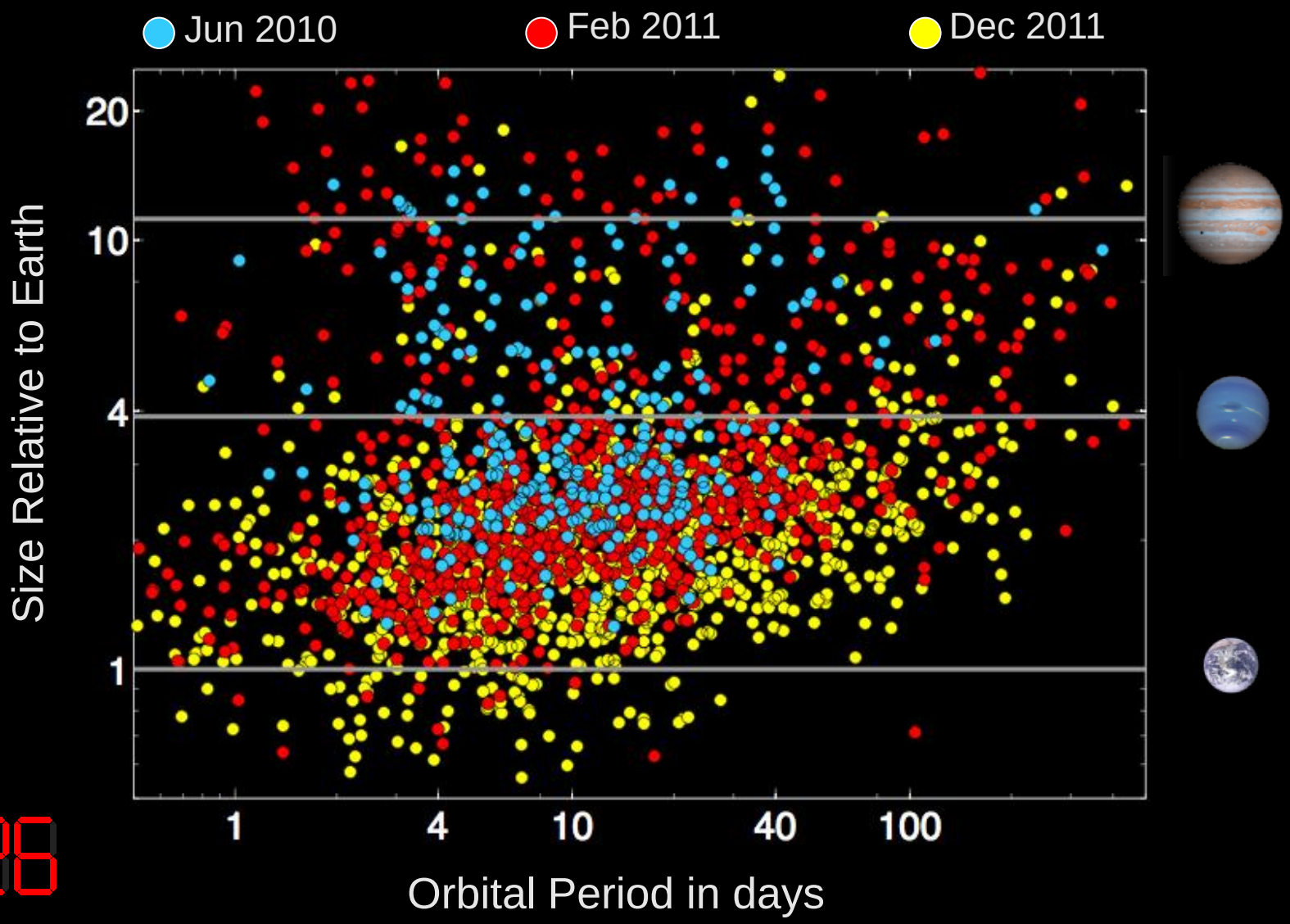
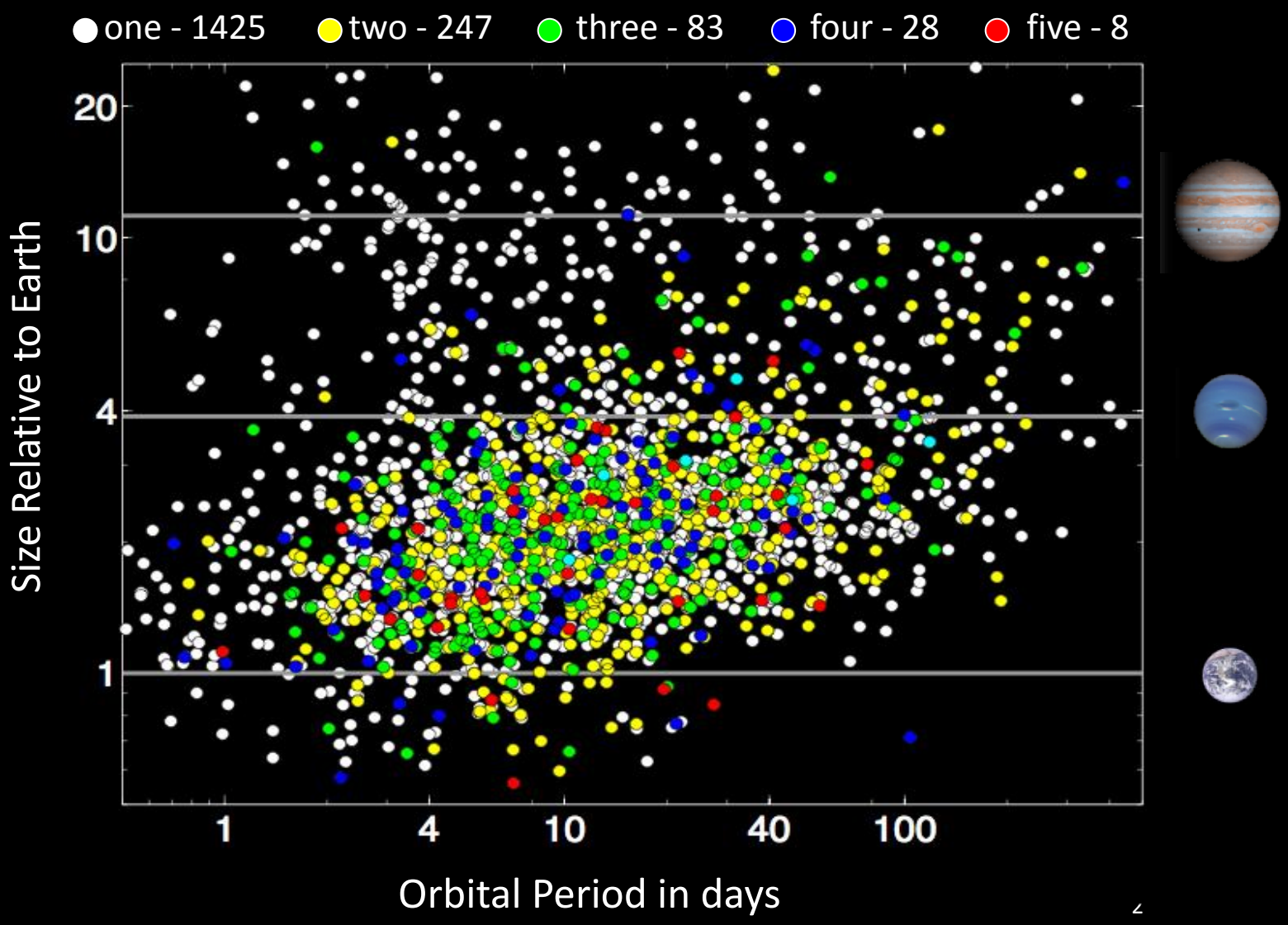
Masses for Kepler Planets

David W. Latham – Harvard-Smithsonian Center for Atrophysics



2388

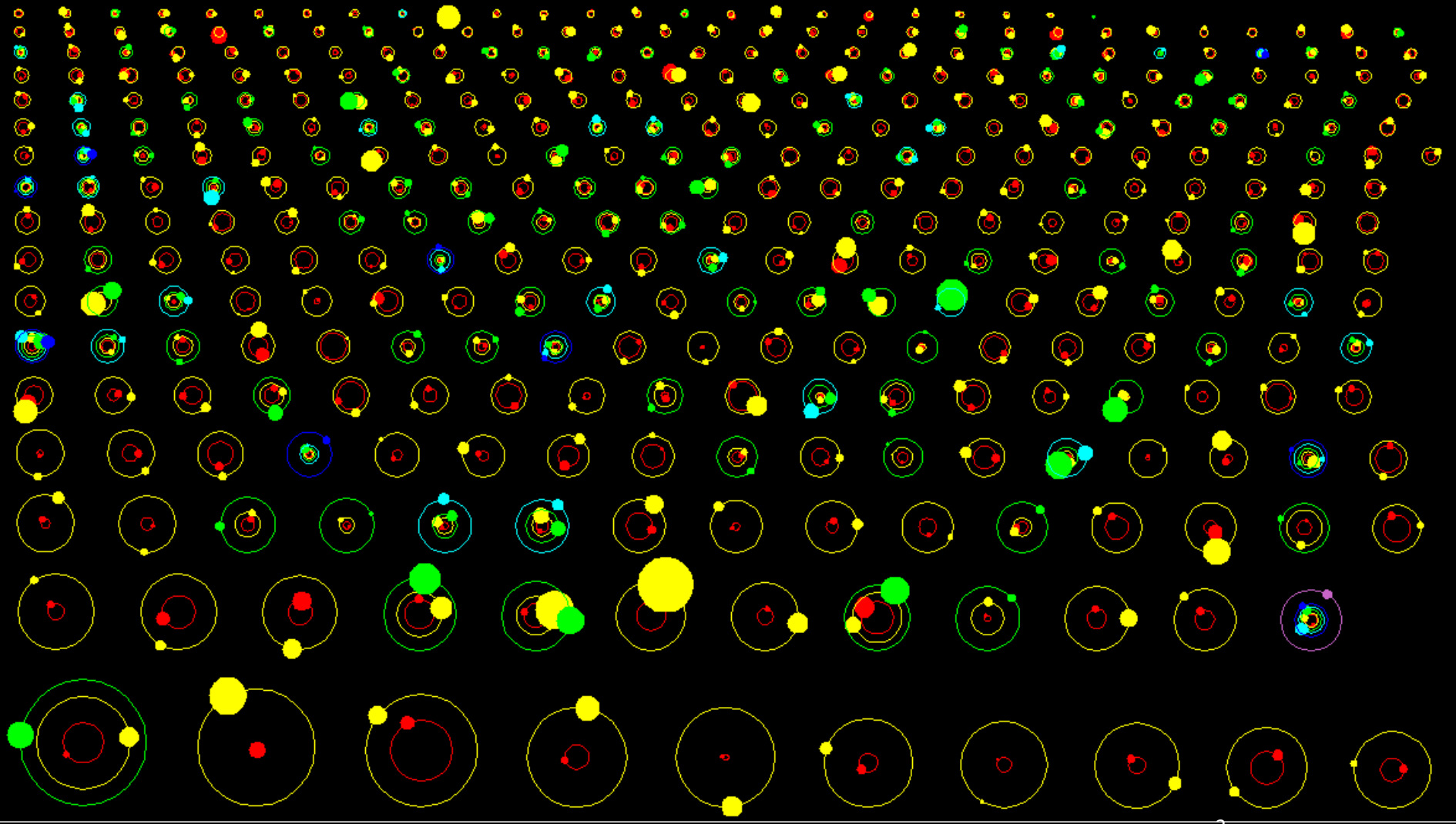
The Multiples

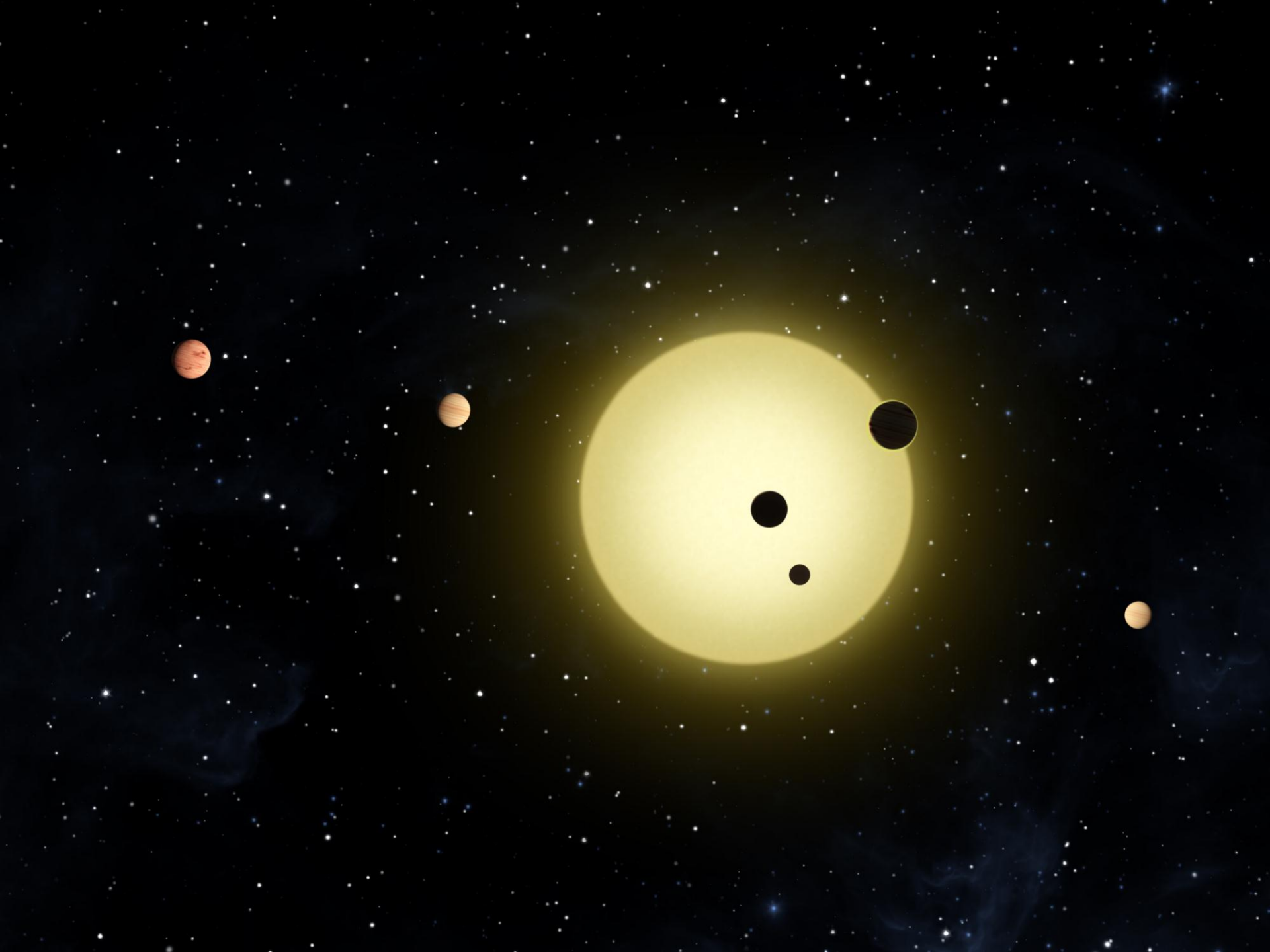


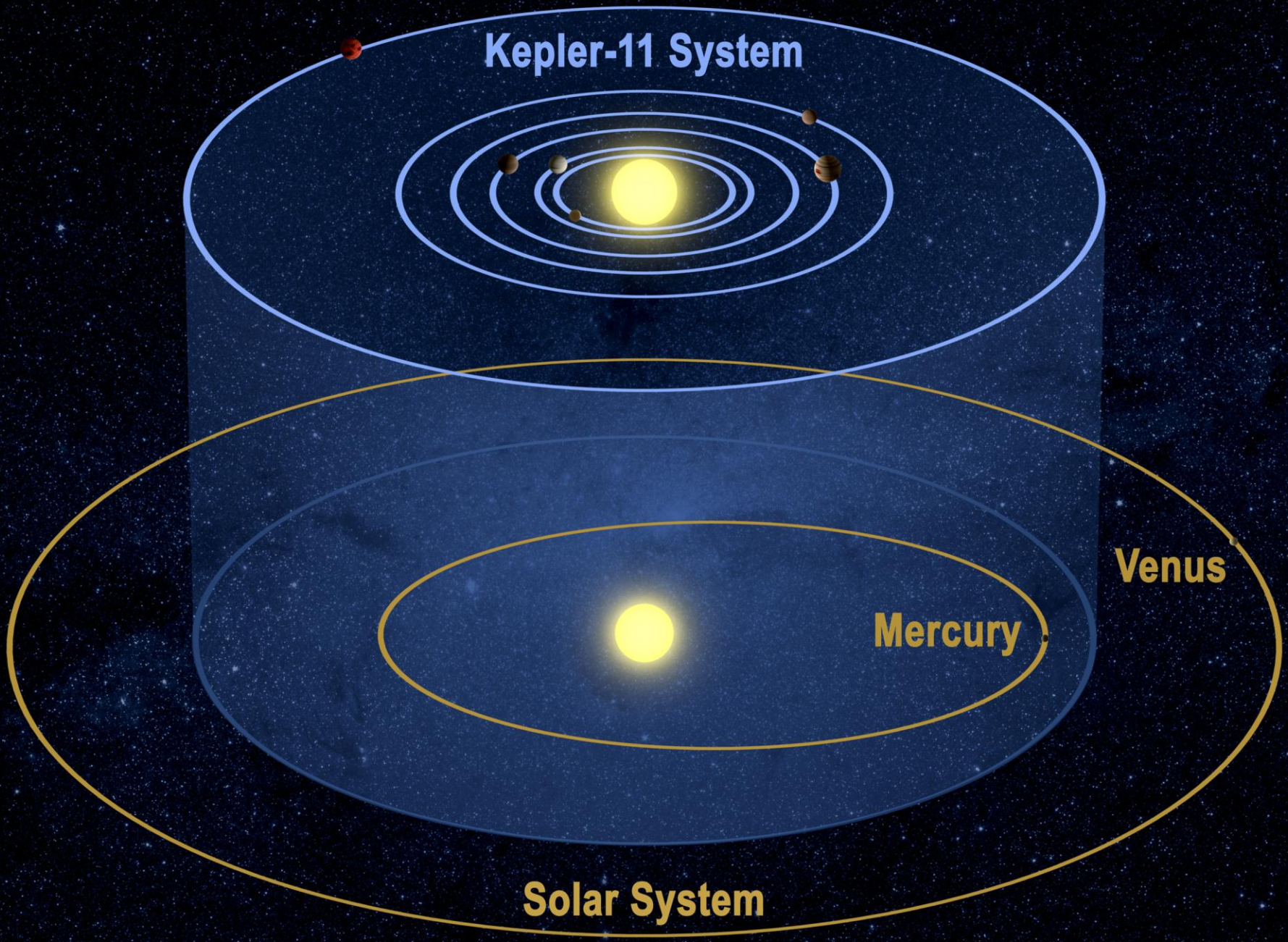
The Kepler Orrery II

t[BJD] = 2455879

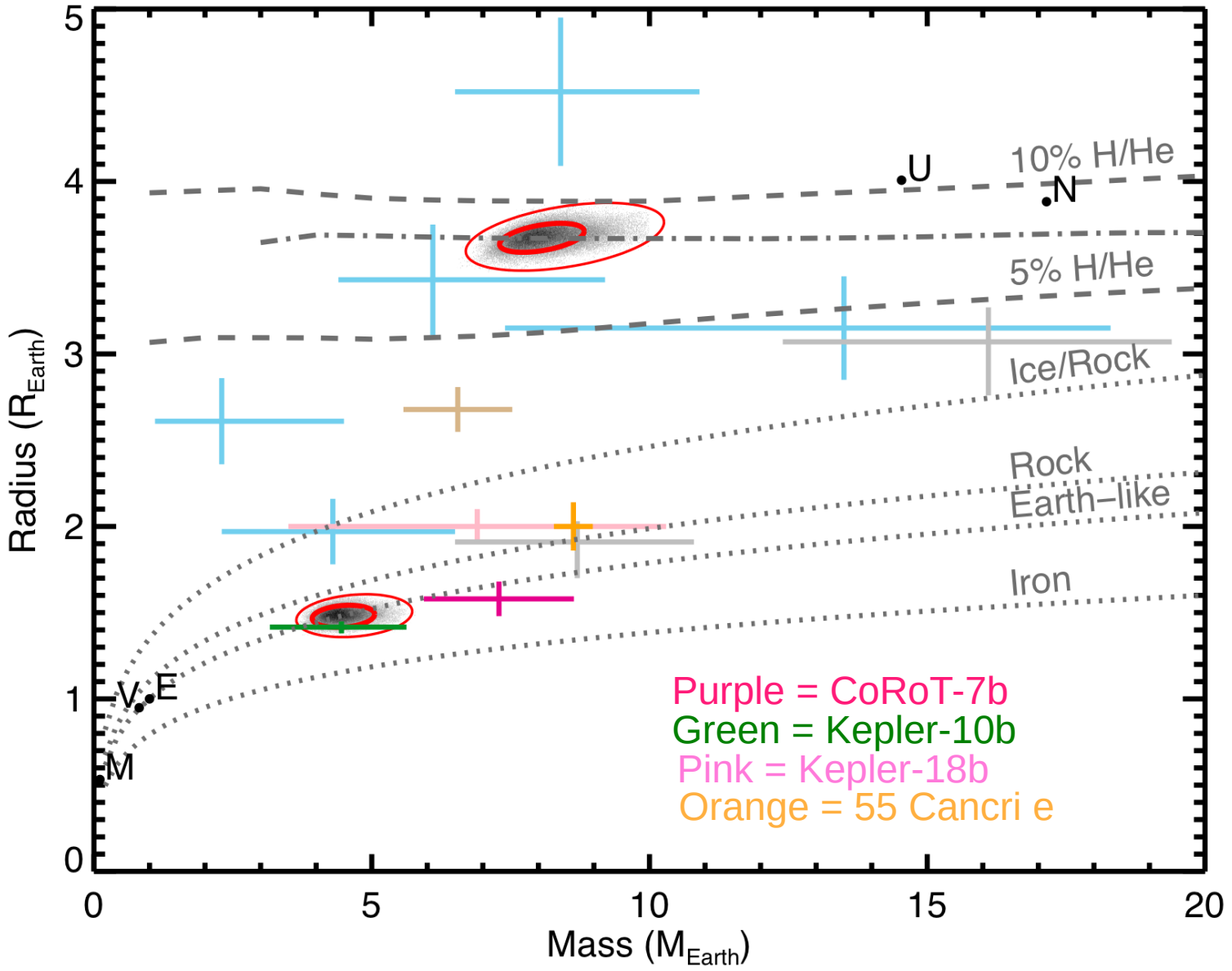
D. Fabrycky 2012



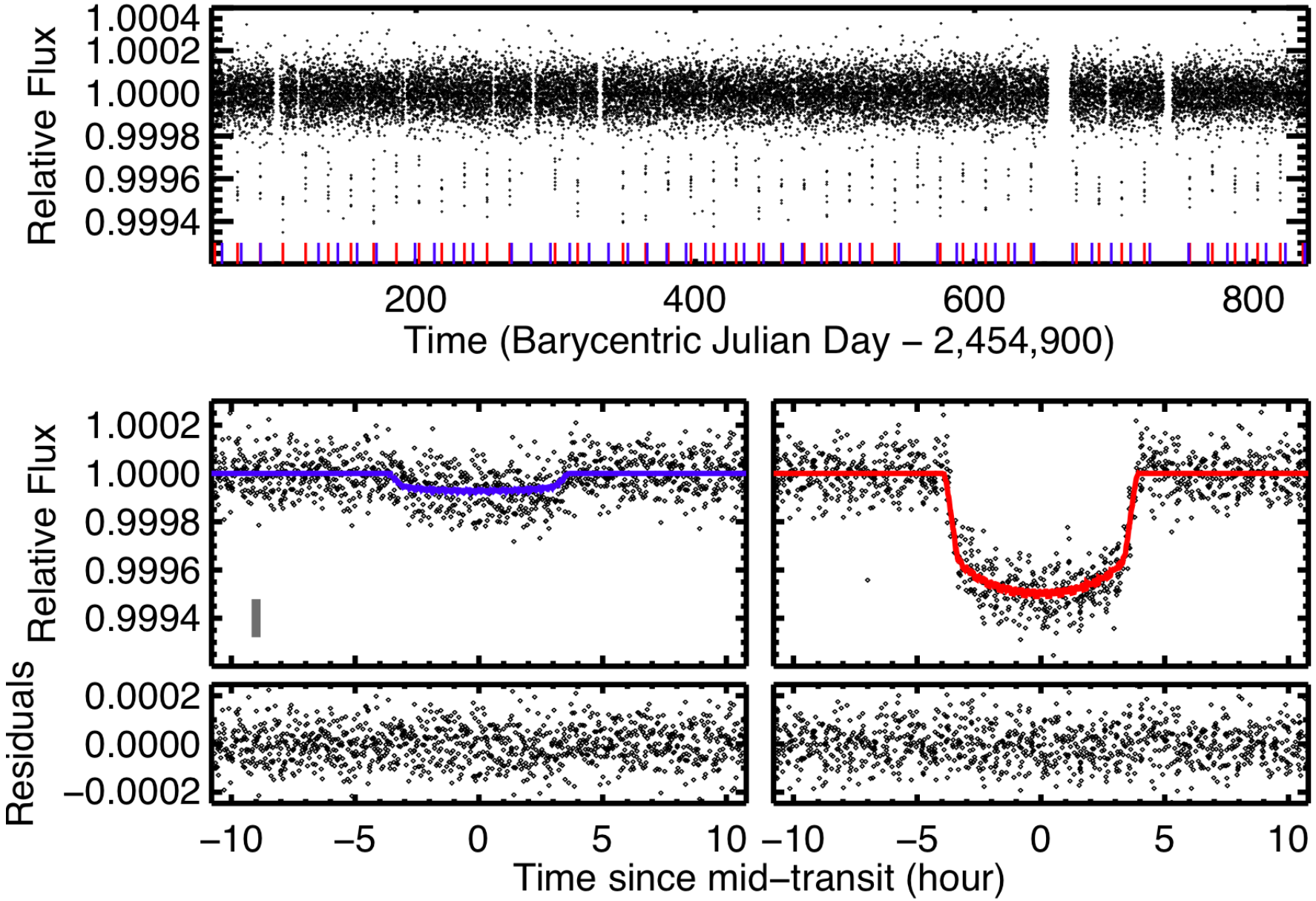



Kepler-11 System
Venus
Mercury
Solar System

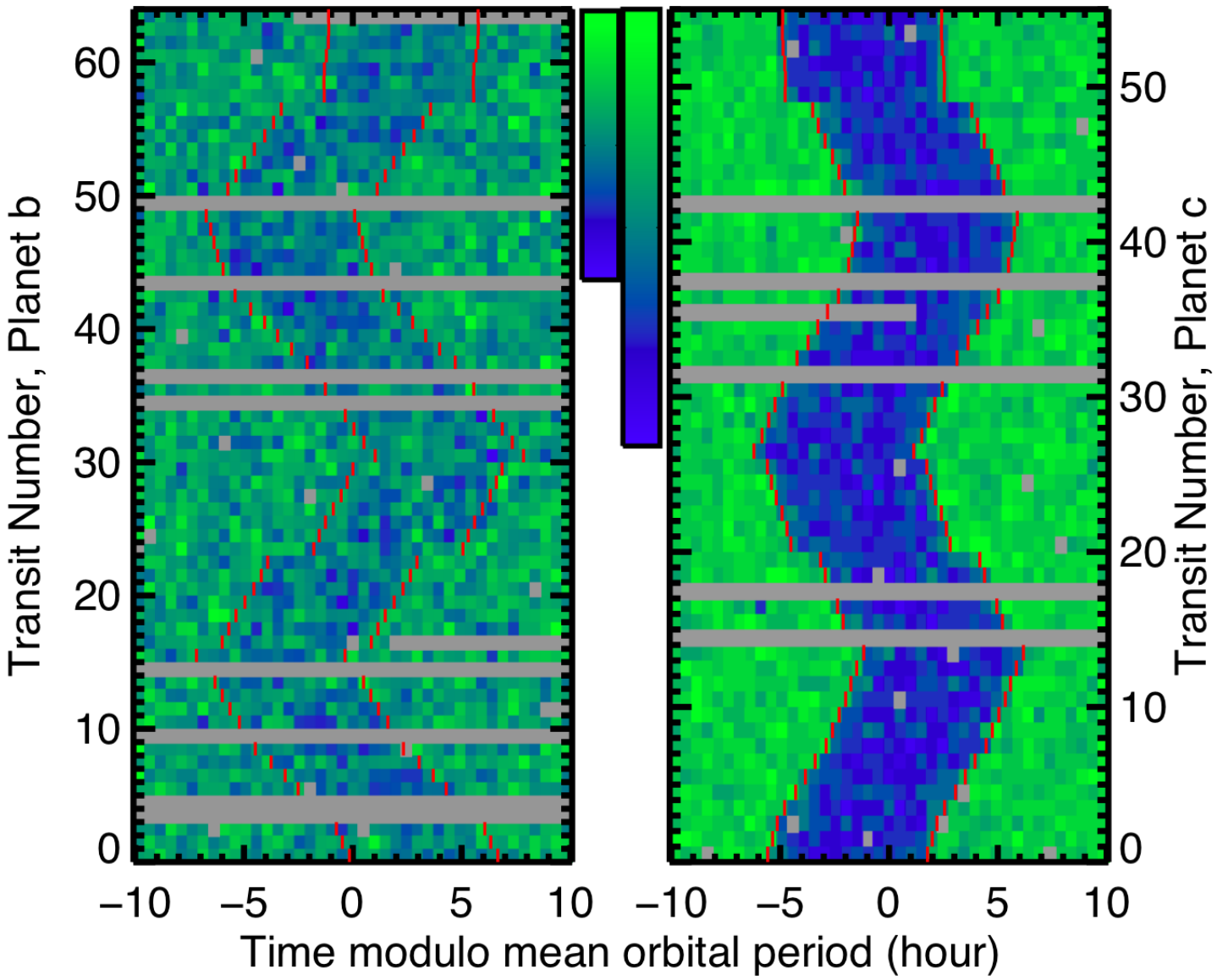
Five Kepler-11 planets with TTV masses in blue

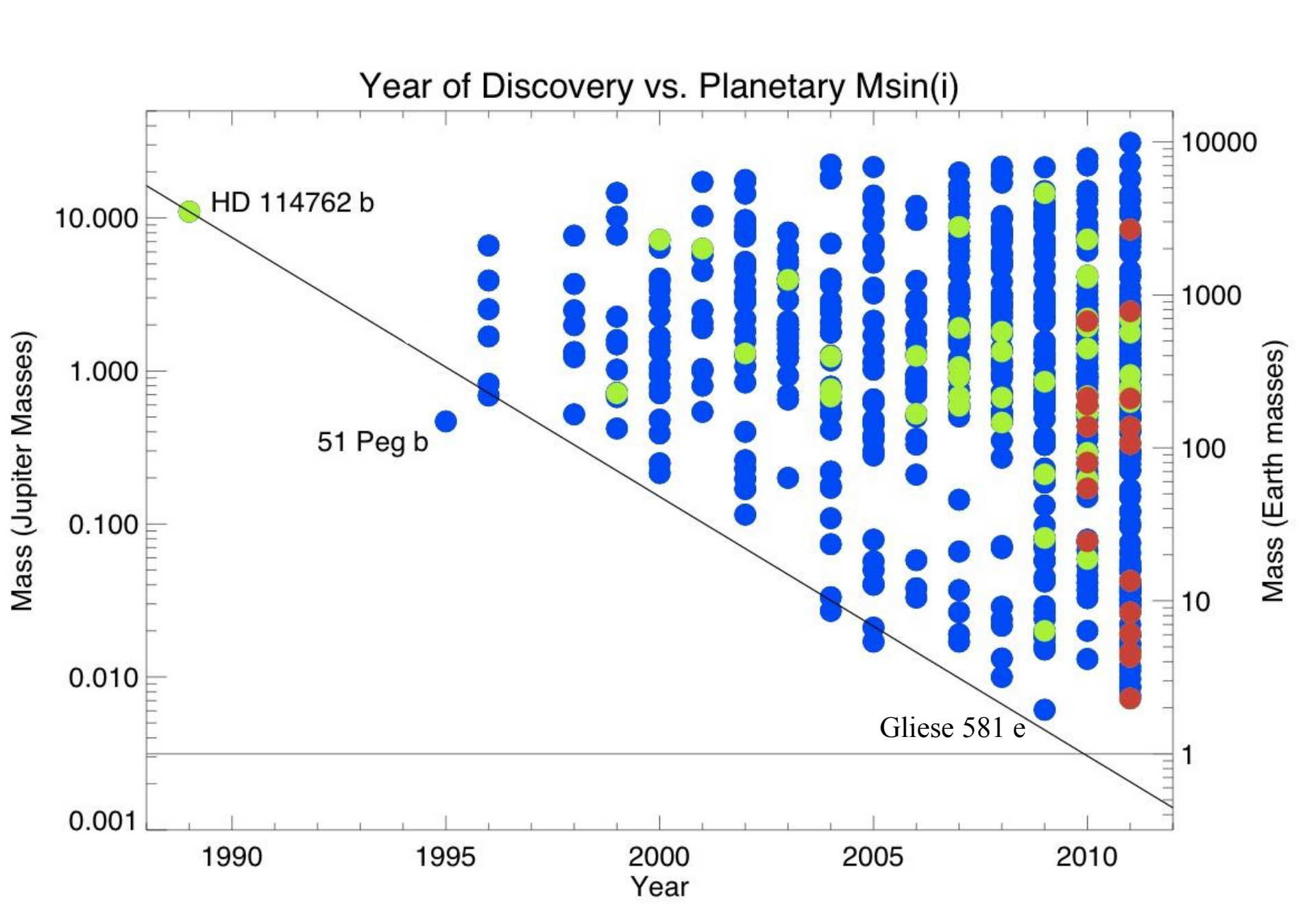


Kepler 36: P_b = 13.84, P_c = 16.24 days; 6 to 7 resonance



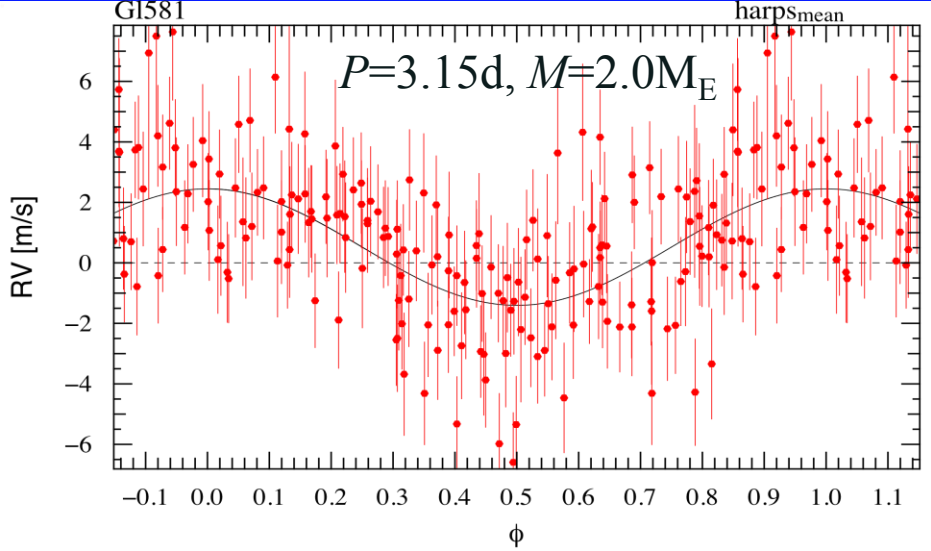
Anticorrelated transit time variations



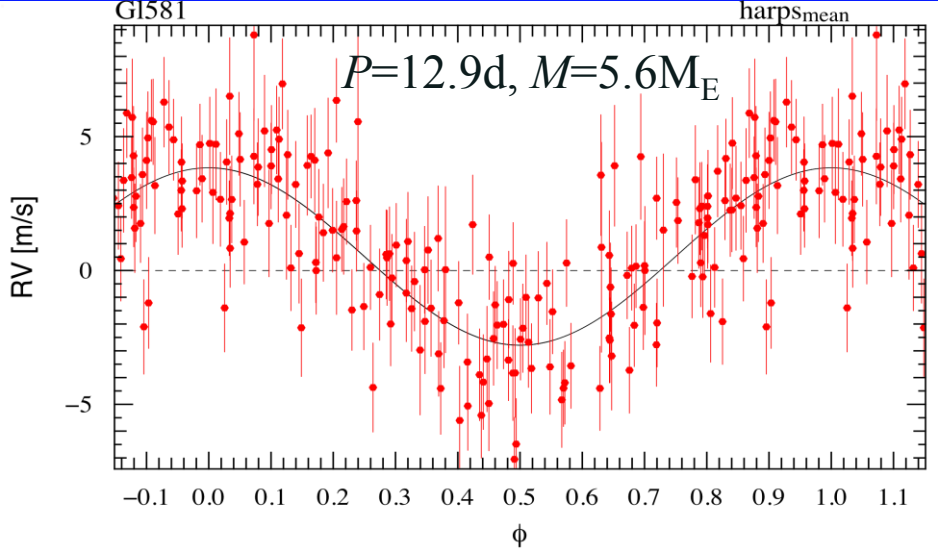


Green = CfA

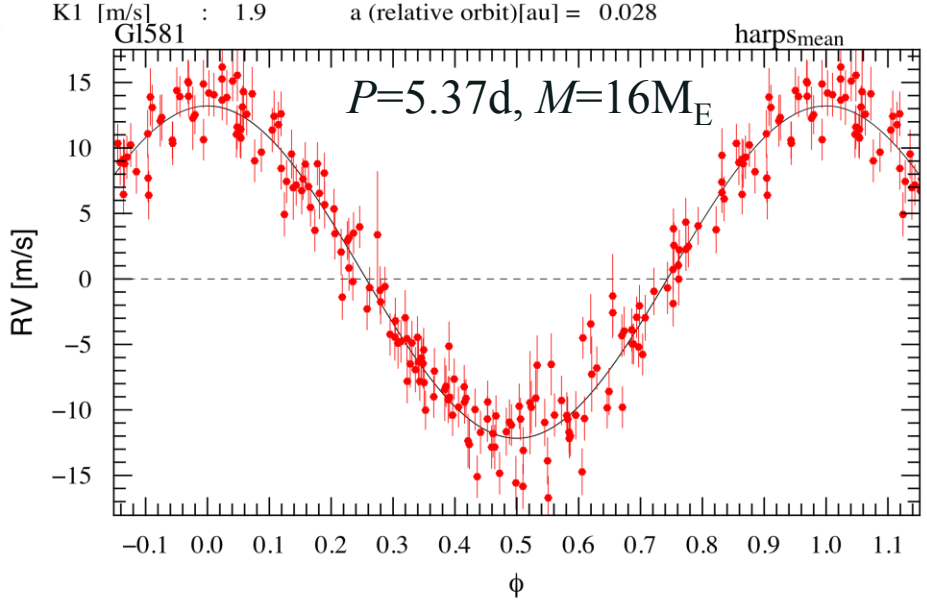
Red = Kepler



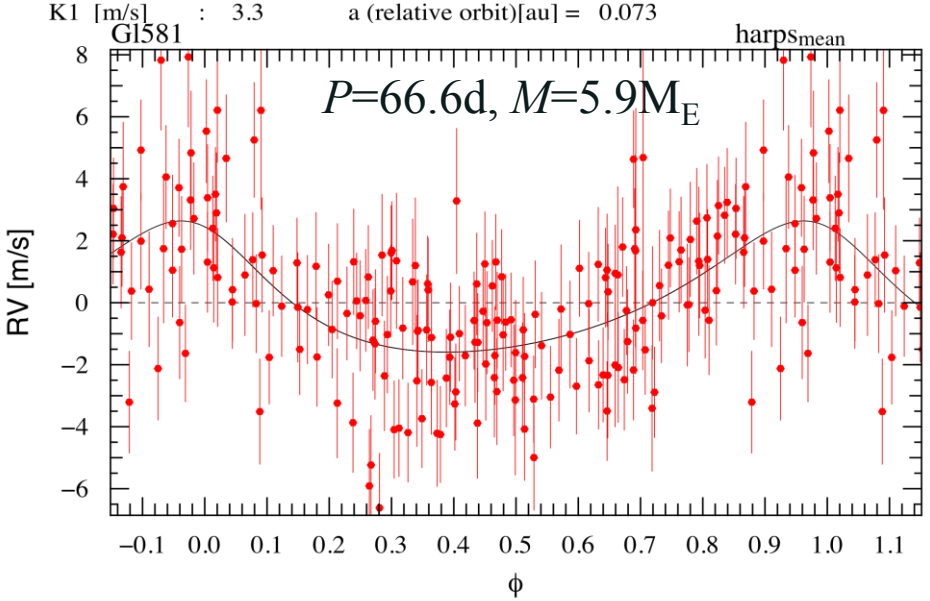
P [days] : 3.150 a$_1$.sin(i) [1E−3 au] = 0.00056
e : −0.000 f(m) [1E−9 Msol] = 0.00000
ω [deg.] : 0.0 m$_1$ [Msol]=0.31
phi$_0$: 54525.79 m$_2$.sin(i) = 0.00636[M$_{jup}$], 0.118[M$_{nept}$], 2.02[M$_{earth}$]
K1 [m/s] : 1.9 a (relative orbit)[au] = 0.028



P [days] : 12.917 a$_1$.sin(i) [1E−3 au] = 0.00393
e : −0.000 f(m) [1E−9 Msol] = 0.00005
ω [deg.] : 0.0 m$_1$ [Msol]=0.31
phi$_0$: 54529.76 m$_2$.sin(i) = 0.01752[M$_{jup}$], 0.324[M$_{nept}$], 5.57[M$_{earth}$]
K1 [m/s] : 3.3 a (relative orbit)[au] = 0.073



P [days] : 5.369 a$_1$.sin(i) [1E−3 au] = 0.00626
e : −0.000 f(m) [1E−9 Msol] = 0.00114
ω [deg.] : 0.0 m$_1$ [Msol]=0.31
phi$_0$: 54524.91 m$_2$.sin(i) = 0.05007[M$_{jup}$], 0.925[M$_{nept}$], 15.91[M$_{earth}$]
K1 [m/s] : 12.7 a (relative orbit)[au] = 0.041



P [days] : 66.641 a$_1$.sin(i) [1E−3 au] = 0.01248
e : 0.271 f(m) [1E−9 Msol] = 0.00006
ω [deg.] : 24.5 m$_1$ [Msol]=0.31
phi$_0$: 54538.75 m$_2$.sin(i) = 0.01861[M$_{jup}$], 0.344[M$_{nept}$], 5.92[M$_{earth}$]
K1 [m/s] : 2.1 a (relative orbit)[au] = 0.218

HARPS: Instrumental stability

⊗RV = 0.1 m/s

⇕

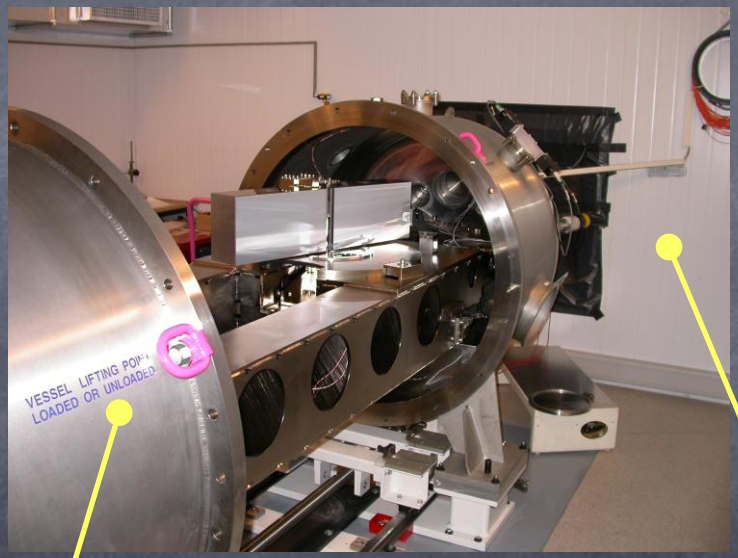
⊗λ = 0.000001 A

⇕

1.5 nm

⇕

1/10000 pixel



⊗RV = 0.1 m/s

⇕

⊗T = 0.001 K

⇕

⊗p = 0.001 mBar

Vacuum operation

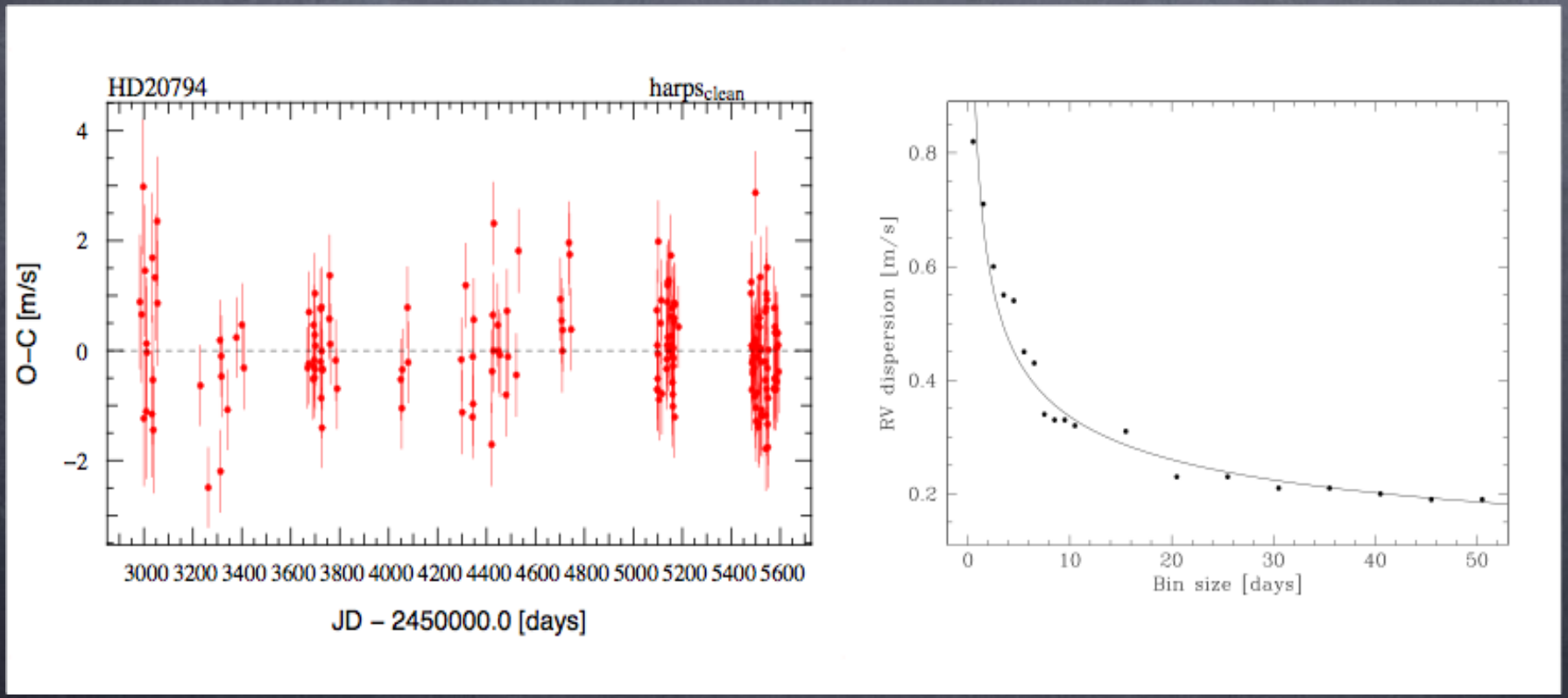
Temperature control

HARPS Rocky Planet Search

Francesco Pepe PI

10 quiet FGK dwarfs, 3x15min visits/night

50 nights/season, 2-3 seasons



But HARPS is on the ESO 3.6

Kepler stares at Cygnus/Lyra

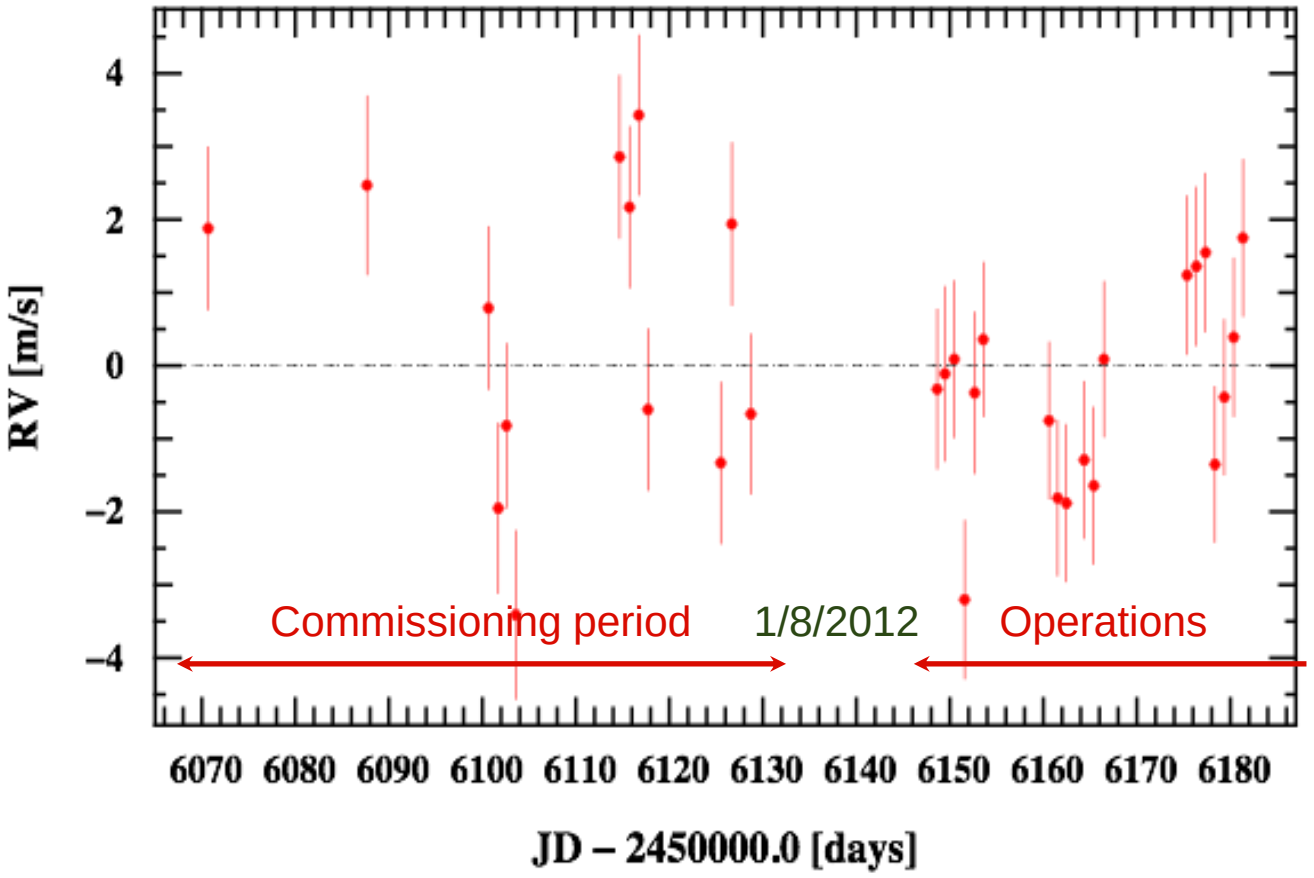

HARPS-N Collaboration:
Geneva, CfA, UK, INAF-TNG

Guaranteed Time Program

- 80 nights/year for five years, two projects
  - Follow up of small KEPLER candidates
  - Rocky Planet Search: 10 nearby, bright, quiet FGK dwarfs
- Science Team: 16 Co-Is plus collaborators
  - Manage program, target selection, observing, publications
- HARPS-N time open for proposals from the community via the INAF TAC

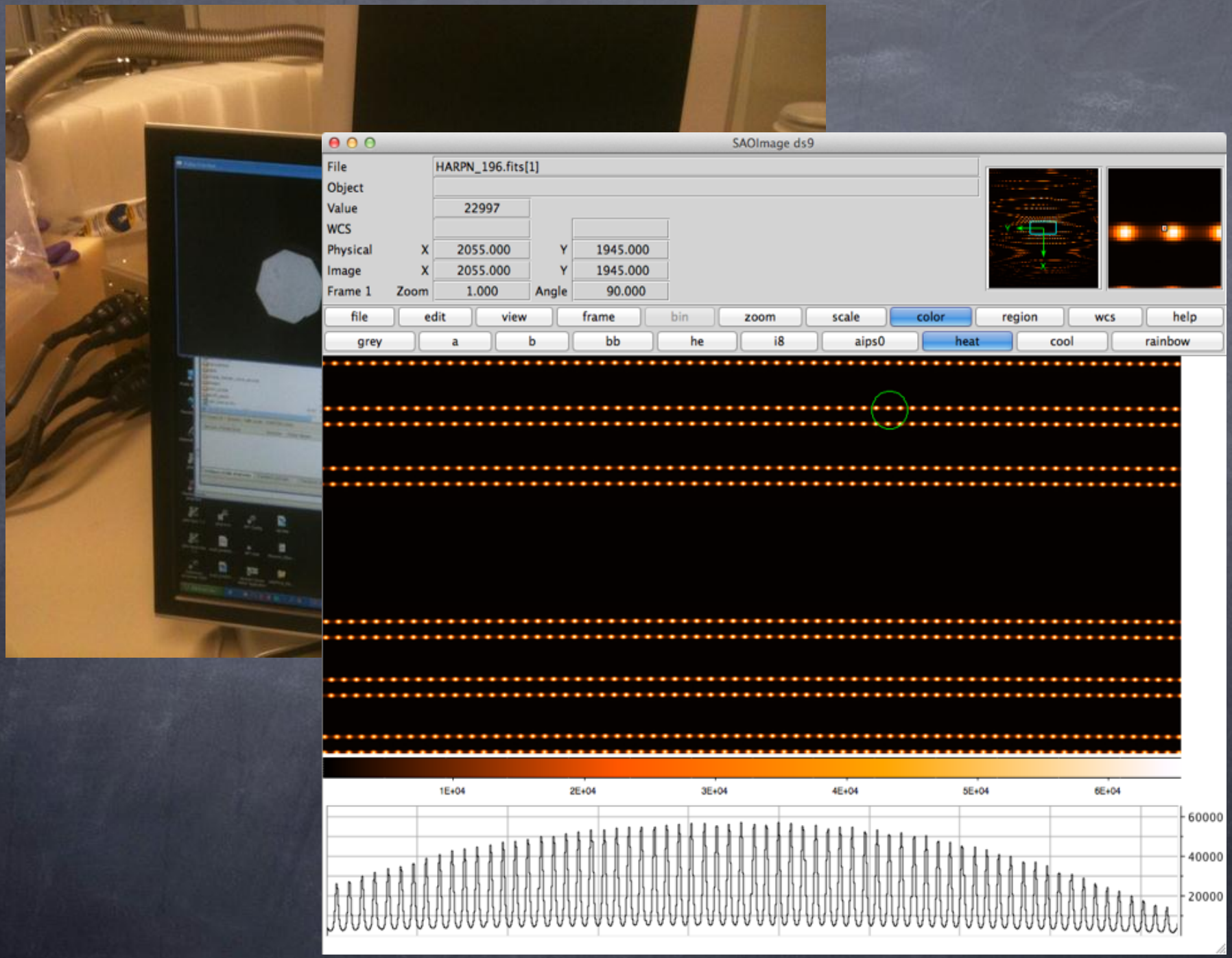
HARPS-N first light April 2012

‘Early-days’ RV performance



New in HARPS-N vs HARPS

- Octagonal fibers
- 4Kx4K E2V CCD
- Ultra-stable Fabry-Perot for simultaneous wavelength calibration, monitored with a laser frequency comb (to come)

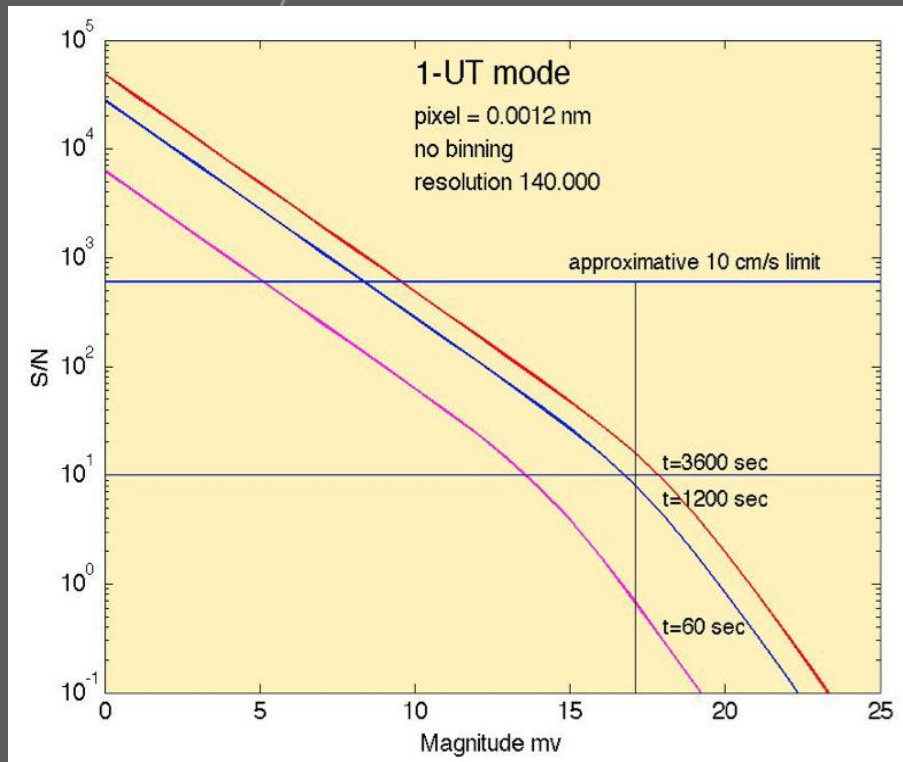

SAOImage ds9
File
HARPN_196.fits[1]
Object
Value
22997
WCS
Physical X 2055.000 Y 1945.000
Image X 2055.000 Y 1945.000
Frame 1 Zoom 1.000 Angle 90.000
file edit view frame bin zoom scale color region wcs help
grey a b bb he i8 aips0 heat cool rainbow
1E+04 2E+04 3E+04 4E+04 5E+04 6E+04
60000
40000
20000

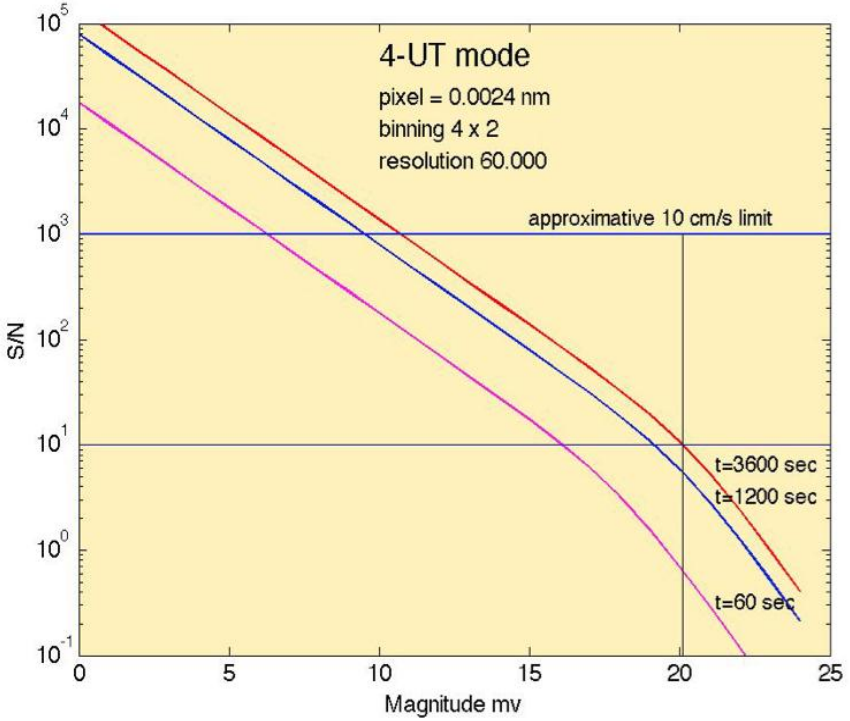
ESPRESSO

Next generation ‘HARPS’ for ESO VLT

10 cm/s precision
1 or 4 Unit Telescope modes
Commissioning 2016
Switzerland, Portugal, Spain, Italy, ESO

ESPRESSO performances





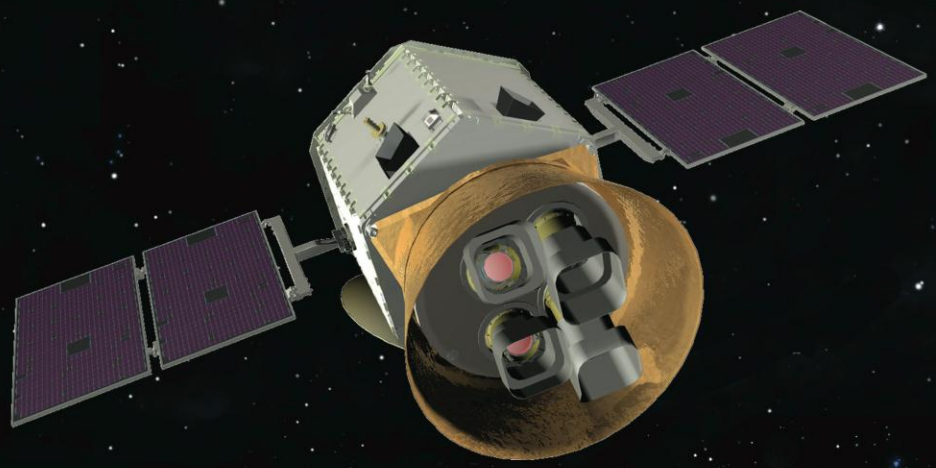
Explorer Proposal

Tess

Transiting Exoplanet Survey Satellite

Dr. George R. Ricker, PI, MIT

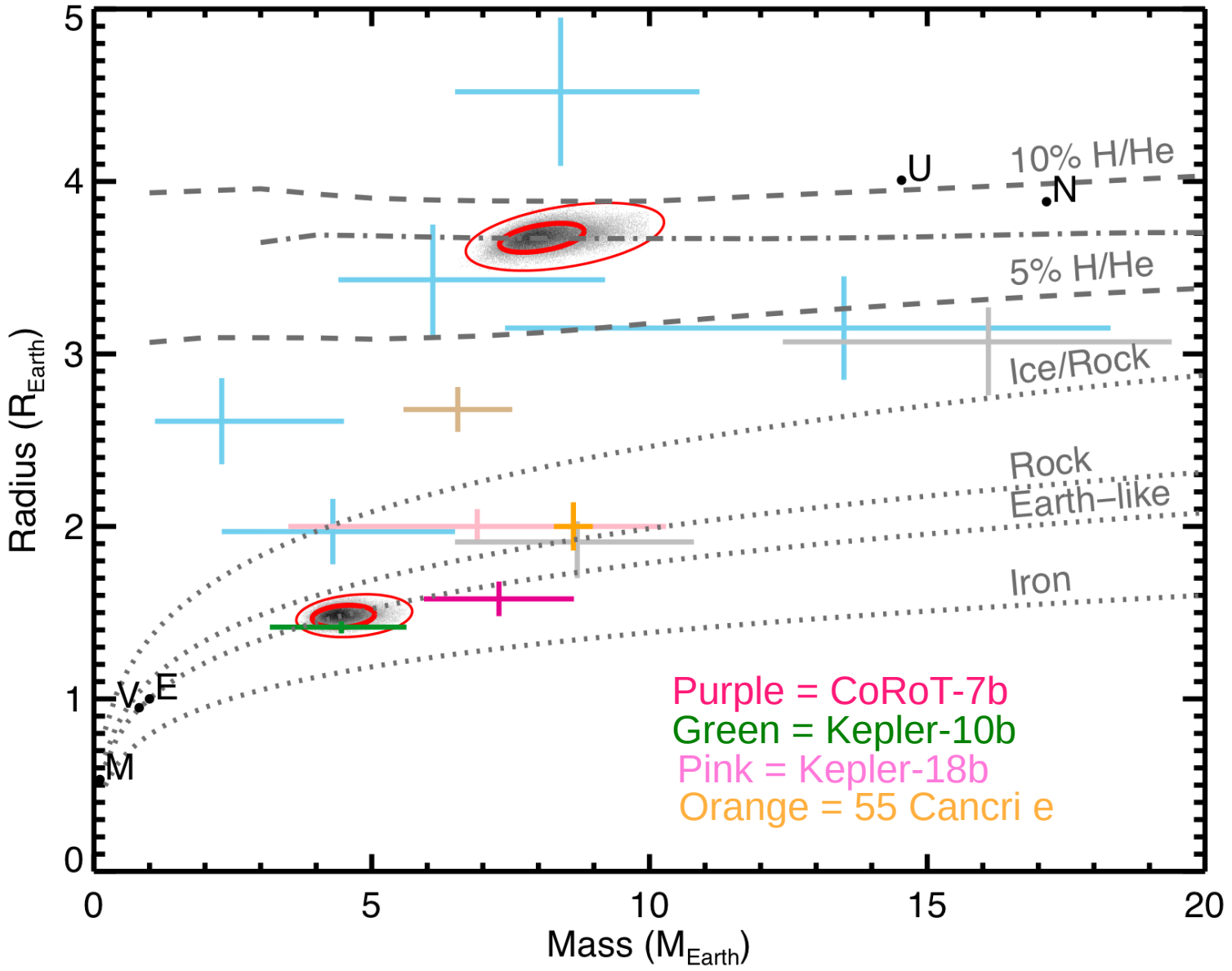
[redacted]

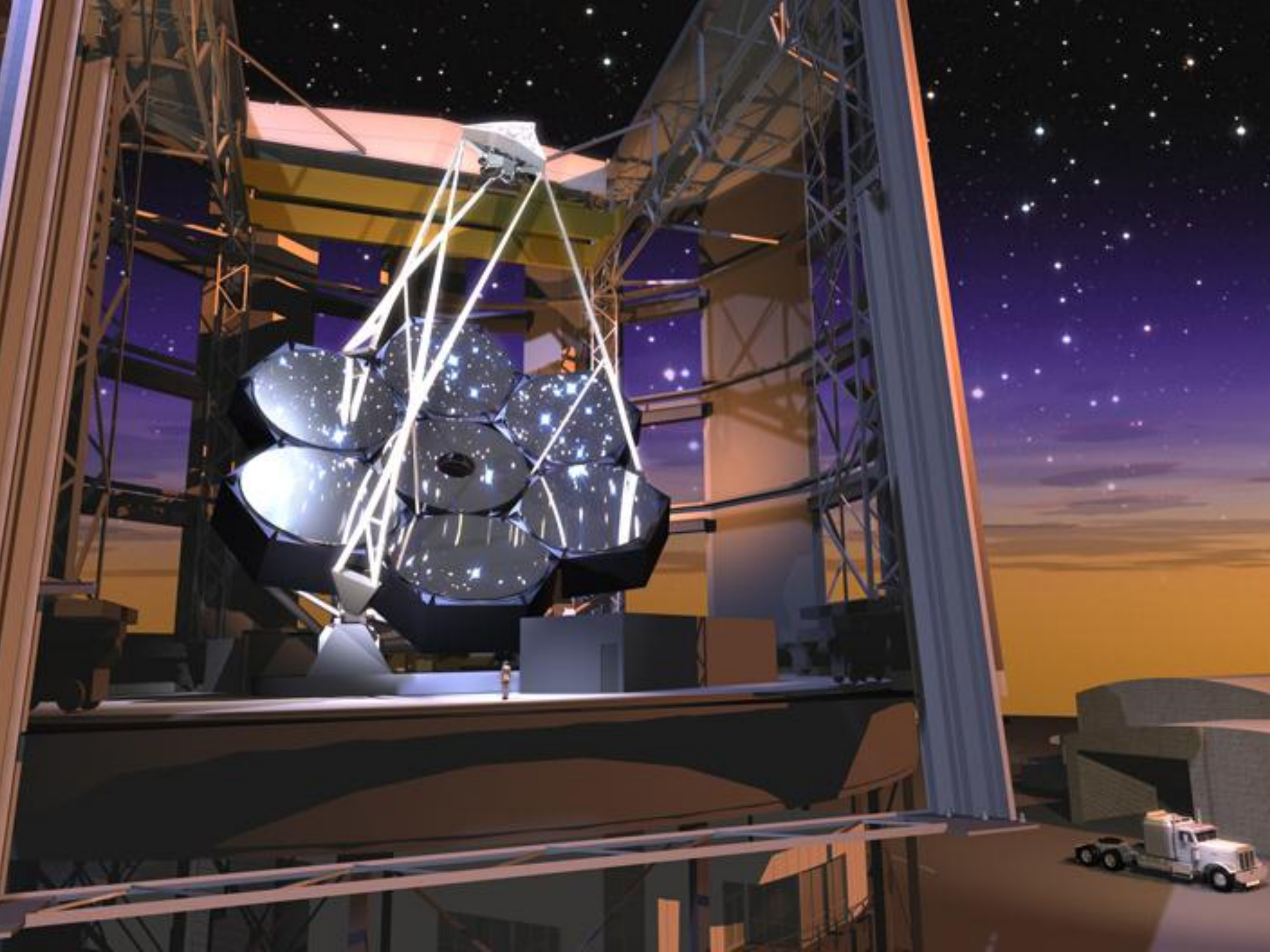


Submitted in Response to NNH11ZDA002O

Concept Study Report
submitted 20 Sep 2012

Five Kepler-11 planets with TTV masses in blue





System characteristics

Parameter	*singleUHR*	*singleHR*	*multiMR*
Wavelengths		Blue arm: 380 – 520 nm Red arm: 520 – 780 nm	
Spectral coverage		Full	
Spectra format	Up to 4 spectra per order (2 fibers, 2 spectra / fiber)		
Resolving power	200’000	130’000	55’000
Aperture on sky	0.5 arcsec	1.0 arcsec	4x1.0 arcsec
Spectral sampling	>2 pixels	>3.5 pixels	>4 pixels (binned x 2)
Spatial sampling	>4 pixels	>8 pixels	>5 pixels (binned x 4)
Sky/Simultaneous reference		Yes (mutually exclusive)	
Instrumental RV precision	<10 cm/s	<10 cm/s	<1 m/s