Jet Propulsion Laboratory
California Institute of Technology

ATST Exoplanet Science

Wesley Traub
Exoplanet Exploration Program

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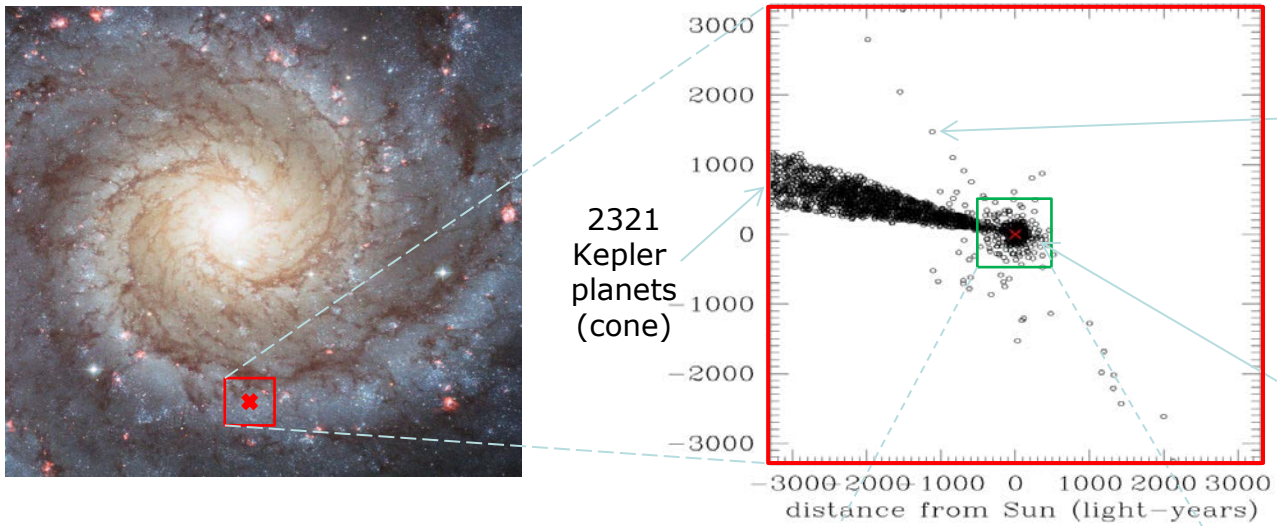
Kepler today, nearest neighbors tomorrow



17 Corot planets (pencils)

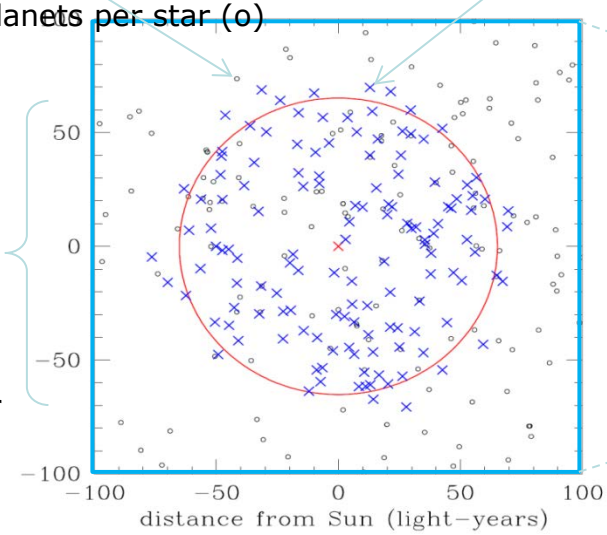
2321 Kepler planets (cone)

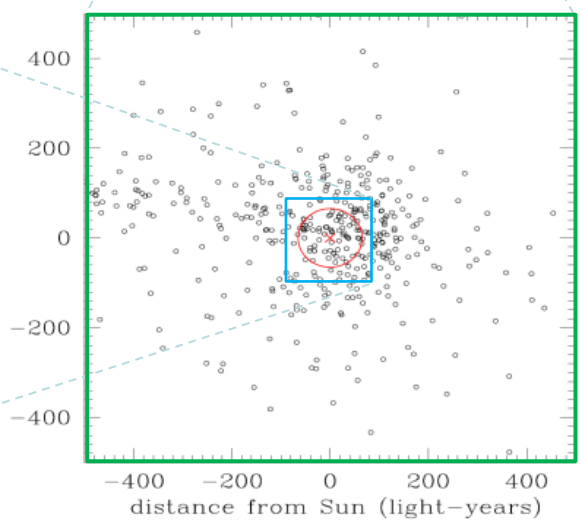
471 RV, transit & imaging, +36 HAT +13 WASP planets (cloud)

Already known planetary systems 1-4 planets per star (o)

136 TPF-C target stars (x)

prime hunting grounds for direct imaging & astrometry missions





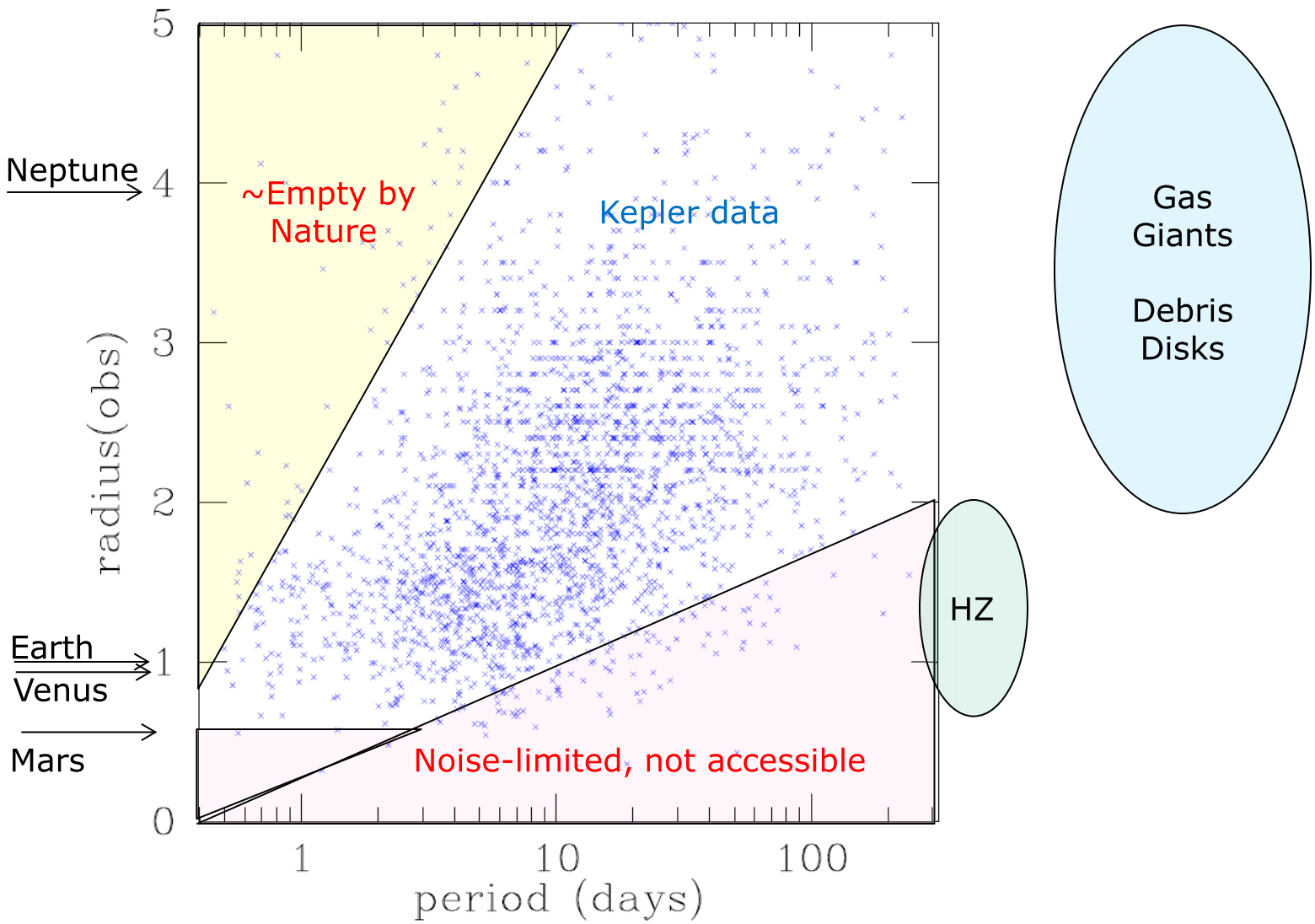
Exoplanet science by 2030

- 2009-2013: Kepler gets statistics of planets out to ice line
- 2024-2030: AFTA grav. microlensing gets statistics of planets beyond ice line
- 2024-2030: AFTA coronagraph finds & characterizes gas giants & disks beyond ice line, around nearby stars, and *perhaps* a super-Earth if all goes well

- 2030…: Big questions will be "are there Earths, where, how many, what type, any signatures of habitability, any signs of life, how related to full system, where are the zodi and Kuiper belts, how bright are they, are there unseen planets, how do these all interact, …" ?

- Will need a 4-16-m telescope to answer some or all of these.

Exoplanet data today, & possibilities for tomorrow



Eta-Earth

- 2011: Catanzarite & Shao estimated 1-3% from early Kepler data
- 2012: Traub estimated 34 ± 14%, same data
- 2013: Gaidos estimates 46 (± 16) %, from newer Kepler data
- 2013: Dressing & Charboneau est. 15% for M dwarfs from Kepler
- 2013: Kopparapu revised that up to 48 % with new HZ definition
- 2013: Bonfils etal estimate 41% for M dwarfs from RV
- 2013: Traub TBD, from current Kepler data

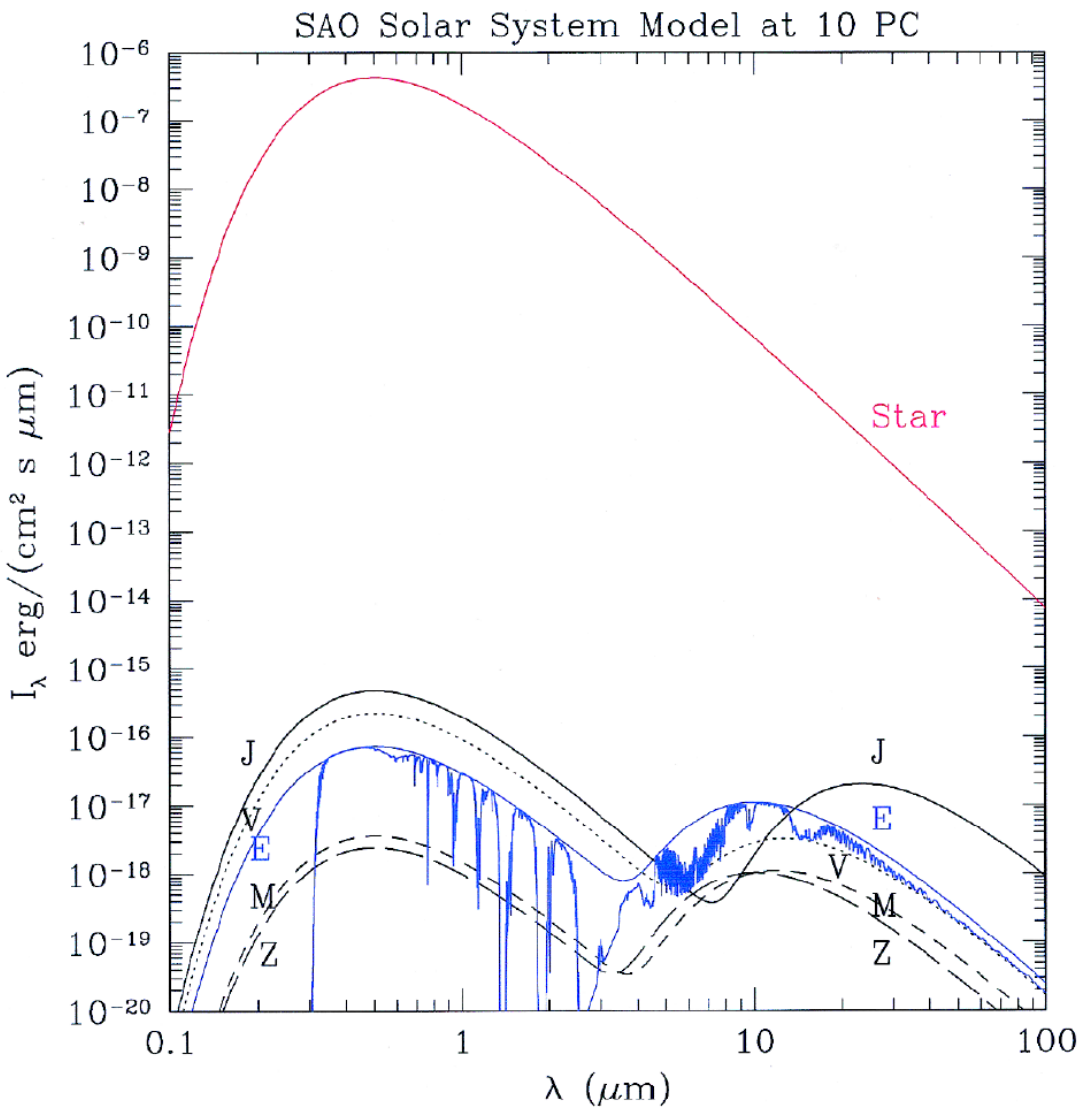
ATST requirements ~ ATLAST requirements, updated

Table 1. ATLAST Science Flowdown Requirements for Biosignature Detection on Exoplanets

Science Question	Science Requirements	Measurements Needed	Design and Implementation
Is there life elsewhere in the Galaxy?	Detect at least 10 Earth-like Planets in HZ with 95% confidence if $\eta_{EARTH} = 0.15$	High contrast (ΔMag>25 mag) SNR=10 broadband (R=5) imaging with IWA ~ 40 mas for ~100 target stars.	At least 8 m PM aperture to achieve sample size (~100 stars) and the desired SNR spectra in <500 ksec for most distant (~25 pc) exoplanets in the sample. Stable 10^{-10} starlight suppression on detector at IWA. 0.1 nm WFE at 0.6 µm over 2 hr; ~1.3 to 1.6 mas pointing stability. **IFU** with sensitivity from 0.3 to 2.4 µm, with broadband imaging and two spectroscopic modes (R=70, R=500).
	Detect the presence of habitability and bio-signatures in the spectra of Earth-like HZ planets	High contrast (ΔMag>25 mag) SNR=10 low-resolution (R=70-100) spectroscopy with an IWA ~ 40 mas. Exposure times <500 ksec.	

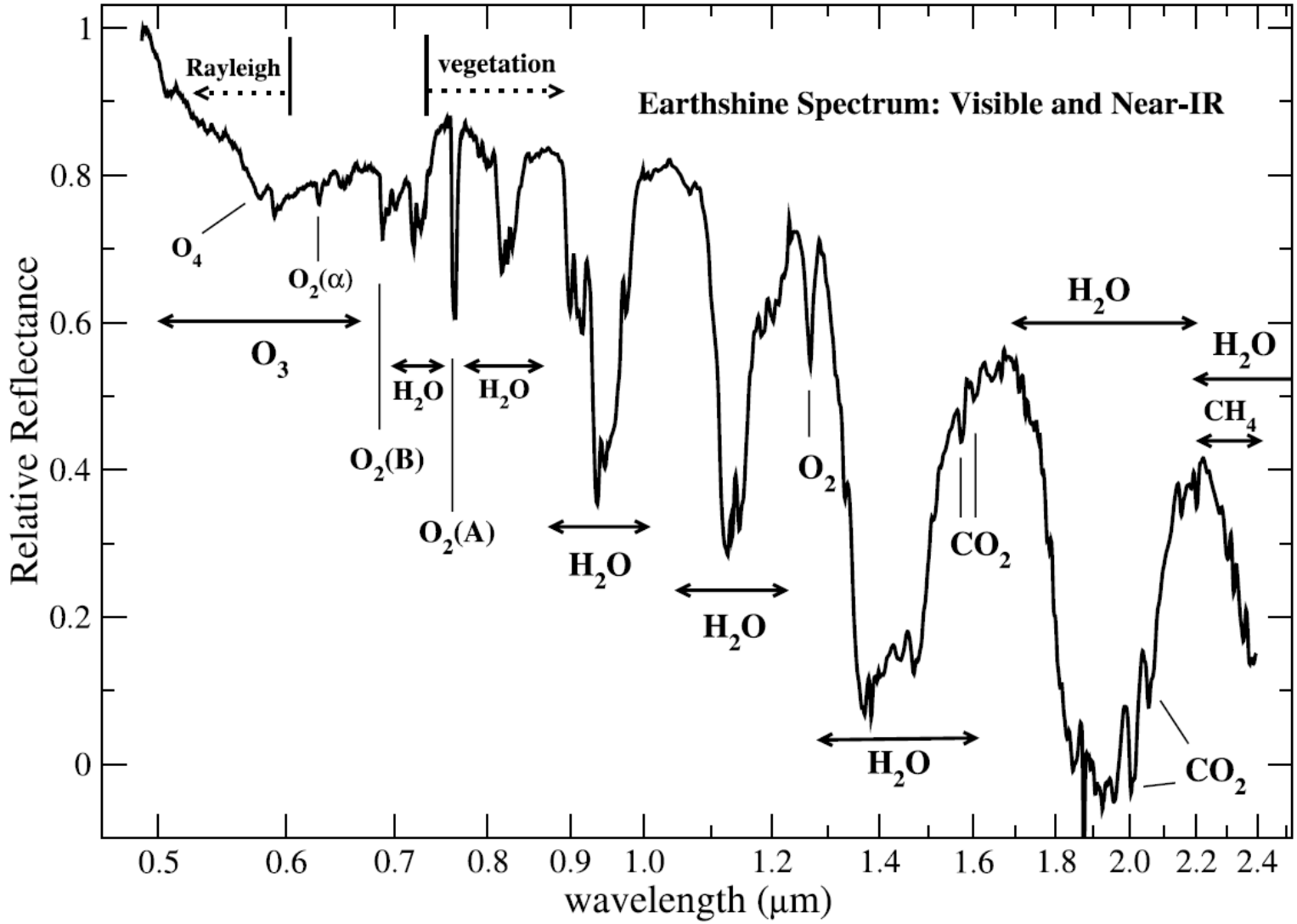
Postman et al., 2010

Earth model in visible and thermal infrared



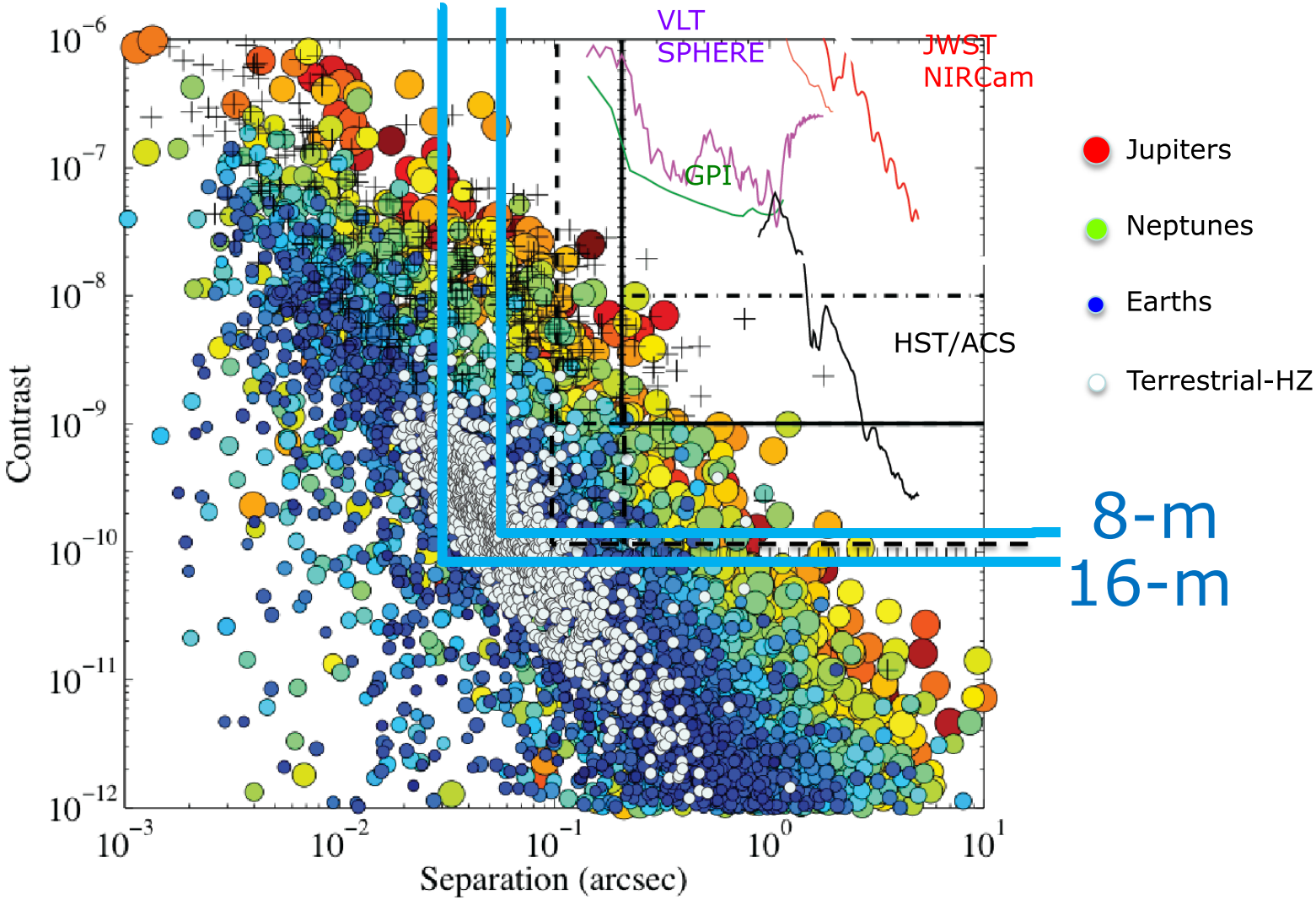
Des Marais et al., 2002

Spectrum of Earth: example



Turnbull, Traub, et al., 2006

AFTA modified to show Earths and 8-16-m ranges



AFTA Final Report 2013, for 2.4-m, modified by Traub & Lawson