Exo-solar Planets Science with GSMT

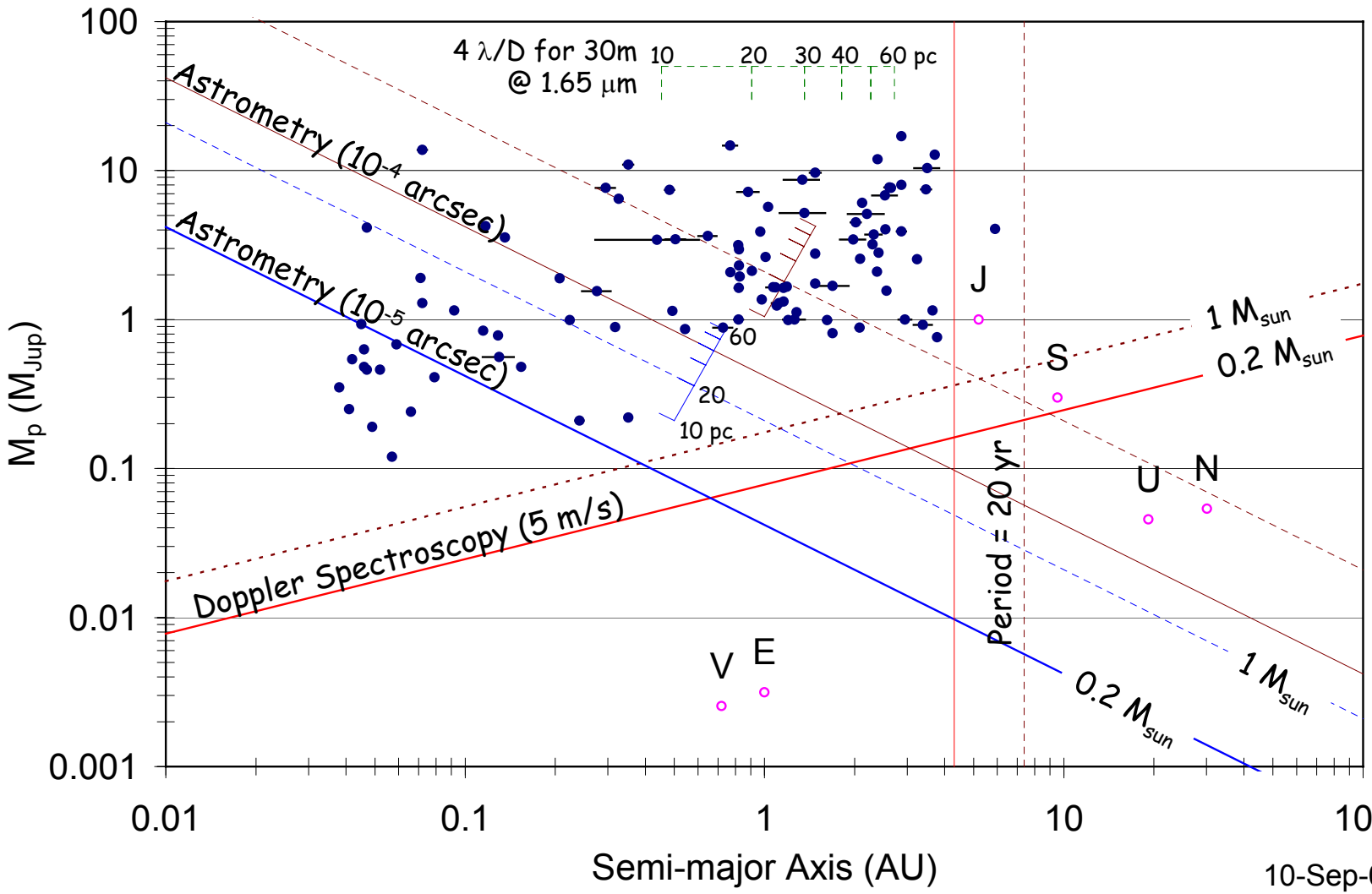
Terry Herter

Exo-solar Planet Science with GSMT

- Doppler Spectroscopy (lower stellar masses)
  - m_v = 13.5 vs. m_v = 11 for Keck (30 nearby stars)
  - Can observe 0.15 M_{sun} => 0.04 M_J (13 M_{Earth}) detectable
- Photometric Direct detection
  - Reflected light and/or thermal emission
  - Orbital size and inclination $\Rightarrow$ planet mass
  - Radii (using transits or albedo & luminosity)
- Spectroscopy
  - Composition (atomic, molecular, solids)
  - Weather (clouds) and Rotation
- Will involve AO (young planets) and/or EAO
  - Some form of coronagraphy, apodization, and/or nulling techniques with possibly differential techniques (in and out of spectral bands, etc.)

Current Status

- Approximately 100 exo-solar planets have been indirectly detected via Doppler spectroscopy
  - Range in mass from 0.1 – 17 M_{Jup} at distances from 0.04 – 6 AU.
  - Angular separations from 0.001 to 1 arcsecond.
- One transiting system (HD 209458b)
  - a = 0.05 AU, M = 0.69 M_J, R = 1.39 R_J
  - Possible detection of change in size in Na doublet.



Discovery space for exo-solar planets around stars of 0.2 and 1 M_{sun}. Lines for signatures of 10^{-4} and 10^{-5} arcsec for astrometry (at 10pc) and 5 m/s for radial velocities (sin i = 1). Also shown are the 10–60 pc limits for astrometry and resolution (4λ/D) of a 30-m telescope at 1.65 μm. Included are currently detected exo-solar planets (exoplanets.org). This is updated version of figure 3.1 of TOPS report (1992).

51 Peg A and B

G5V star
d = 15.4 pc

M_p = 0.46 M_J
a = 0.052 AU

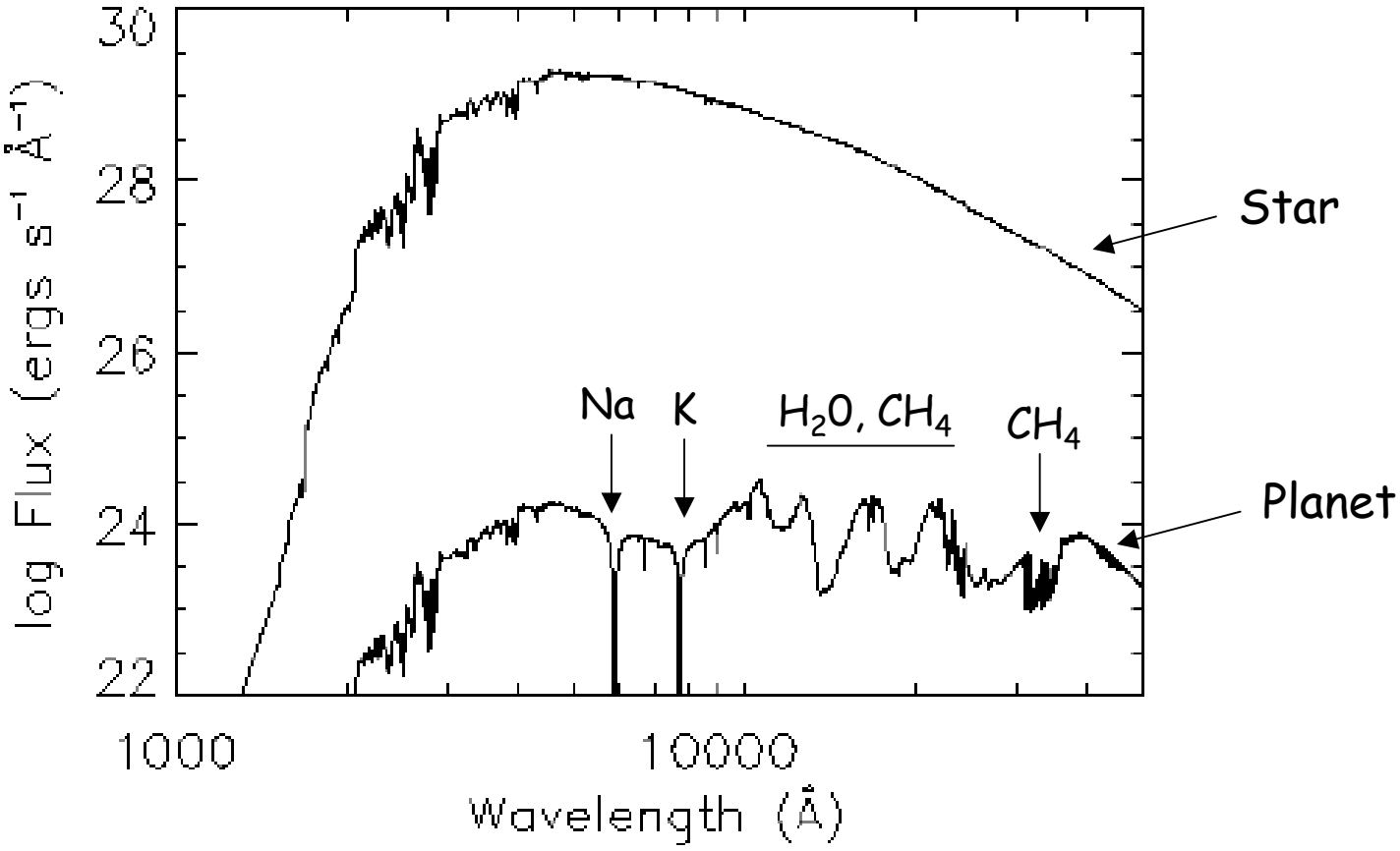
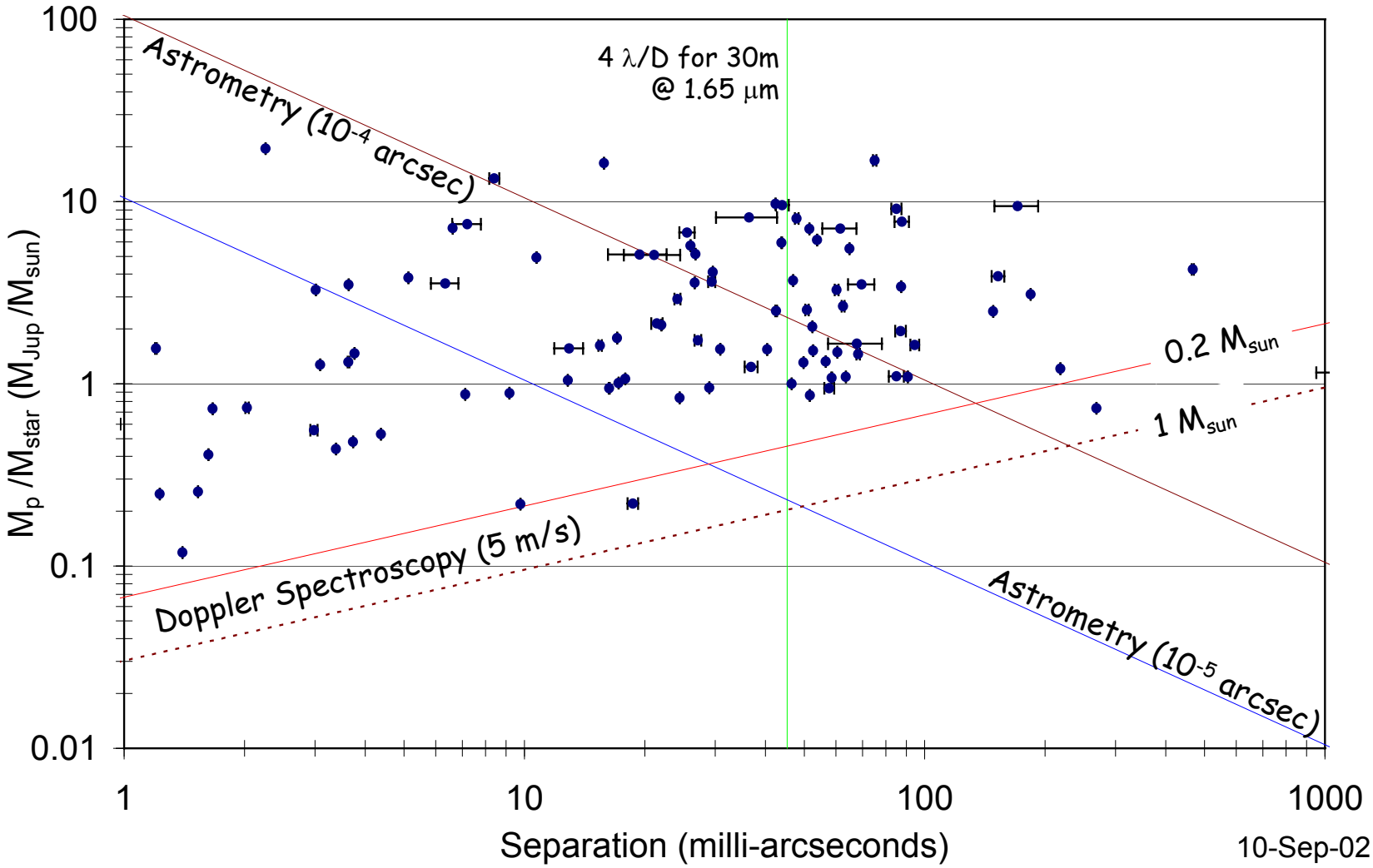


Fig. 32 from Burrows, Hubbard, Lunine, and Liebert, 2002, Rev. Mod. Physics. Logarithm of the fluxes of 51 Peg A and b, according to Seager, Whitney, and Sasselov (2000). The upper curve is the stellar flux and the lower curve is the full-face planetary reflection spectrum.

Next Decade

- More Doppler detection detections
  - Lower masses, longer periods, etc.
- Transit Searches
  - From ground (~ 10 programs) and space (Kepler)
  - Kepler (2005 launch)
    - monitor 100,000 A-KV stars over 4 years
    - 100-1000 "earth-like" plants, ~ 1000 large planets
- Astrometry
  - Ground: Keck - 20 μas/10 years, VLT, etc.
  - Space: HST, SIM (2009) – 1 μas/5 years, GAIA (2013?)
- Hard work on "direct" detection of planets
  - Differential transit spectroscopy
  - Doppler detection

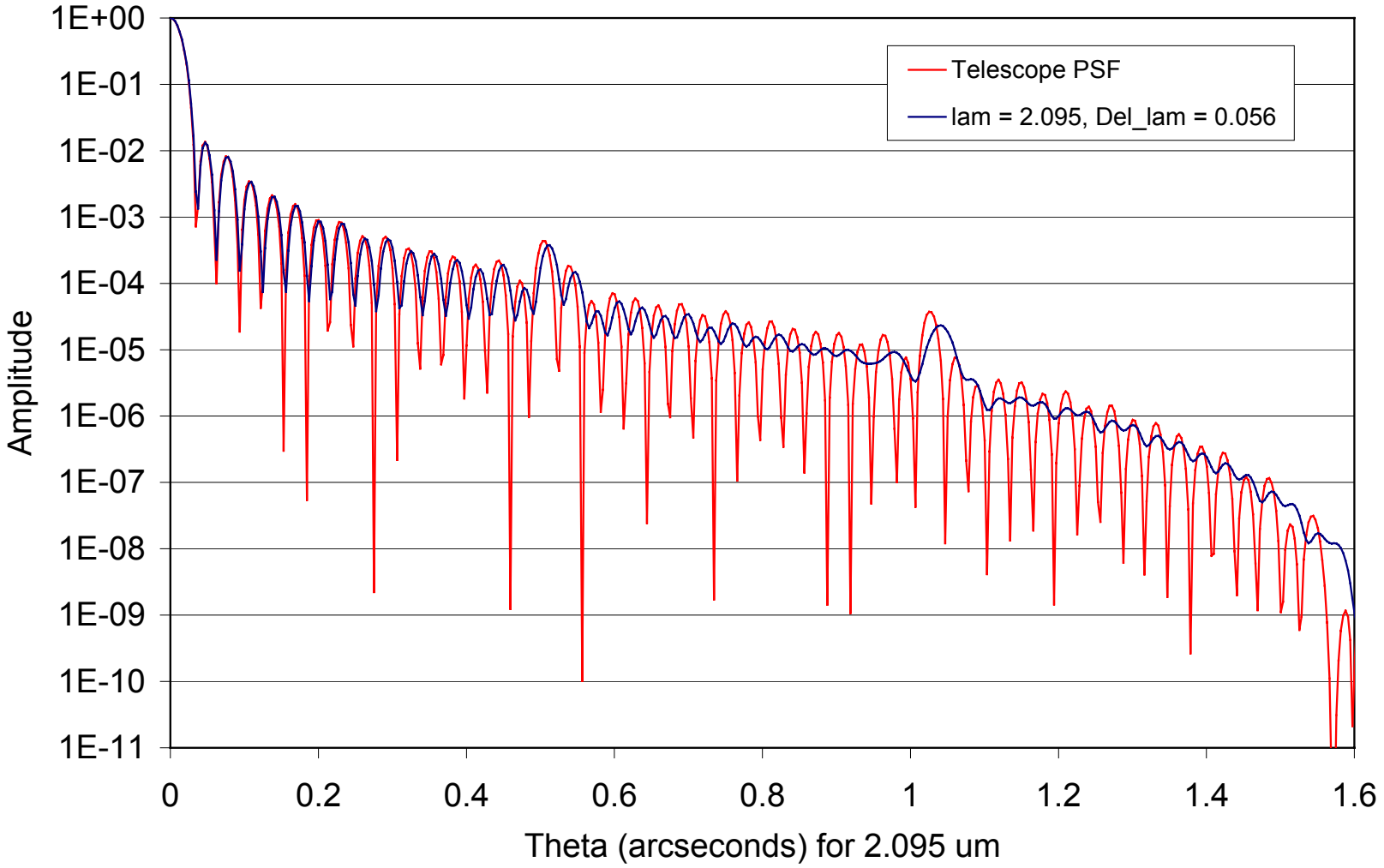


Alternative plot of discovery space for exo-solar planets around stars of 0.2 and 1 M_{sun}. Lines for signatures of 10^{-4} and 10^{-5} arcsec for astrometry and 5 m/s for radial velocities (30pc, sin i = 1). The vertical line represents the resolution (4λ/D) of a 30-m telescope at 1.65 μm. Included are currently detected exo-solar planets (exoplanets.org). Astrometry points at different distances are degenerate, but doppler spectroscopy is not.

Requirements

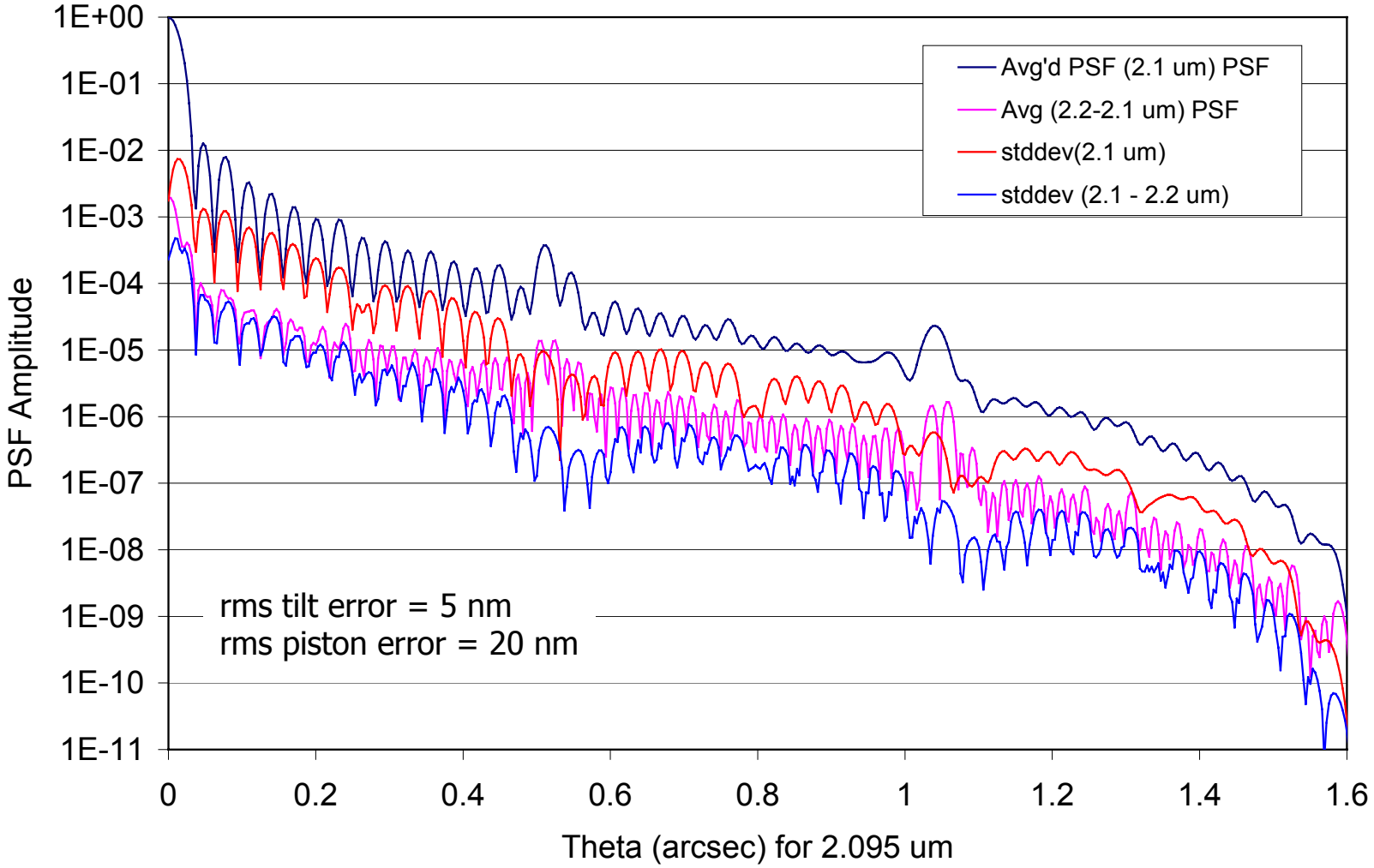
- AO on young planets (~ 10^7 years old)
  - e.g TW Hydrae @ 50 pc
  - 8-m telescopes,
    - 0.5 – 1.0 arcsec separations => 25 – 50 AU
  - 30-m GSMT
    - 0.2 – 0.3 arcsec separations => 10 – 15 AU
- E-AO
  - Suppress scattered light intensity by 10^6 – 10^7
  - 8-m telescopes requires m_R ~ 3.5
  - 30-m GSMT requires m_R ~ 5 – 6.
    - Gives 10 times as many stars as 8-m class telescopes

Finite Bandwidth



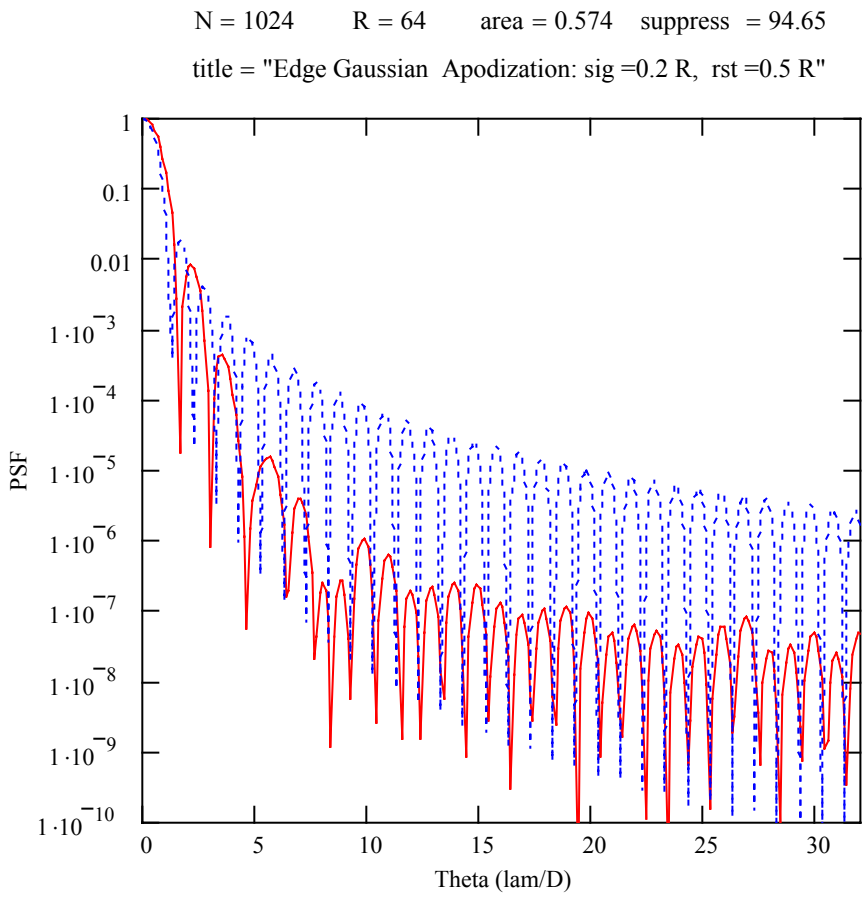
30 degree cut through 15-m segmented telescope w/ 1.1 m segments and 7 mm gaps.

Exosolar Planet/BD search – Avg. vs. Diff. Search

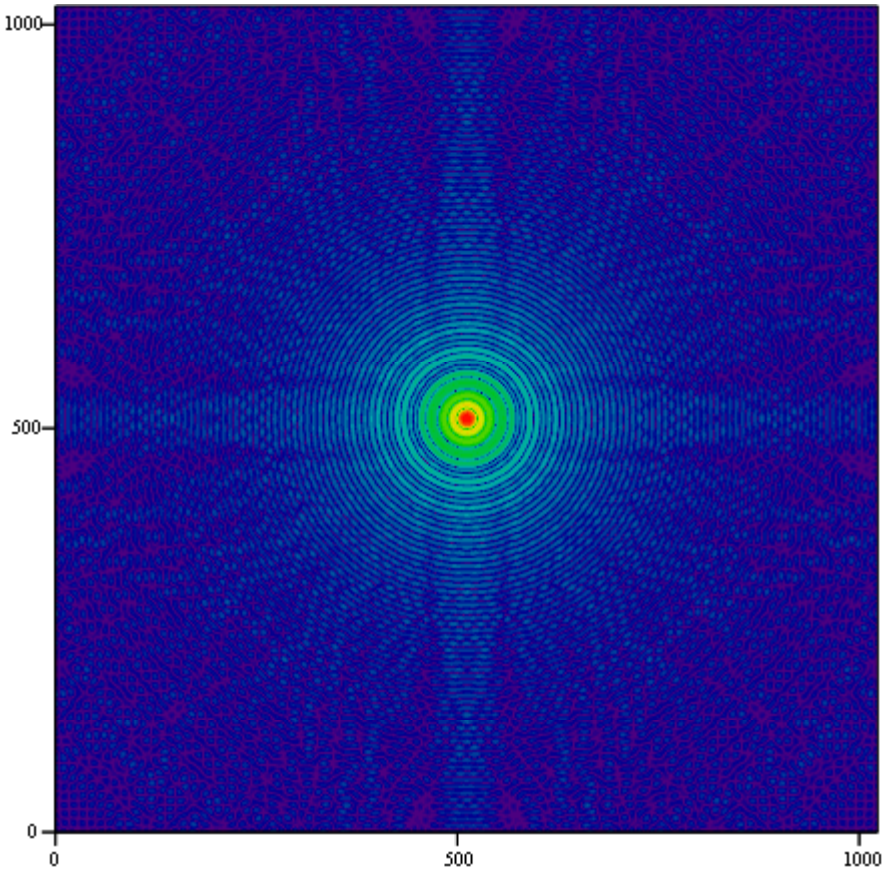


30 degree cut through 15-m segmented telescope w/ 1.1 m segments and 7 mm gaps.

Apodization: Circular Aperture w/ Edge Gaussian



Red: Edge Gaussian taper
Blue: No taper PSF



a

Logarithmic display of PSF

End of Talk

- Spare Slide follow

Full Face Reflectance Spectra

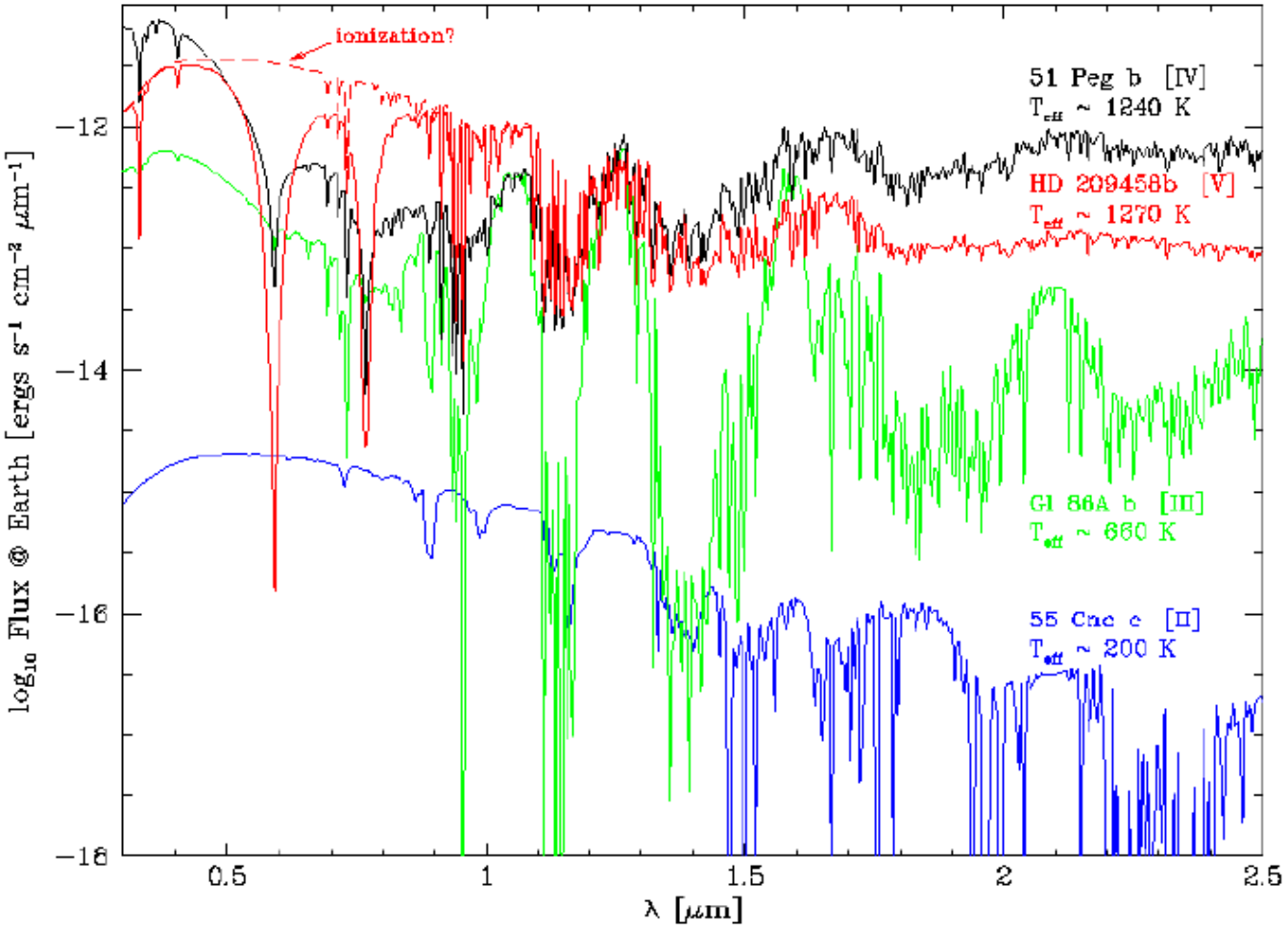


Fig. 33 from Burrows, Hubbard, Lunine, and Liebert, 2002, Rev. Mod. Physics. Full-face reflection spectra of representative EGPs with a range of theoretical equilibrium Teffs. Shown are HD209458b (Class V?), 51 Peg b (Class IV ?), Gl 86Ab (Class III), and 55 Cnc c (Class II). The alkali metal, water, and methane features are most prominent and cloud models as described in SBP were used.

15 M_J brown dwarf

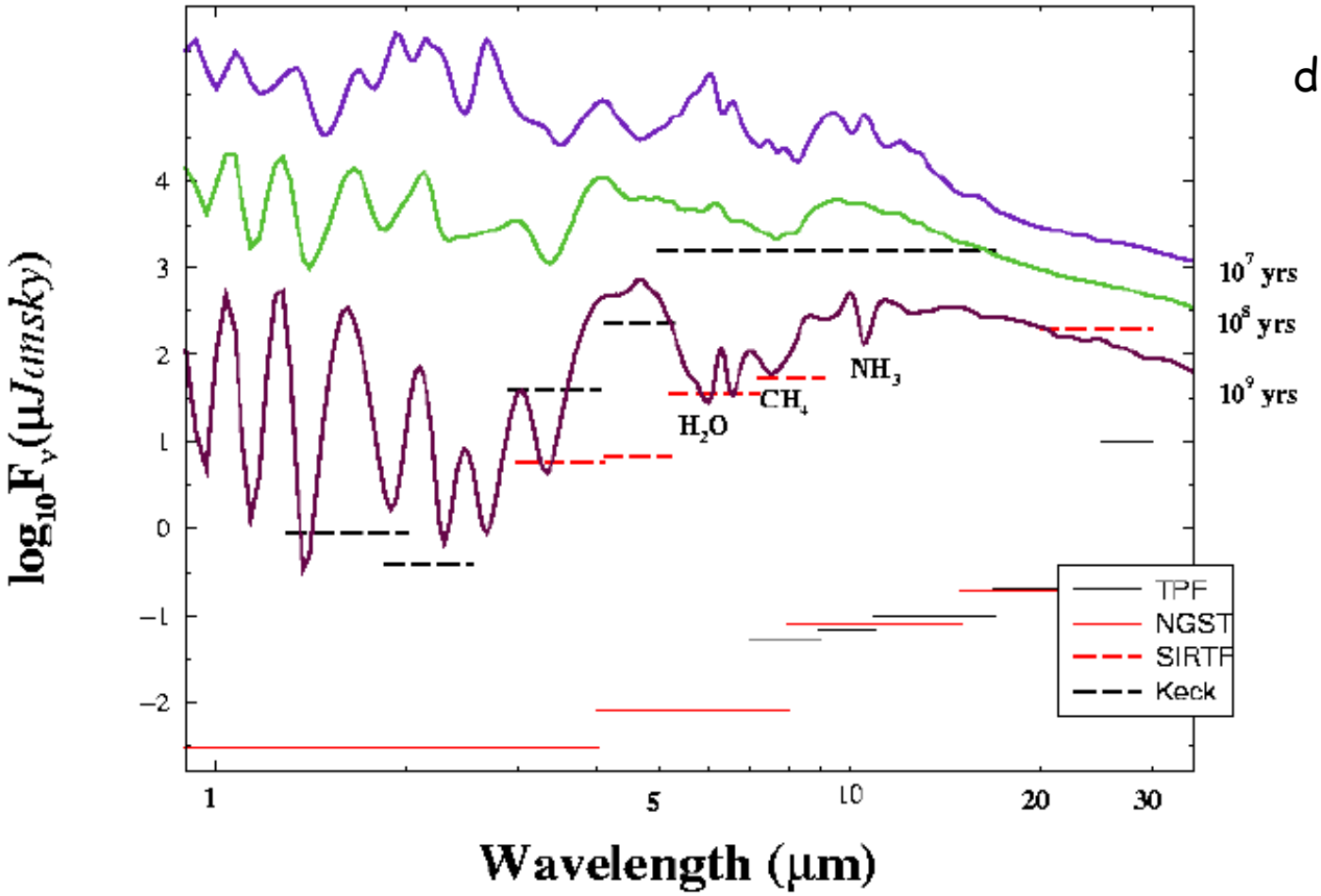


Fig. 36 from Burrows, Hubbard, Lunine, and Liebert, 2002, Rev. Mod. Physics. The theoretical flux versus wavelength for a 15 MJ brown dwarf in isolation at various epochs (10^7, 10^8, and 10^9 years) during its evolution. The corresponding Teffs are 2225 K, 1437 K, and 593 K. Superposed are the putative sensitivities of SIRTF (red dashed), NGST (solid red), TPF (solid black), and Keck (dashed black).

1 MJ Isolated Exo-solar Planet

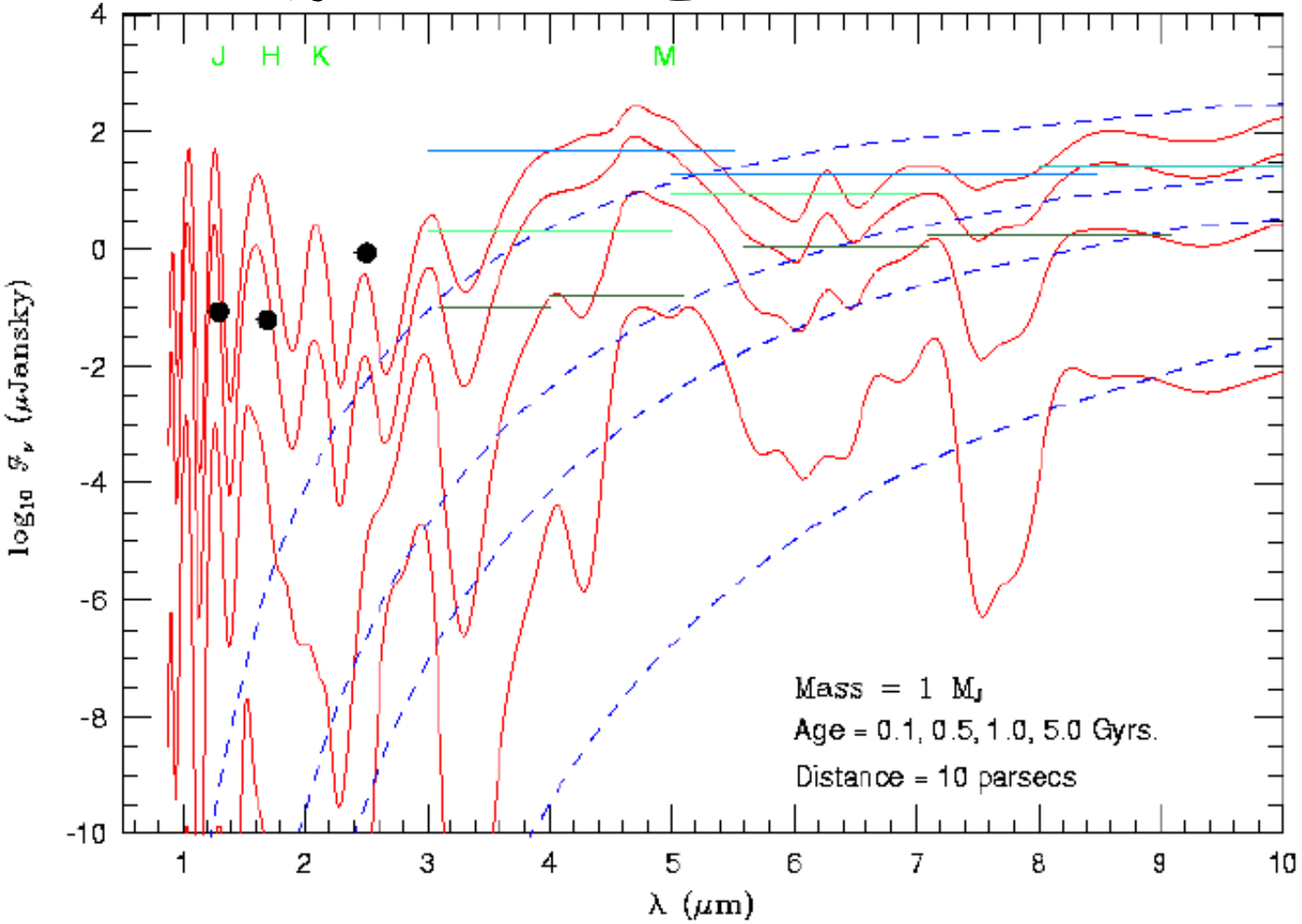
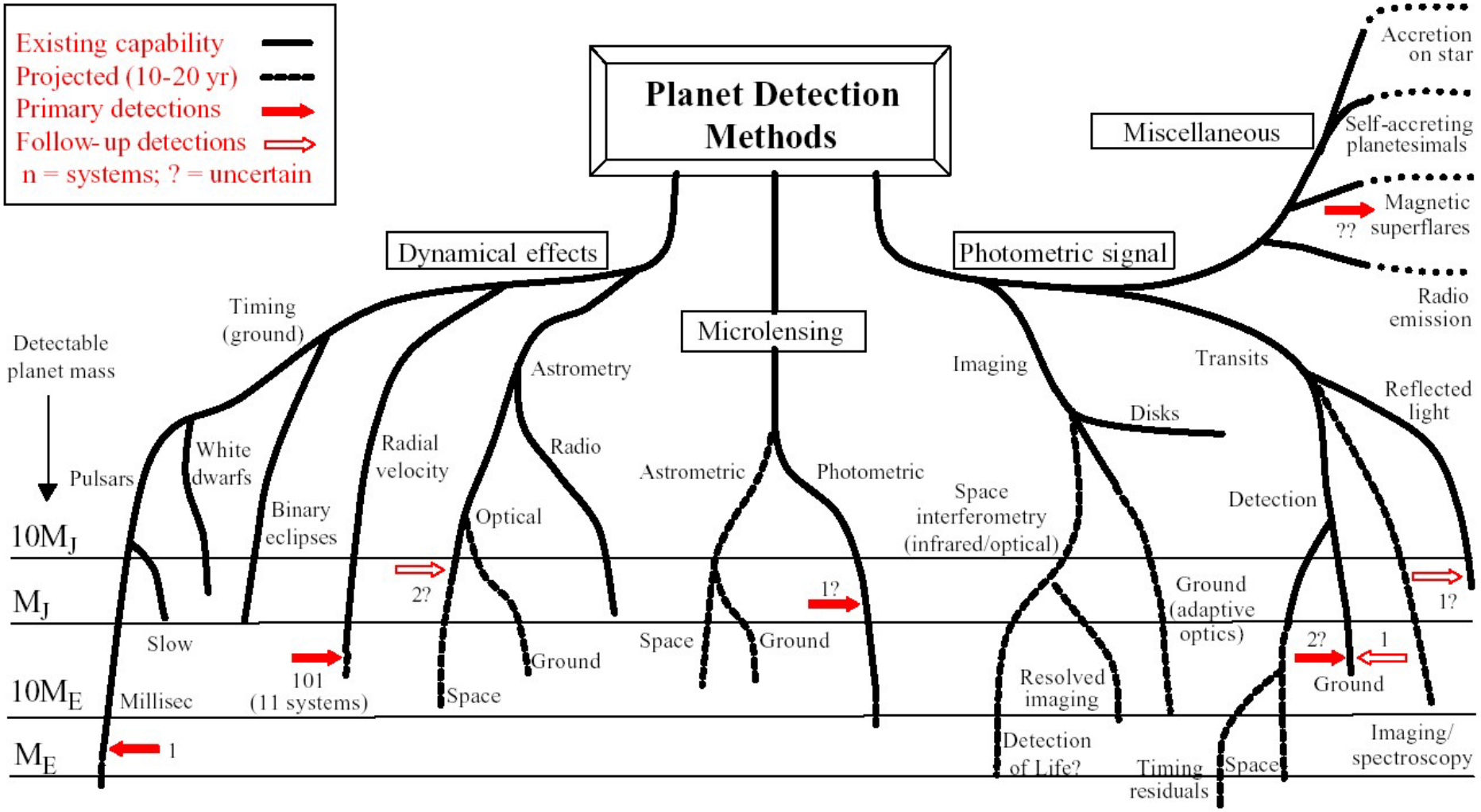


Fig. 18 from Burrows, Hubbard, Lunine, and Liebert, 2002, Rev. Mod. Physics. These spectra are compared with the corresponding black bodies (dashed blue), with Teffs of 290 K, 190 K, 160 K, and 103 K. Superposed are the approximate sensitivities of NICMOS (black dots; Thompson 1992), SIRTF (olive lines; Erickson 1992), and Gemini/SOFIA (light green/solid blue; Mountain, Kurz, and Oschman 1994).

Planet Detection Methods



From Michael Perryman, Rep. Prog. Phys. 2000, 63, 1209.
Updated Aug. 2002 – http://cfa-www.harvard.edu/planets/