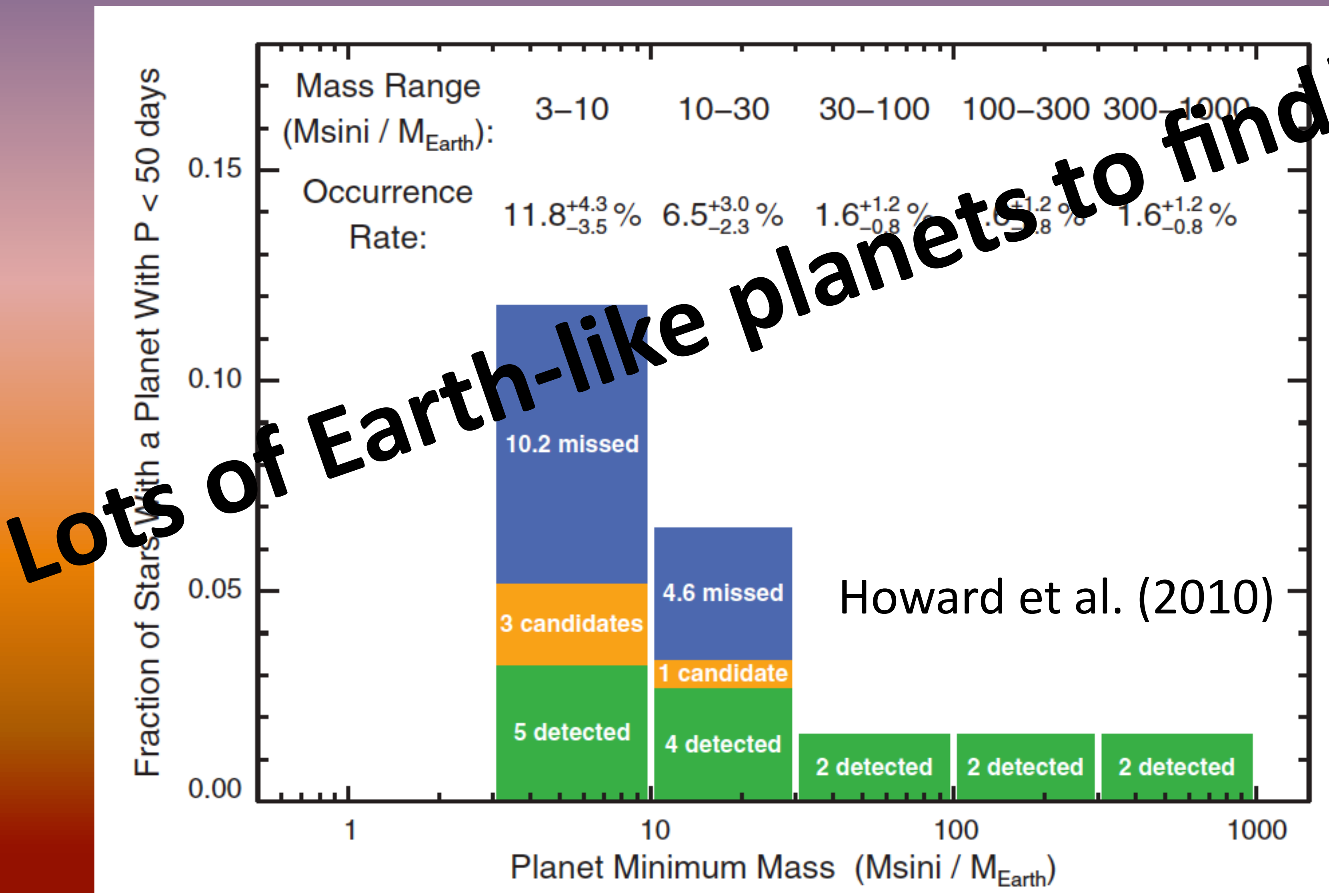
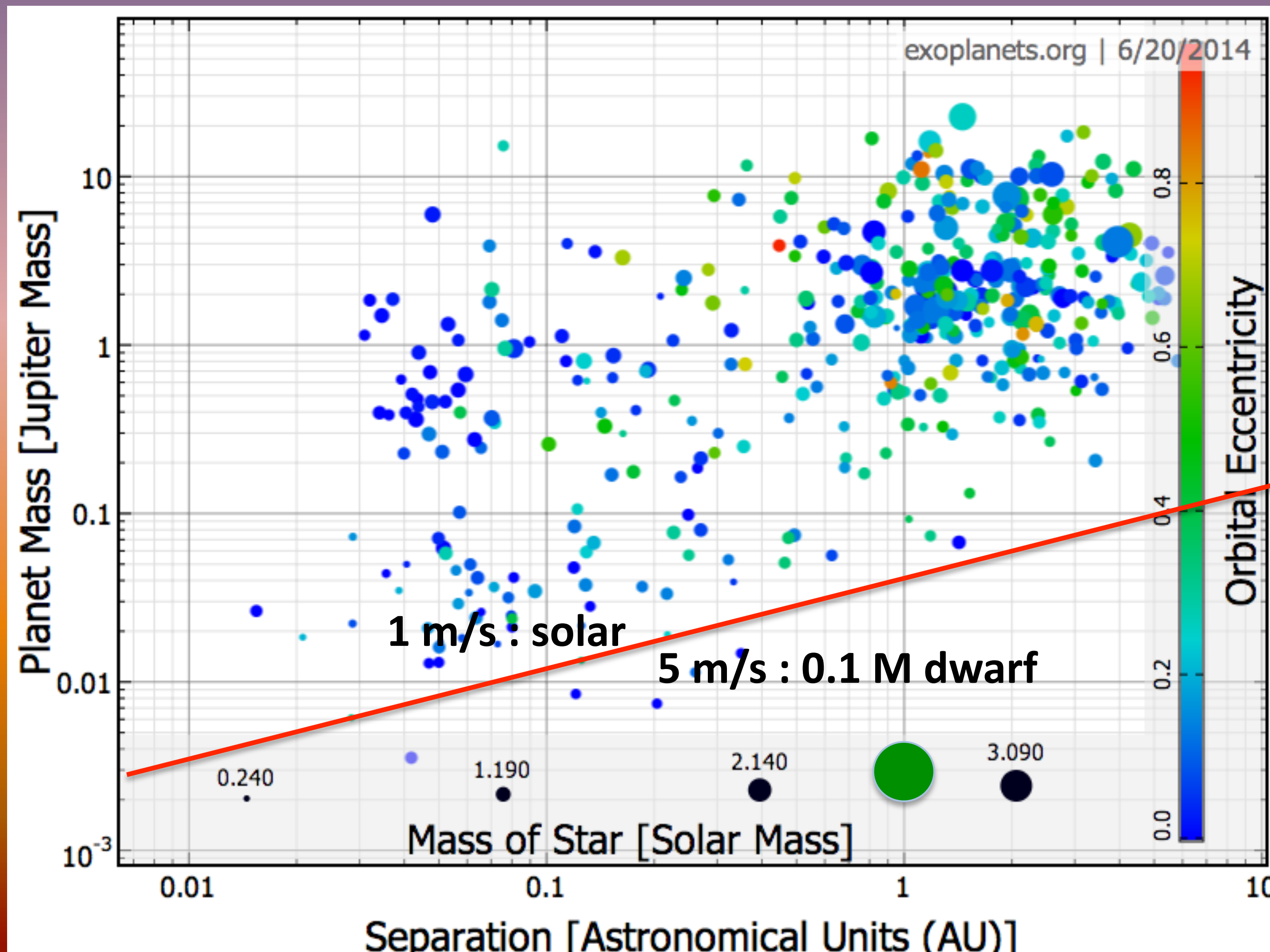
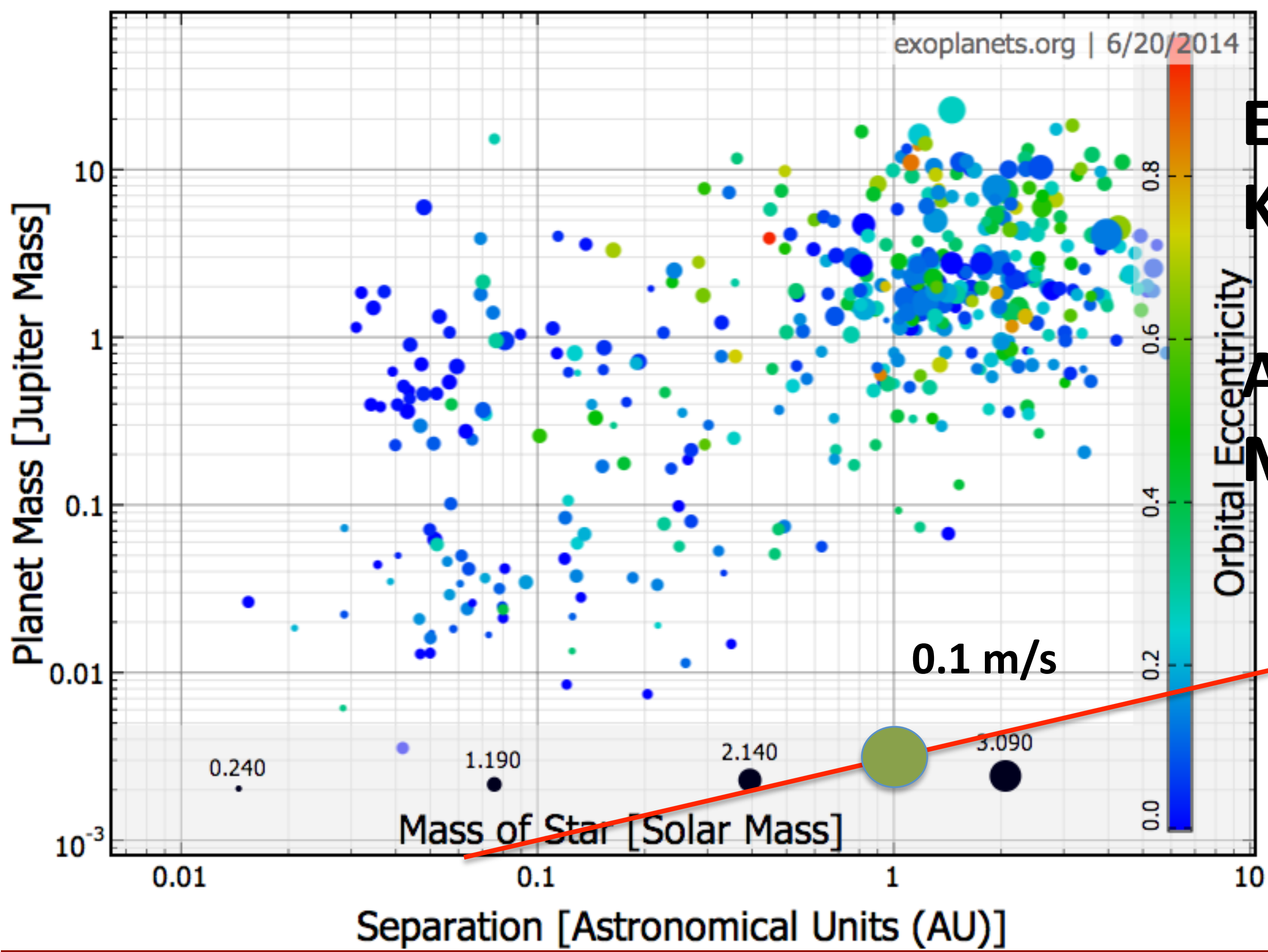


Current state of the art is <1 m/s RV precision in the optical and 5 m/s precision in the IR



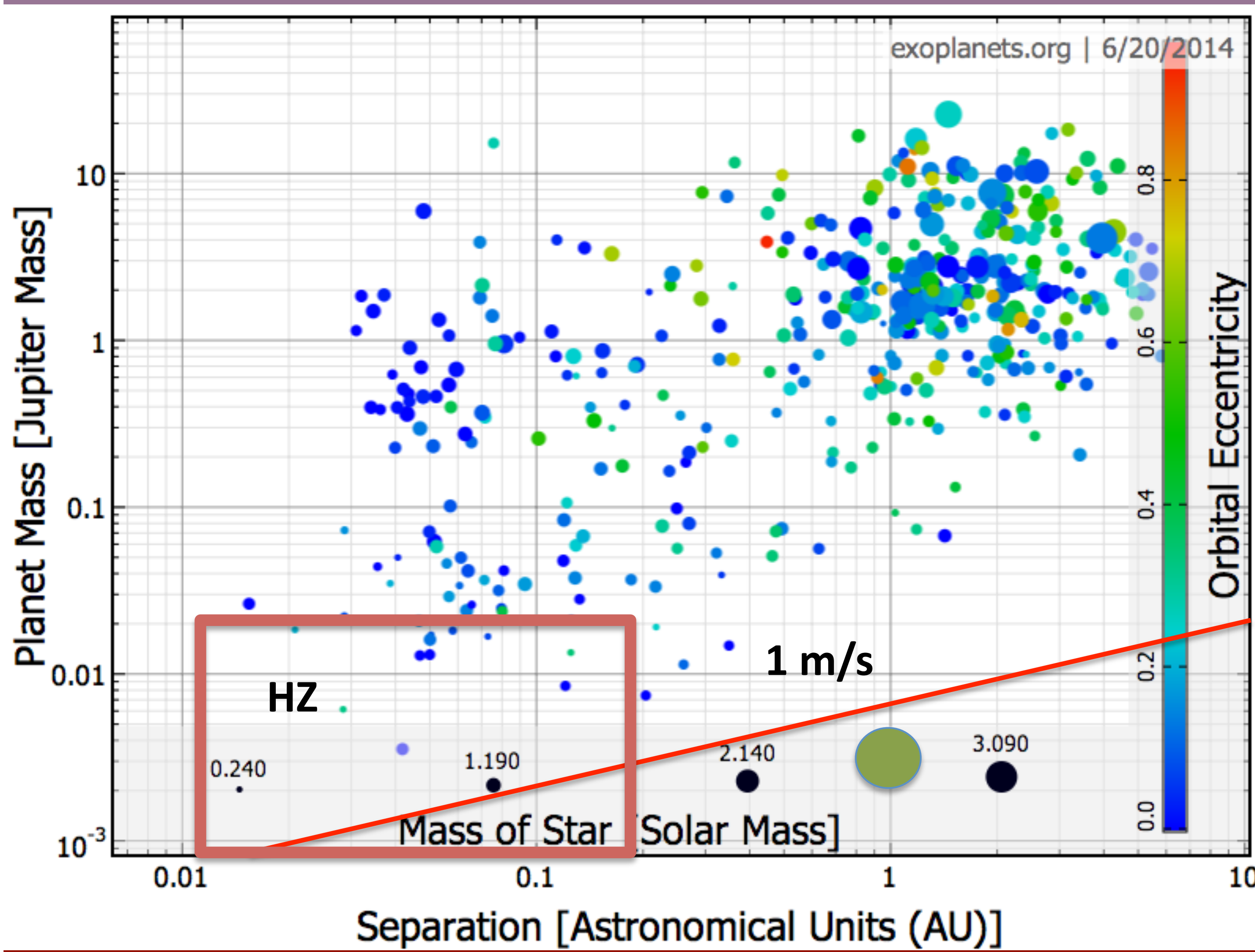
The future: 0.1 m/s in the optical to detect HZ Earth-mass planets around Solar type stars



ESPRESSO/VLT
Keck Shrek

APF
MINERVA

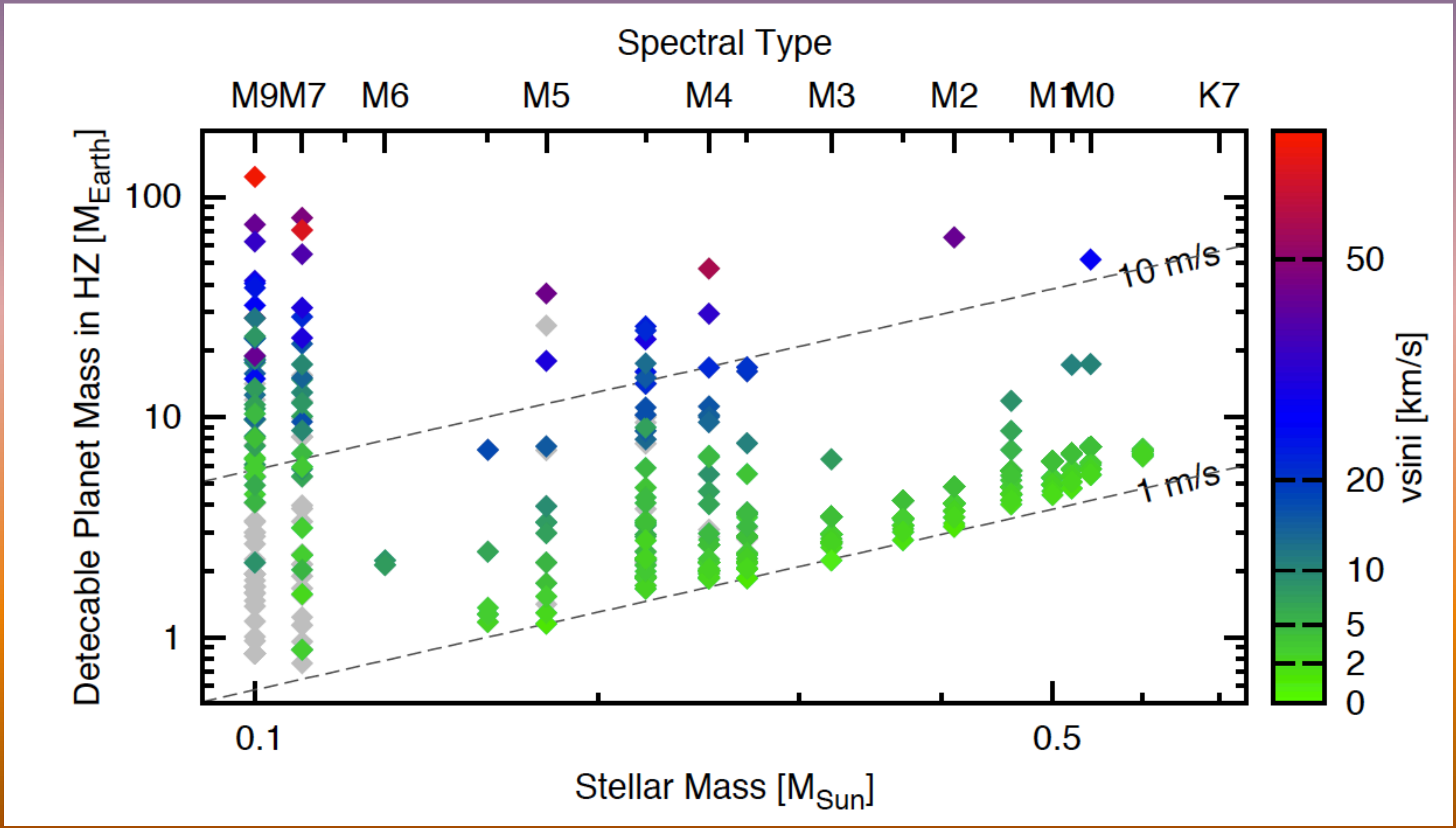
The future: 1 m/s in the IR to detect HZ Earth-mass planets around M dwarfs



CARMENES/ Calar Alto
SPIRou/CFHT
iSHELL/IRTF
NIRSPEC/Keck
CRIRES/VLT
Pathfinder/ HET

see Crossfield et al. 2014

The future: 1 m/s in the IR to detect HZ Earth-mass planets around M dwarfs



Quirrenbach et al. 2012, CARMENES

There are two echelle spectrometers on the books for the TMT

High Resolution Optical Spectrometer (HROS)

Δλ - 0.3-1.0 microns

FOV – 10”

R = 50000 – slit or 90000 imager slicer

σ_{RV} = sufficient to detect planets

Near-Infrared Echelle Spectrometer (NIRES)

Δλ – 1-2.5 microns and 2.9-5 microns

FOV – 10”

R = 20000-90000

σ_{RV} = sufficient to detect planets

Both of these instruments will have additional components to meet the precision requirements.

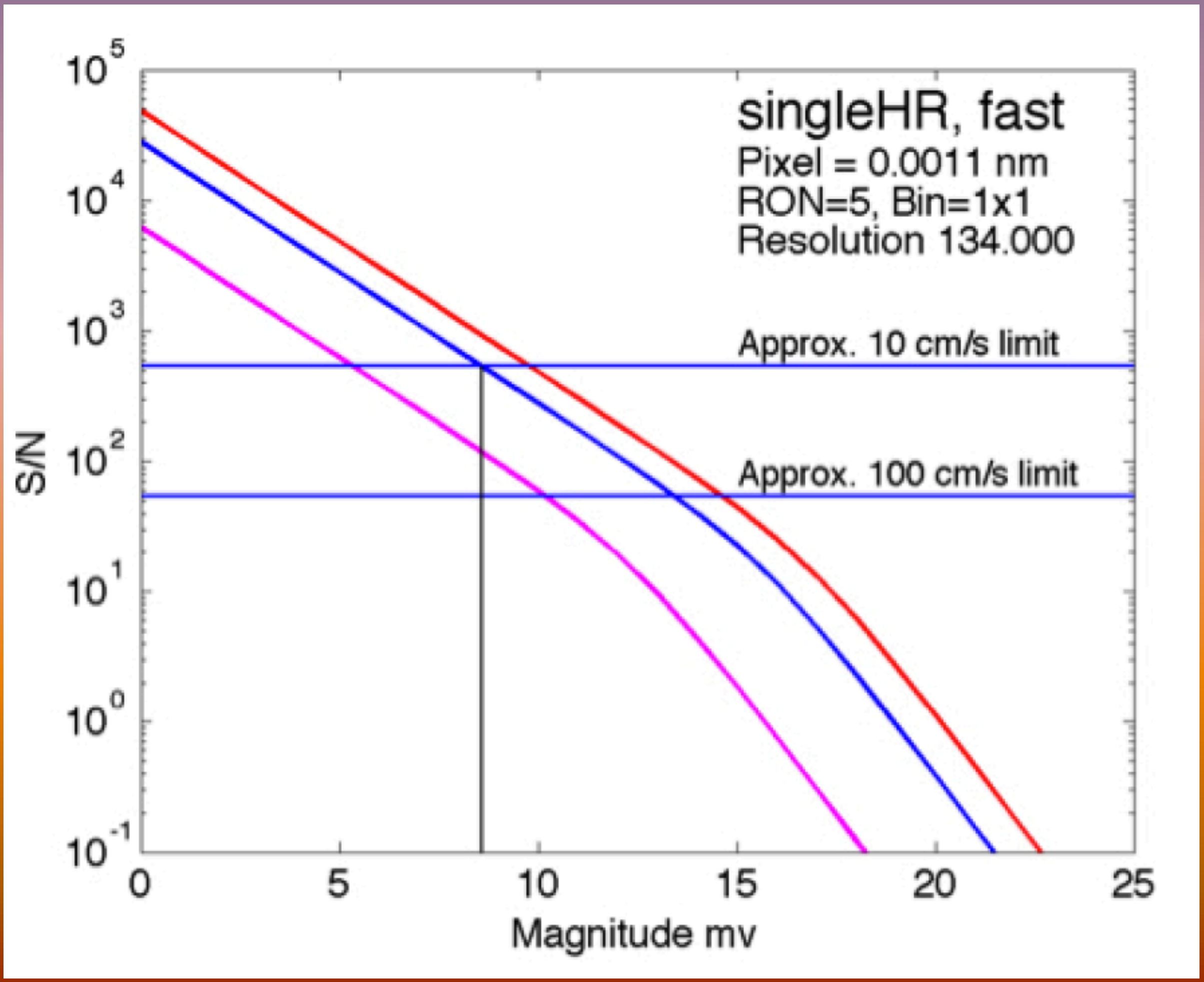
HROS – will rely on knowledge gained from HARPS and HIRES

- iodine cell
- mirrors to remove wind shake
- fiber scramblers (Fischer et al. 2011)

NIRES – high RV precision hardware still being developed on smaller telescopes

- multiple gas cells – ammonia, methane, methane+
- fiber scramblers
- laser combs

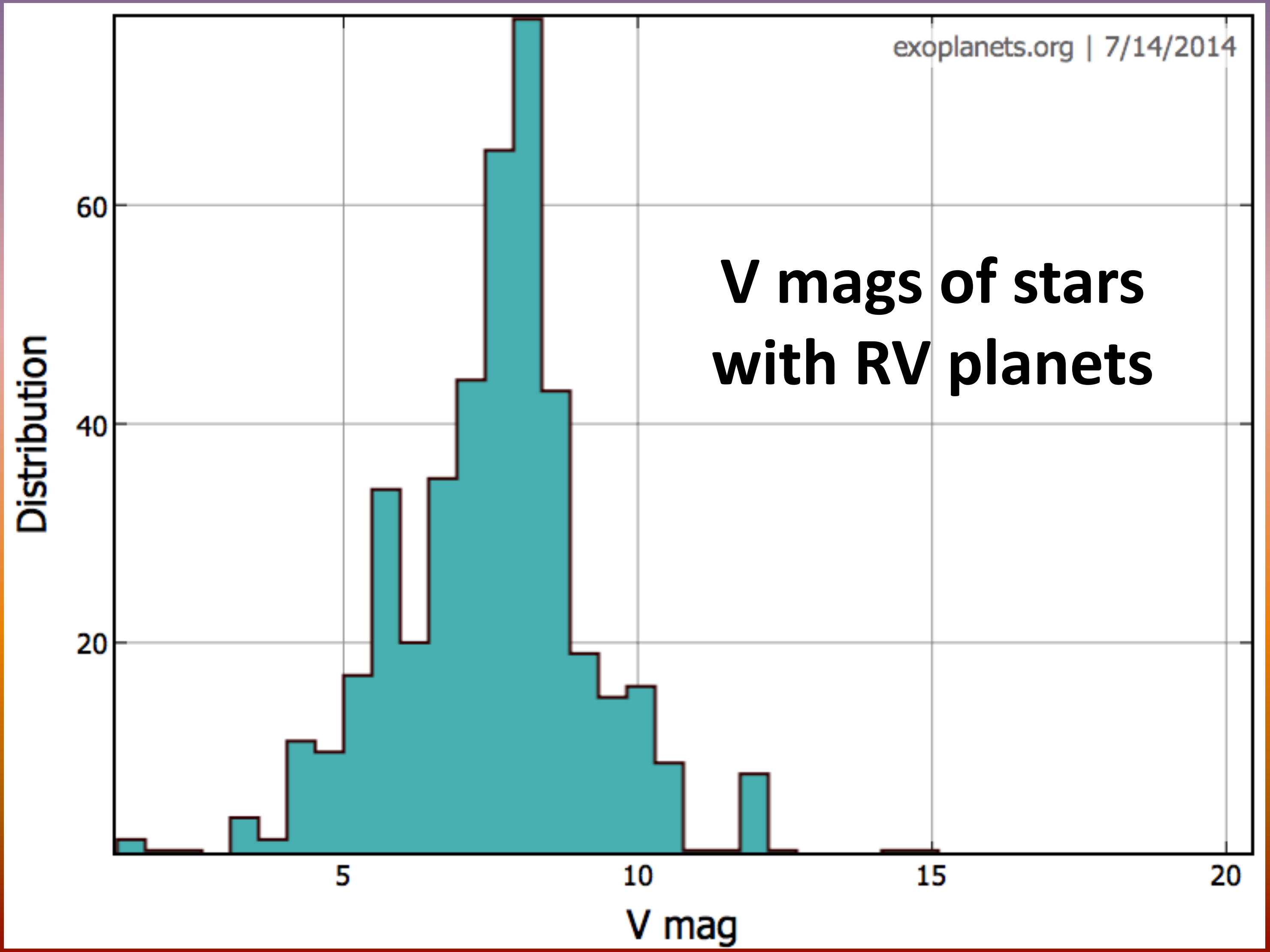
To be able to confidently detect Earth-mass planets around solar-type stars we will need SNR of 200-500 for EACH stellar spectrum



With a 1 hr single exposure time ESPRESSO will reach these SNRs for V<10!

Pepe et al. 2010

The TMT will play an important role in the future of RV planet discoveries with its superior sensitivity.



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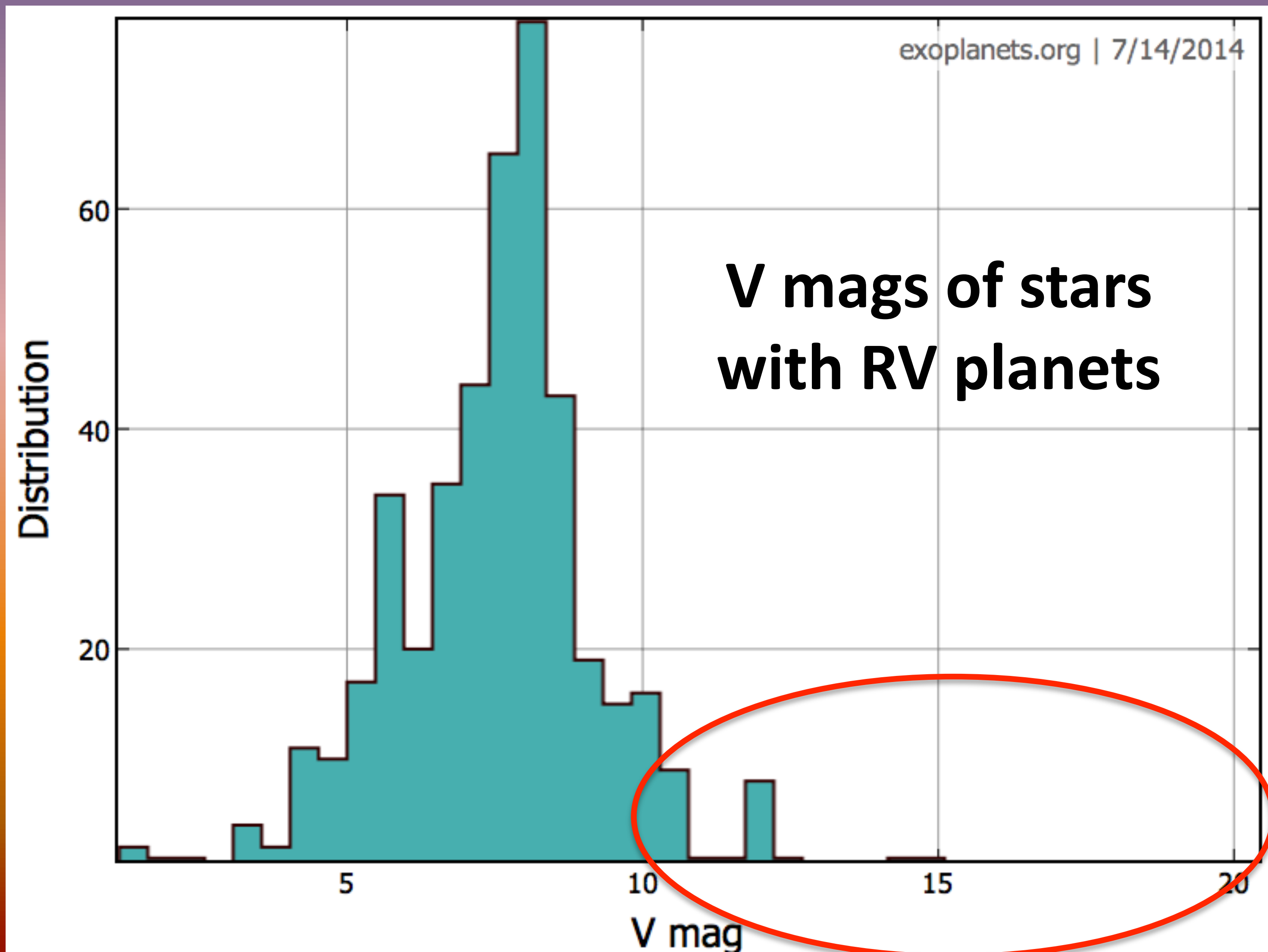
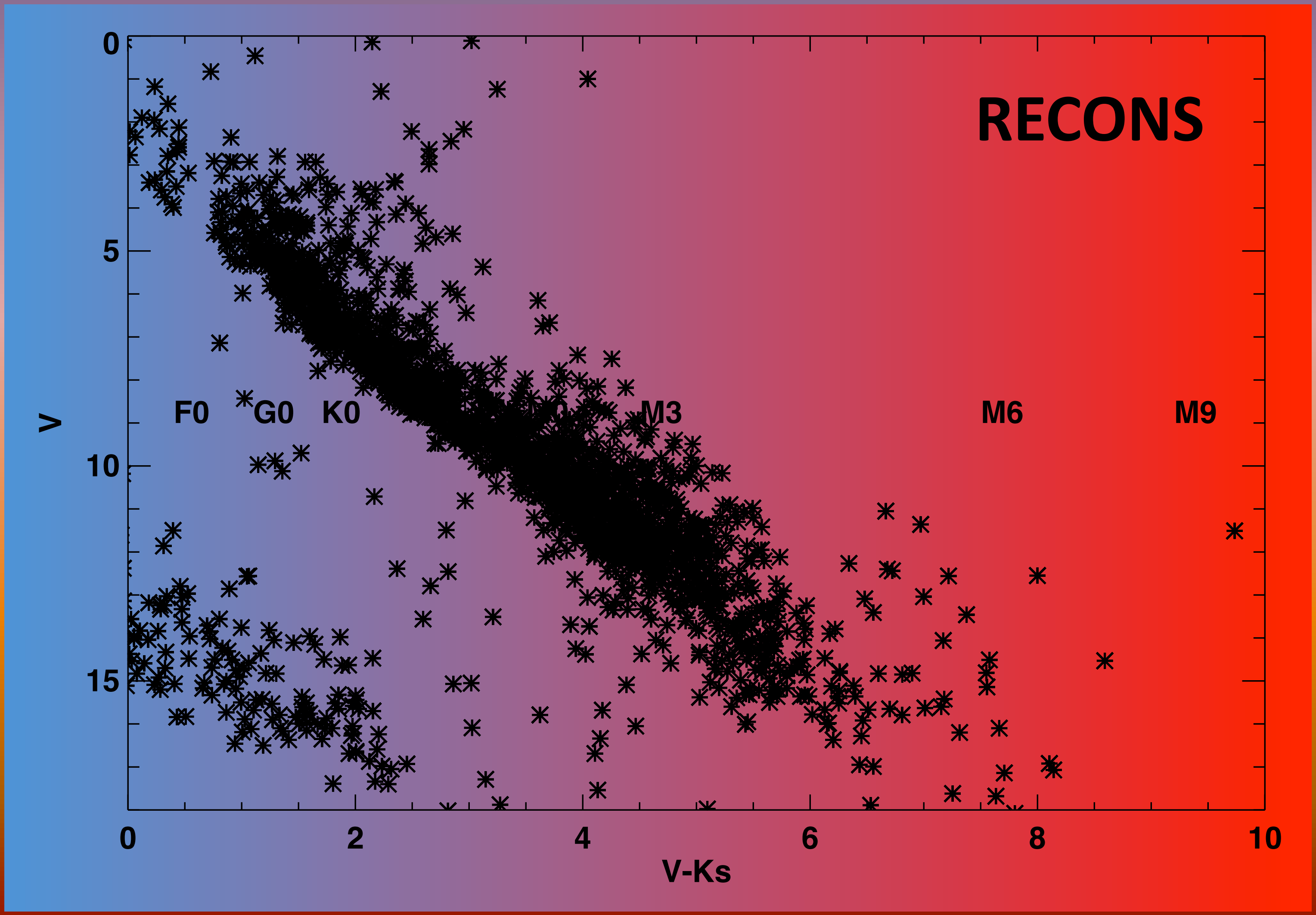


The TMT will help us complete the survey of exoplanetary systems within 25-30 parsecs



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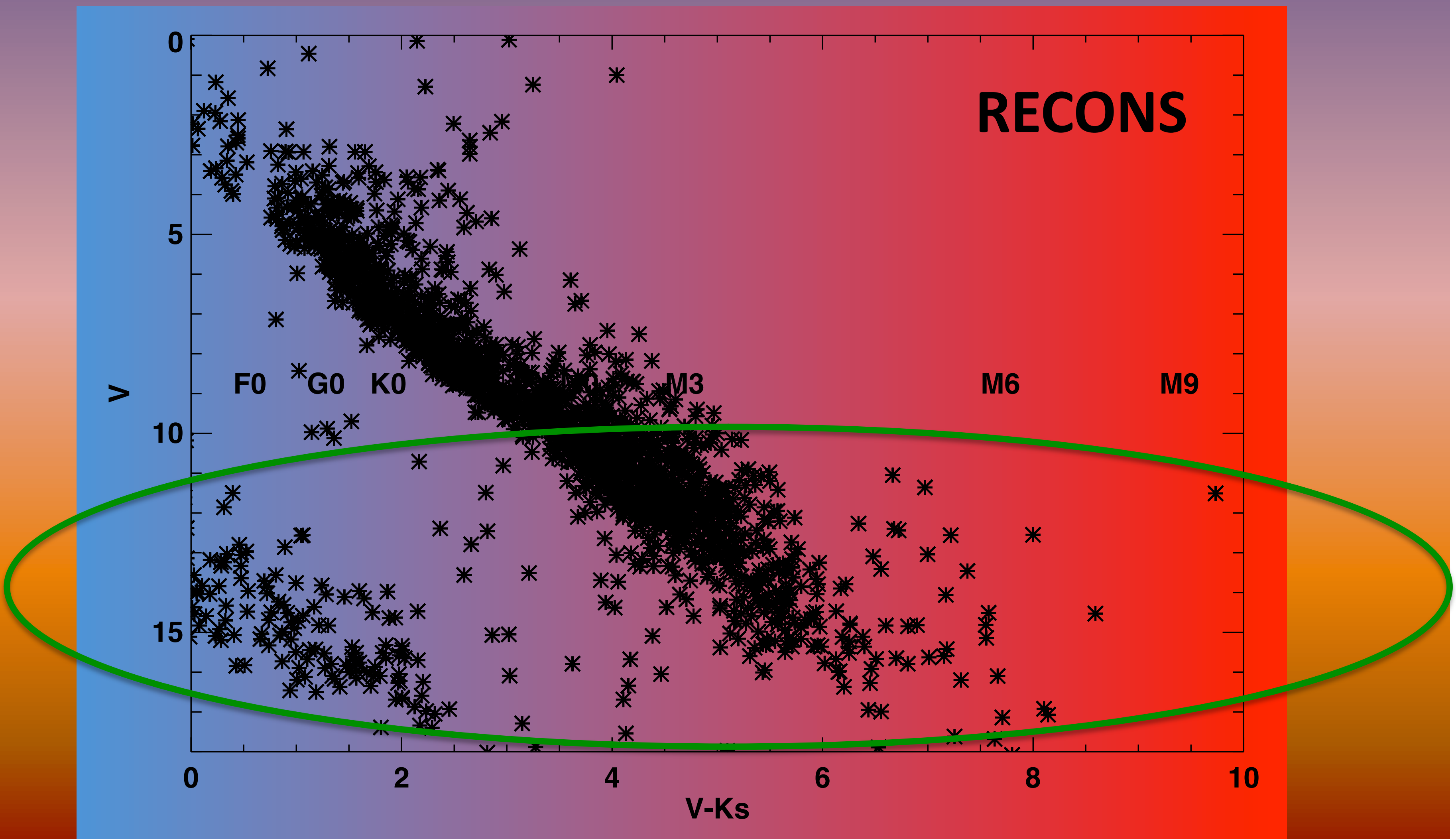
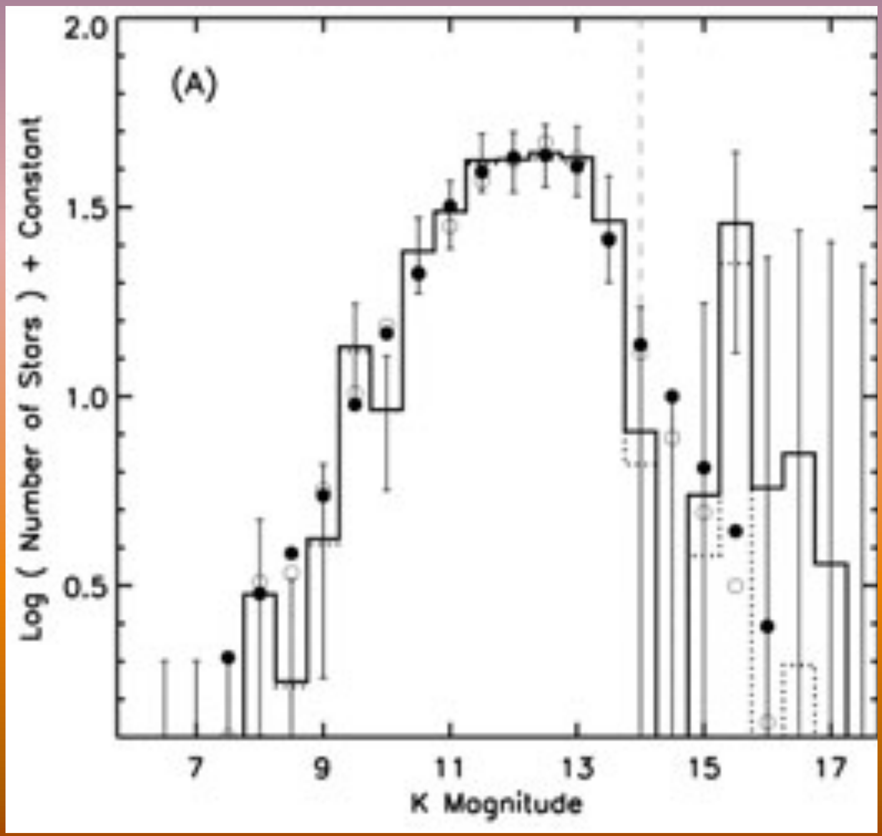


The TMT will help us study planet formation with complete RV surveys of young star associations.



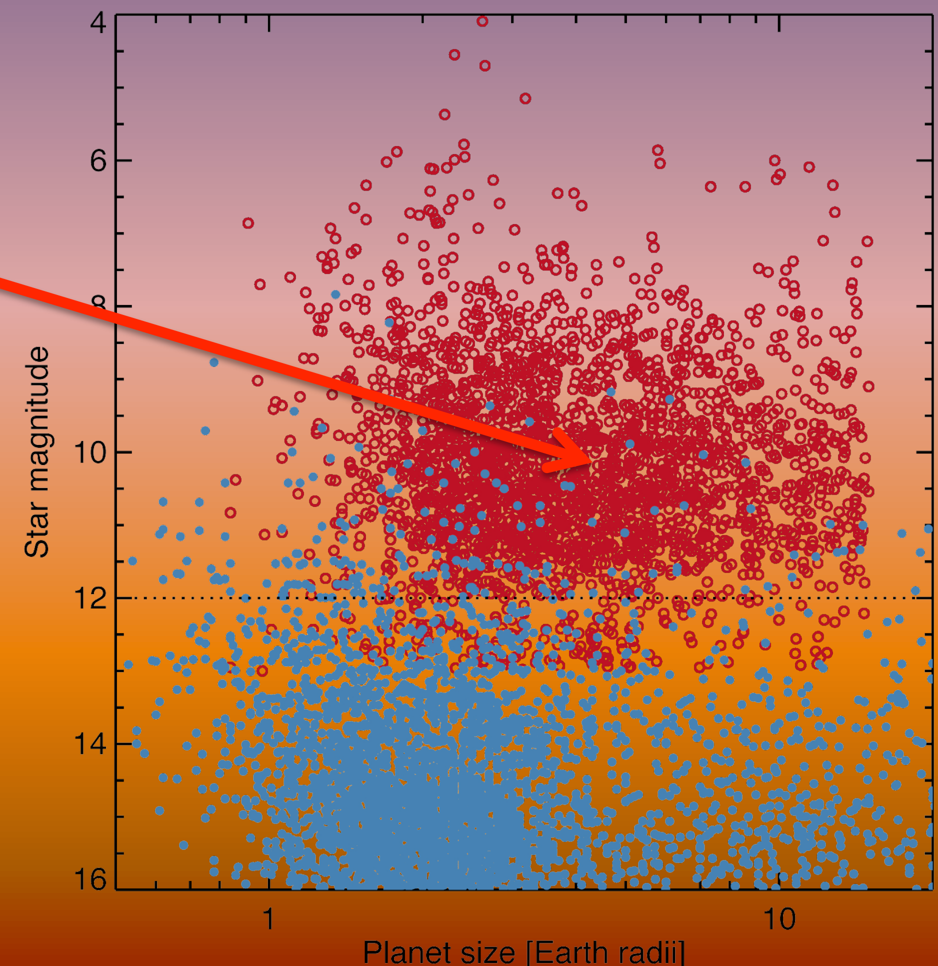
Young stars in IC 348

2 Myr
300 pc

Krumholz et al. 2005

The TMT could provide essential RV follow-up observations for the faintest targets from Kepler, TESS, PLATO, GAIA and JWST.

TESS and PLATO will be focusing on the nearby bright stars where there is a rich sample of V>10 targets



Ricker et al. 2014

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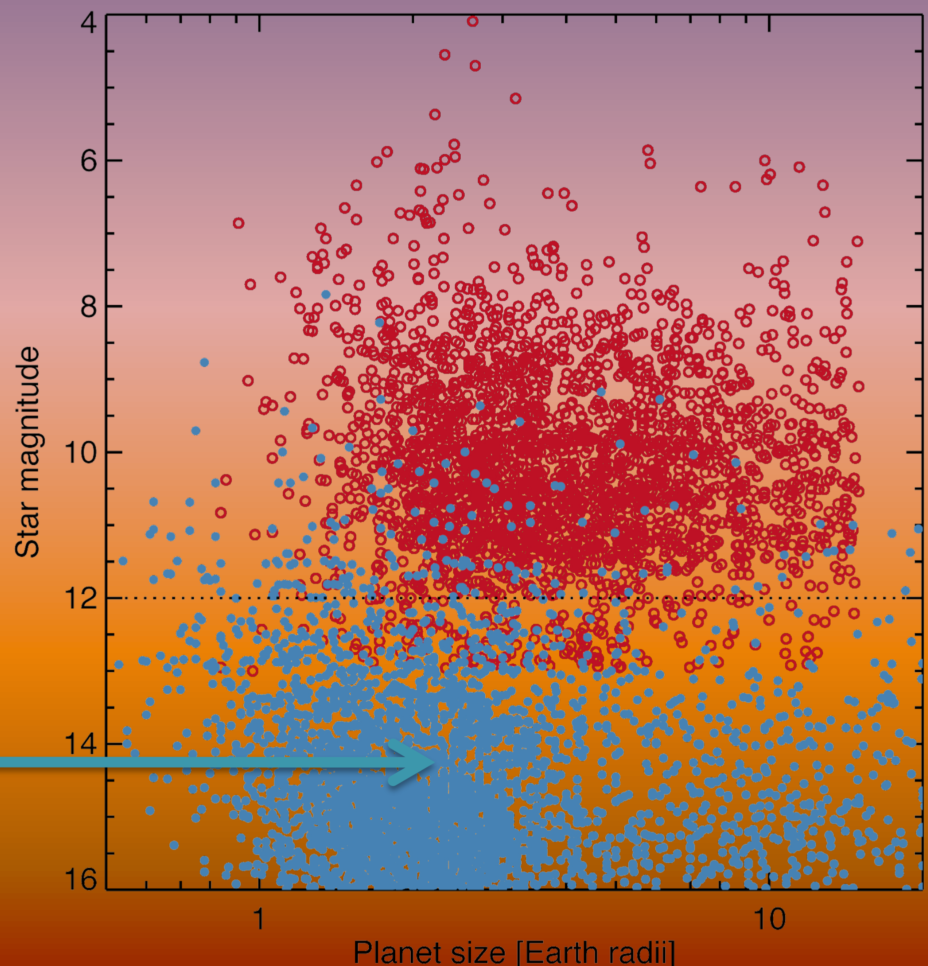


Kepler has many faint KOIs that still need RV follow up and also GAIA

Ricker et al. 2014

Our ability to detect Earth-mass planets around every nearby star will be limited by stellar activity

IN THE NEWS!

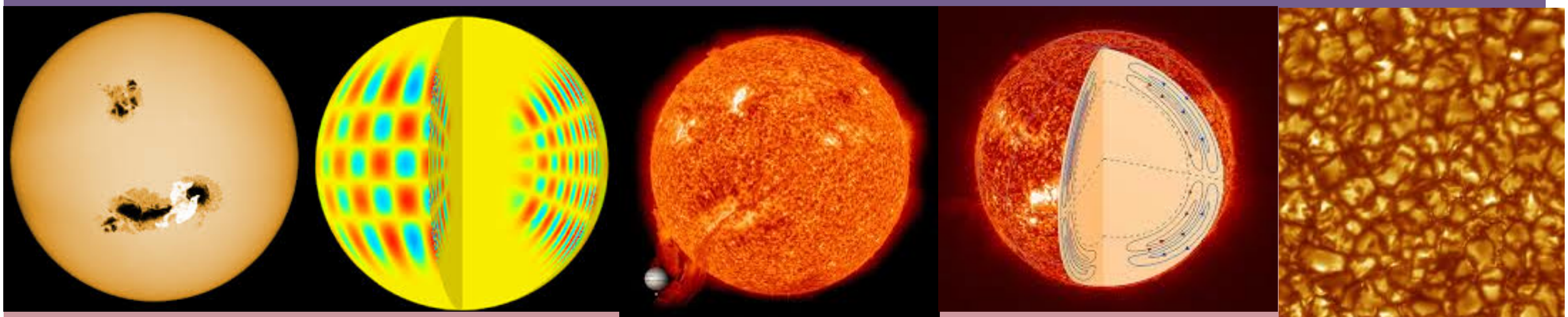
HD 41248

Jenkins & Toumi (2014) – planets are there but are buried in the noise

Santos et al. (2014) – planets are not there as one of the periods matches the stellar rotational period

GJ 581d – not there, it was noise and removes g by association (Robertson et al. 2014)

Types of Activity and their timescales

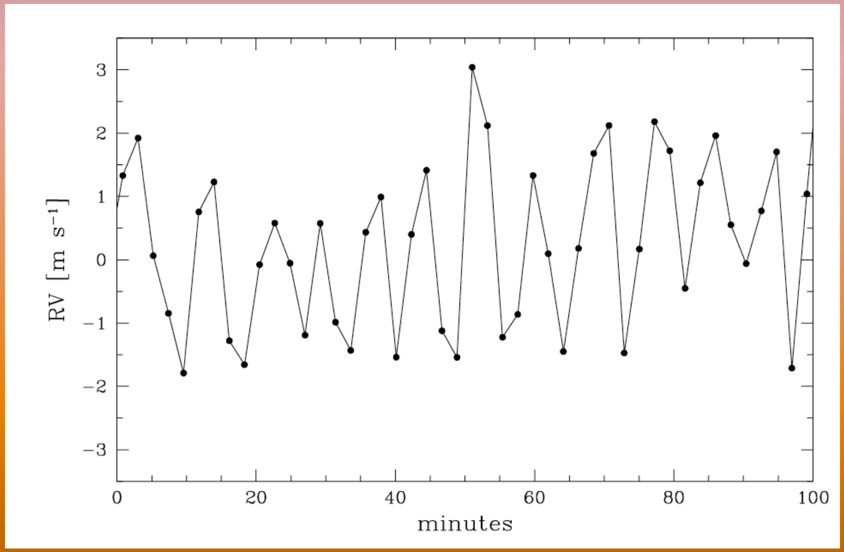


- star spots (days – weeks, the rotation P of the star)
- flares and CMEs (minutes – days, stochastic but seasonal)
- p-modes (minutes)
- meridional flows (years)
- granulation (hours-days)

All of these can induce RV signals of > 1 m/s!

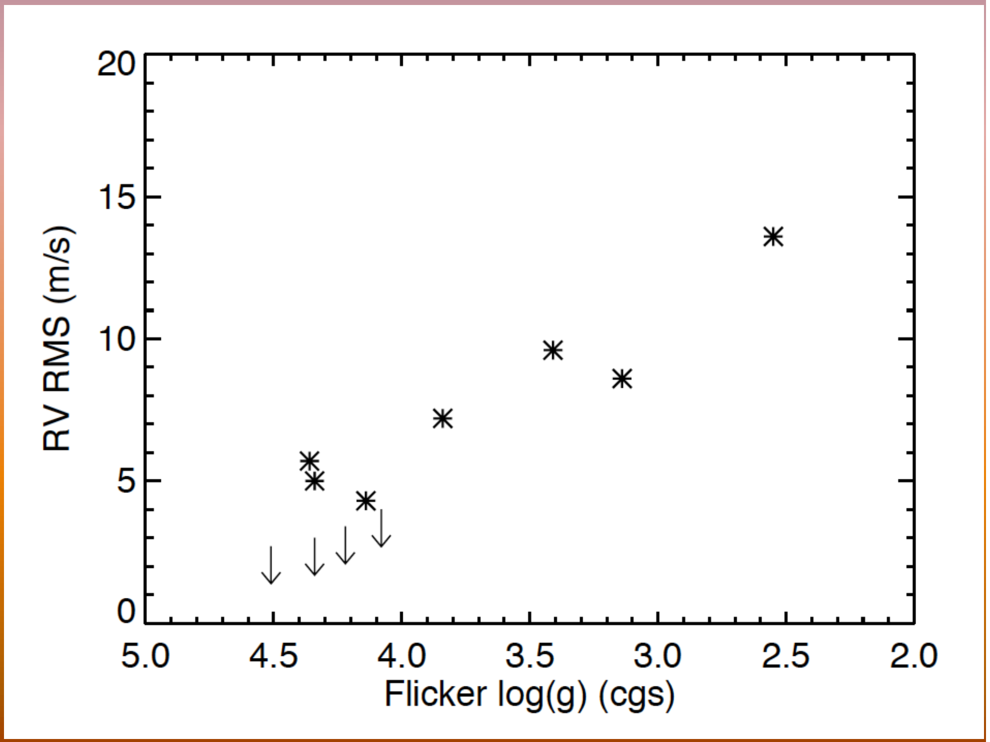
We have methods for predicting the RV jitter for future planet search targets and correcting for SOME sources of jitter.

High cadence observations of μ Ara show the P-modes



Bouchy et al. 2004

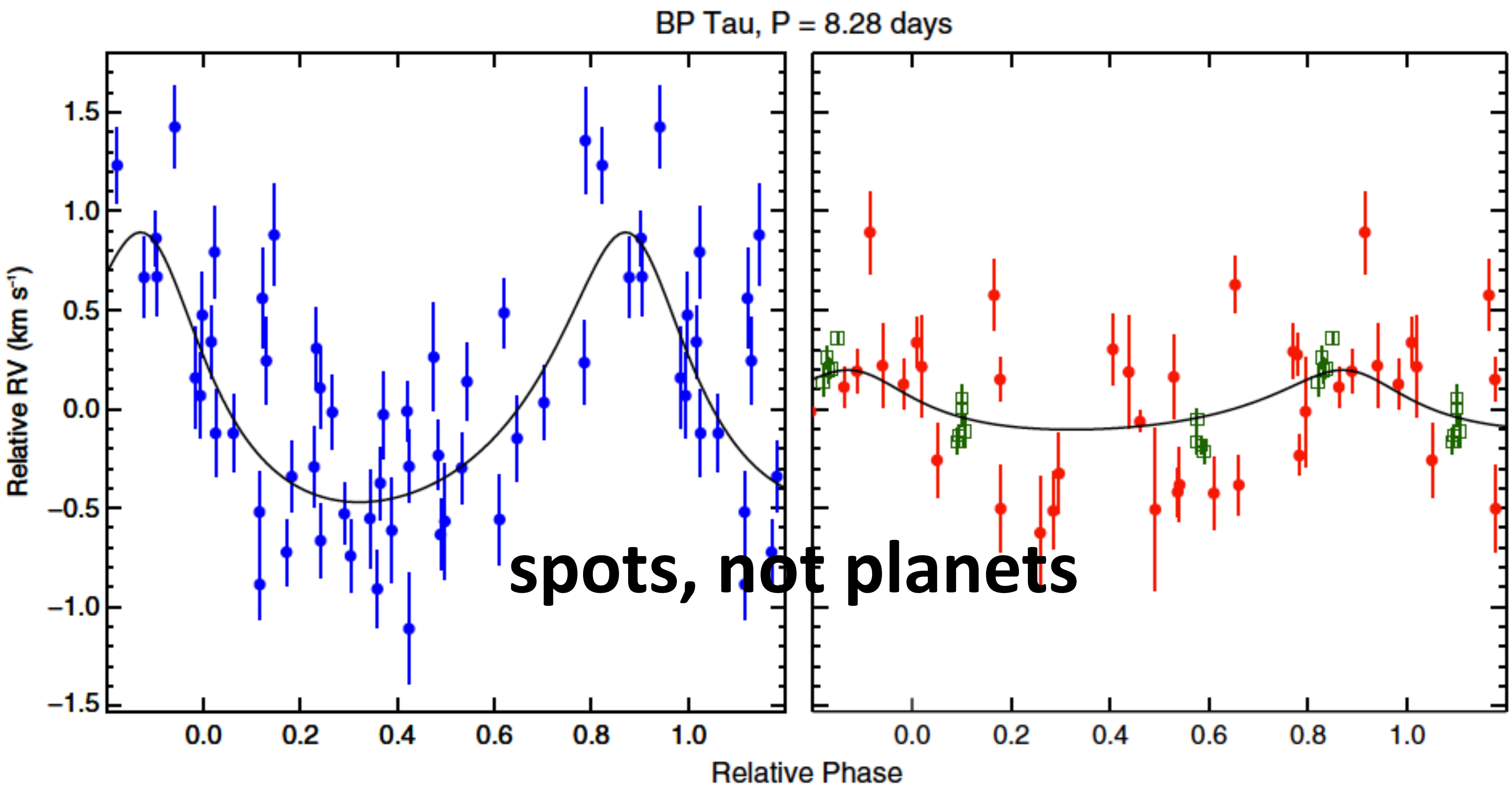
RV jitter correlates with "flicker"



Bastien et al. (2014)

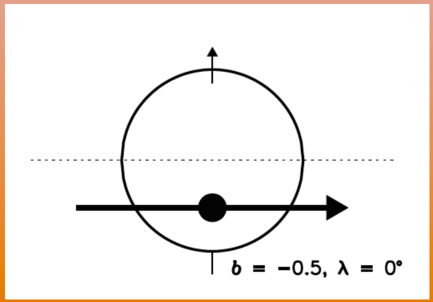
Also, know thy bisectors …

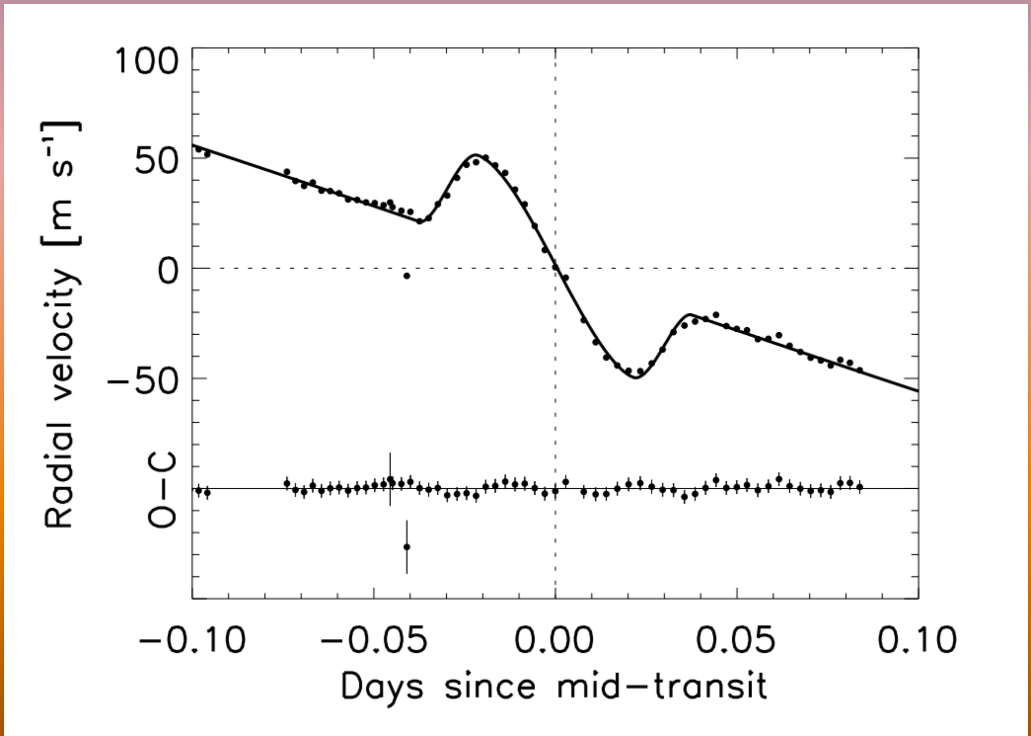
We SHOULD consider developing a dual optical and infrared echelle spectrometer.



Crockett et al. 2012

For transiting planets around faint stars, the TMT could collect high SNR RV measurements with the temporal cadence necessary to study the Rossiter-McLaughlin effect





Winn et al. (2006)

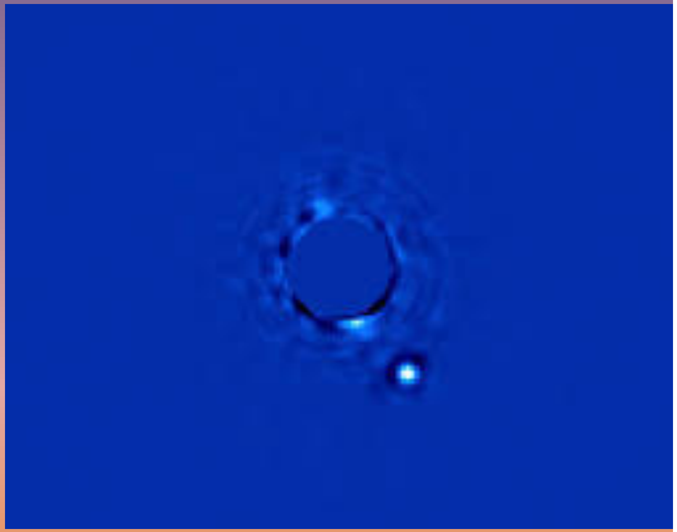
There is synergy between RV and direct imaging programs

RV -> imaging

RV and other searches guide imaging programs on where to look

Imaging -> RV

In some cases, RV follow-up of directly imaged planets can constrain planet masses. This would be beneficial for the young planets!



β Pic from GPI

Areas where the TMT is unique

1) RV targets that are too faint for 10 meter telescopes

-To complete the volume limited census of nearby stars and brown dwarfs down to Earth mass planets

-To complete surveys of stars and brown dwarfs in young star associations

-Targeted studies of compelling stars from other programs like Kepler, K2, TESS, Plato, Gaia, etc

2) Target that would benefit from high SNR and high temporal cadence observations

- RM measurements of transiting systems
- Complicated multi-planet systems

Finally, we should consider allowing for simultaneous optical/RV measurements to help mitigate jitter confusion