Characterization of Extrasolar Planets using SOFIA

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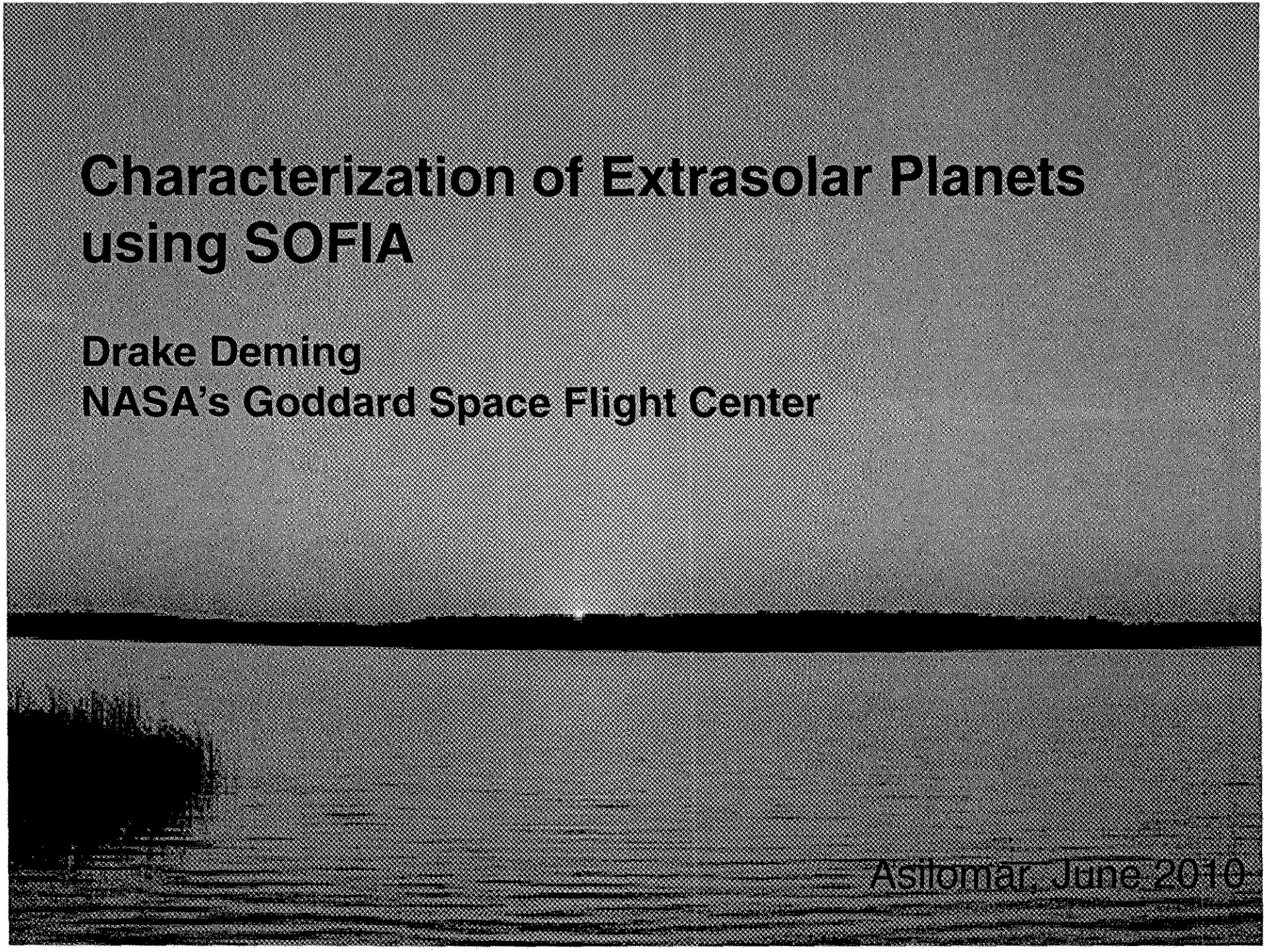


Asilomar, June 2010

First part of this talk:

the landscape of extrasolar planets

why focus on transiting planets

some history, Spitzer results

Posters by Angerhausen & Krabbe

+ HIPO poster by Dunham et al.

Then:

Hot Jupiters: a problem in atmospheric structure

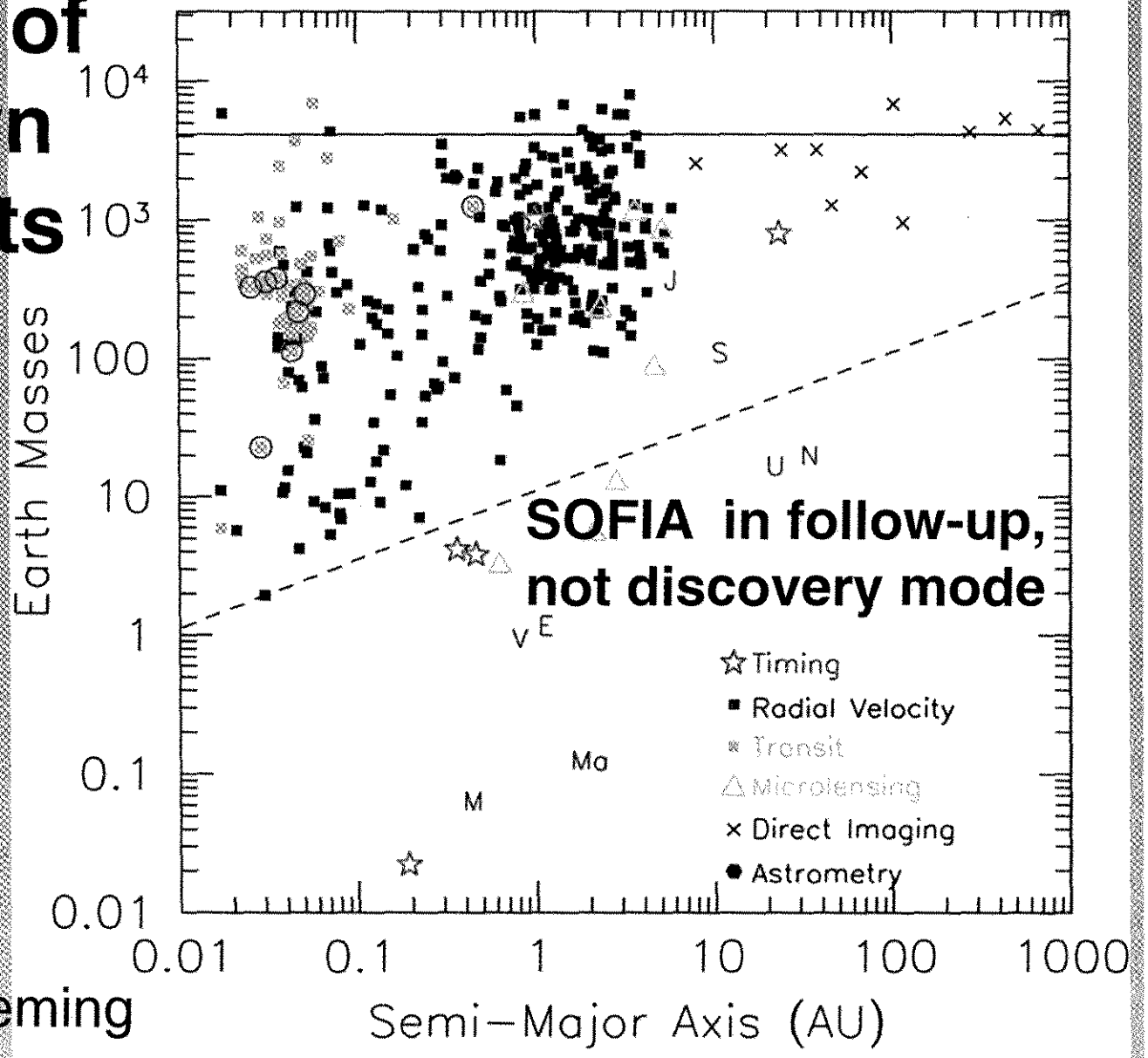
also hot super-Earths

What observations we need to make progress

What SOFIA can currently do

and comments on optimized instruments

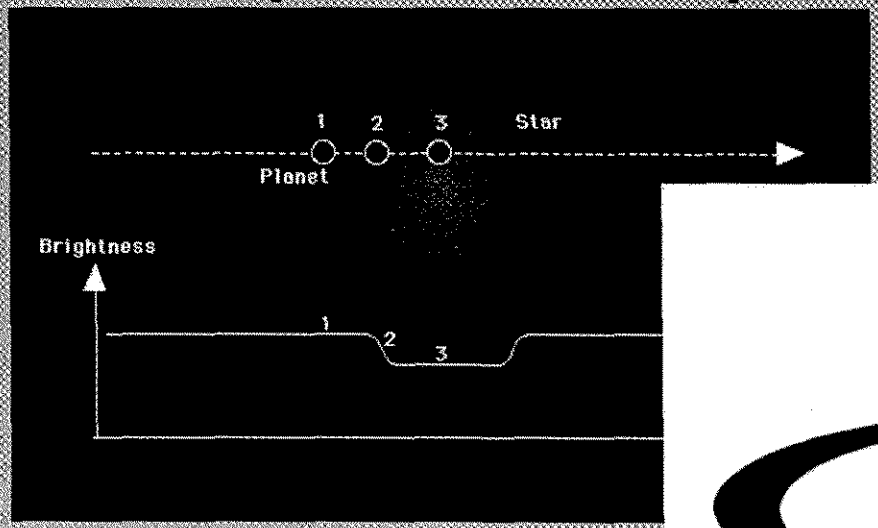
Summary of the known exoplanets



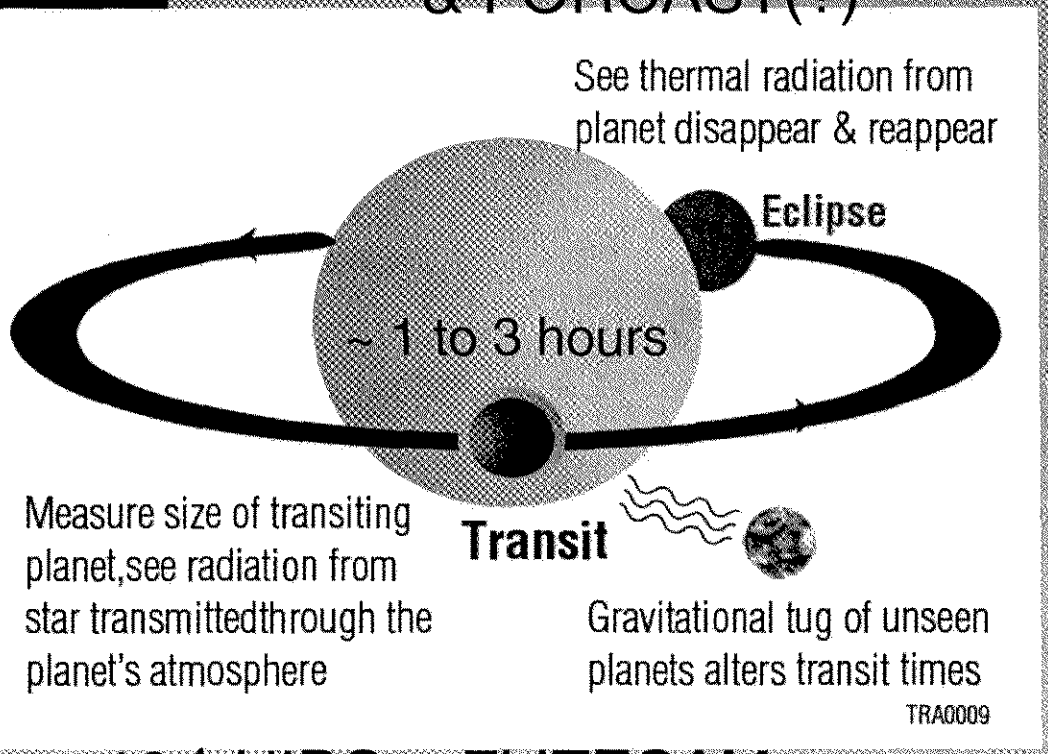
Deming & Seager review in Nature 462, 301 (2009)

Also, Seager & Deming ARAA (2010), astro-ph/1005.4037

Exploit *transits* to characterize exoplanet atmospheres…



few x 10^{-3} FLITECAM & FORCAST(?)

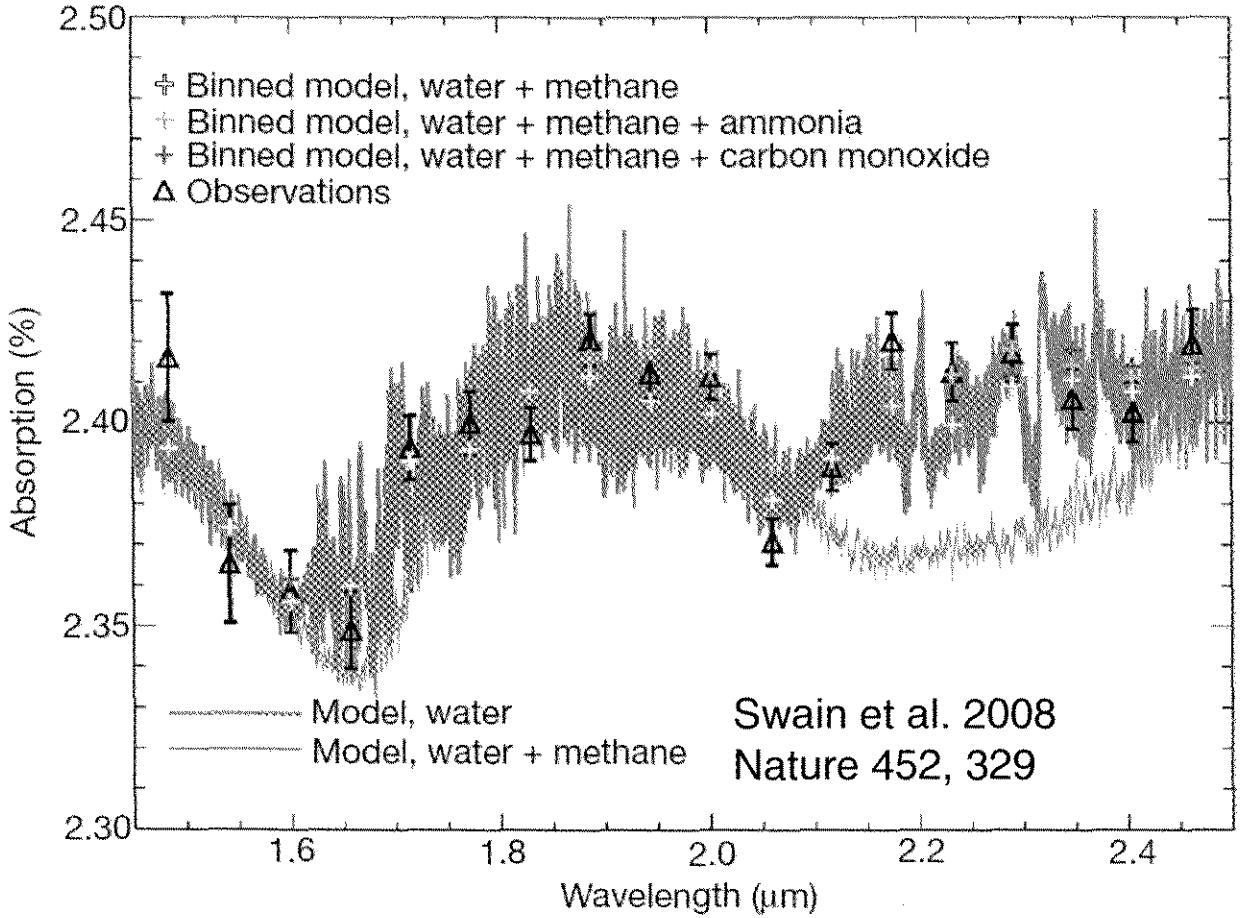


Transits require photometric stability

But tolerate poor image quality

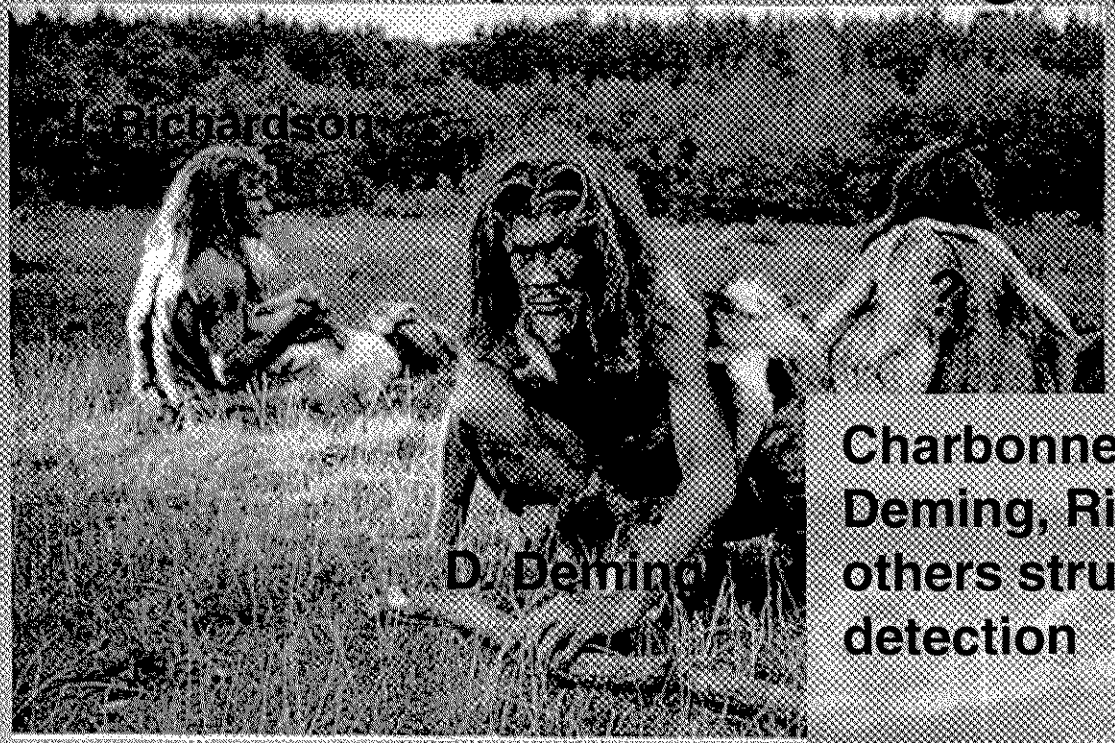
few x 10^{-4} HIPO + FLITECAM

Methane and water vapor in transmission (HD189733b)

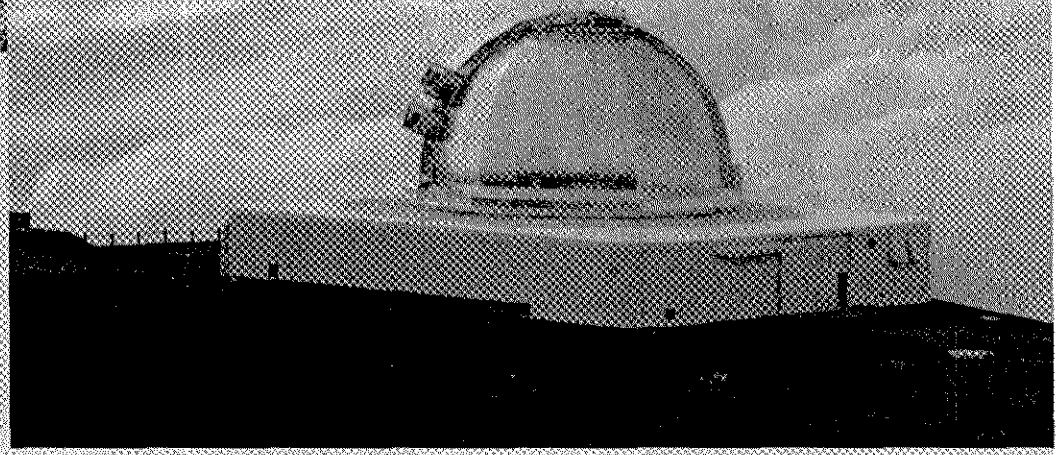


Arguably, SOFIA continuous viewing is a good tradeoff for some telluric water…

Emitted/reflected spectra of hot Jupiters in the paleolithic age (1999-2003)



Charbonneau, Brown, Collier-Cameron, Deming, Richardson, Wiedemann, and others struggled towards ground-based detection

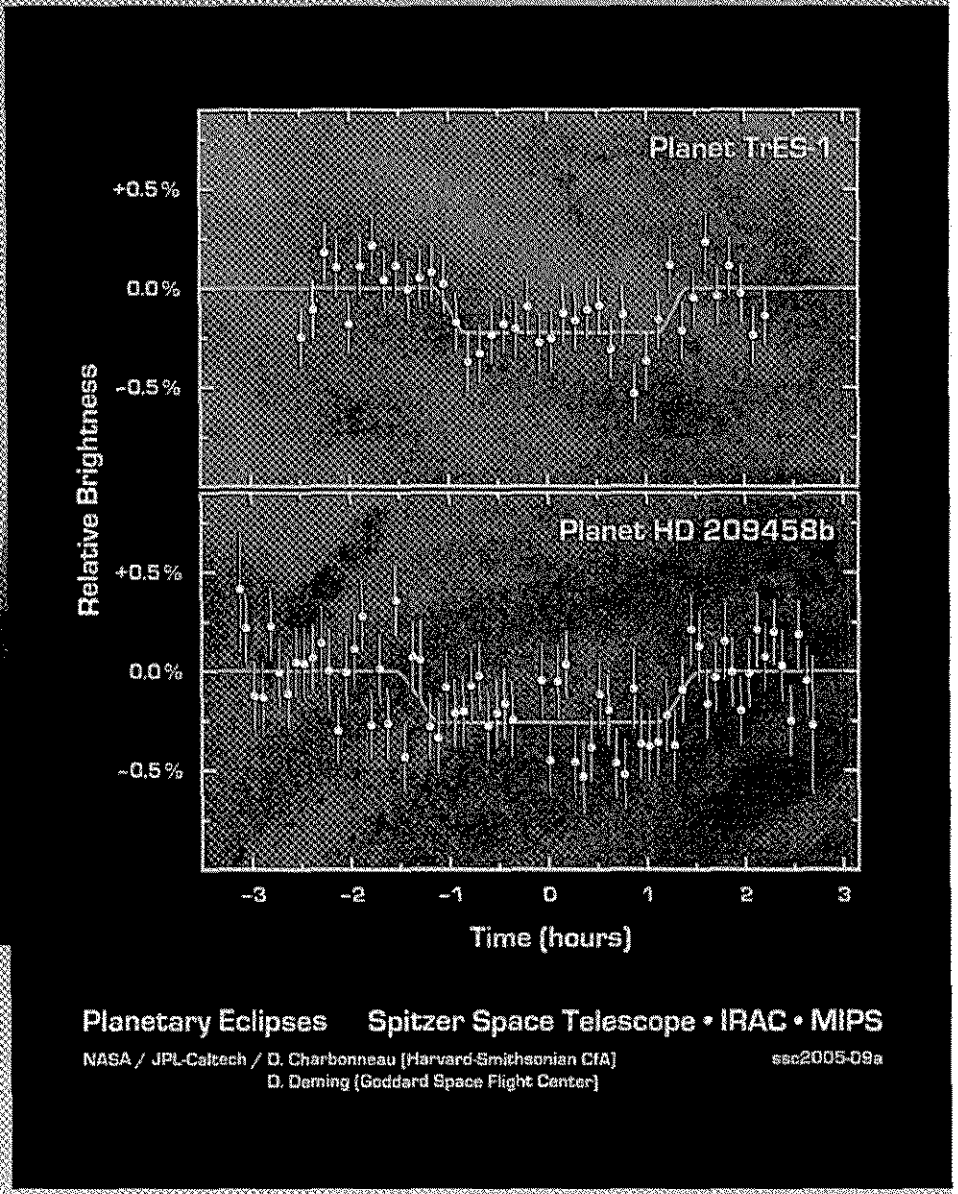


"First Light" Thermal Emission

Spitzer enables direct detection of IR light from the planets

eclipse depth ~ $(R_p/R_{star})^2(T_p/T_{star})$

yields T ~ 1100K



Six Spitzer photometric bands can give a low resolution spectrum of the planet

Eclipse of HD 189733B

eclipse depth ~ $(R_p/R_{star})^2(T_p/T_{star})$

Dominant term

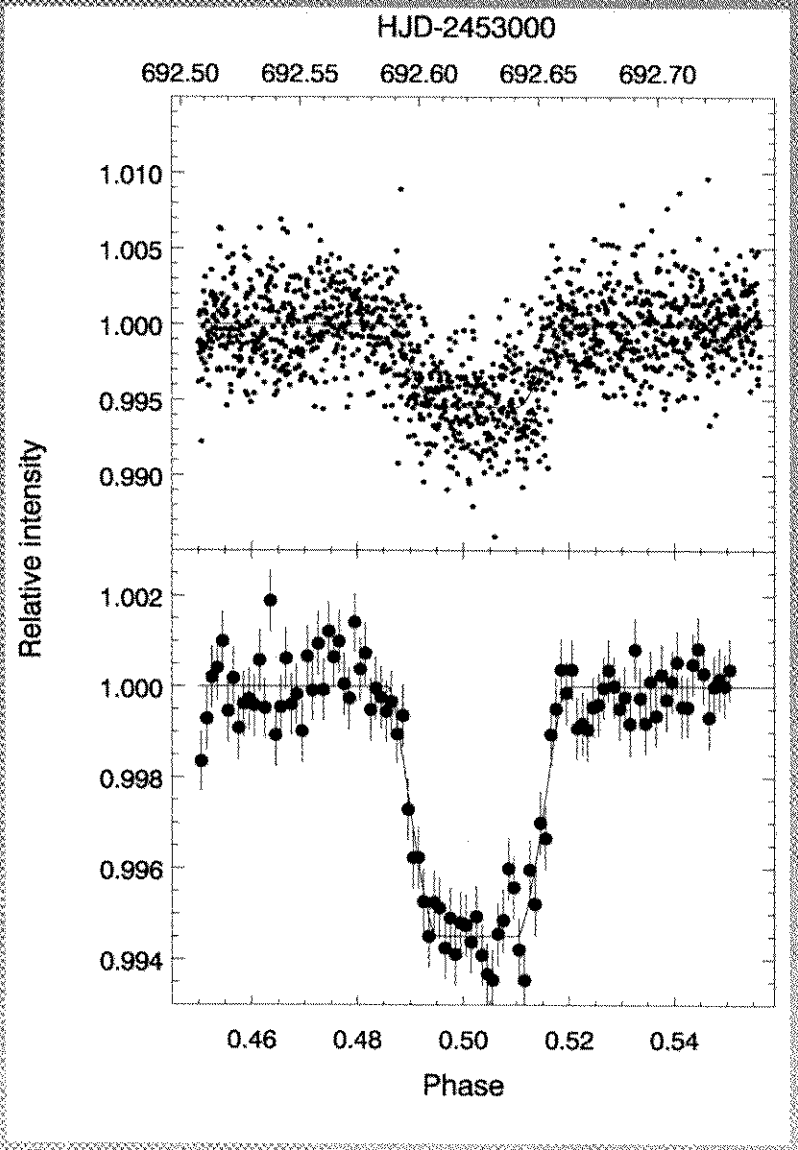
$$T_p \sim T_{star}\,\Delta^{0.5}$$

lower main-sequence stars allow high S/N planet detection

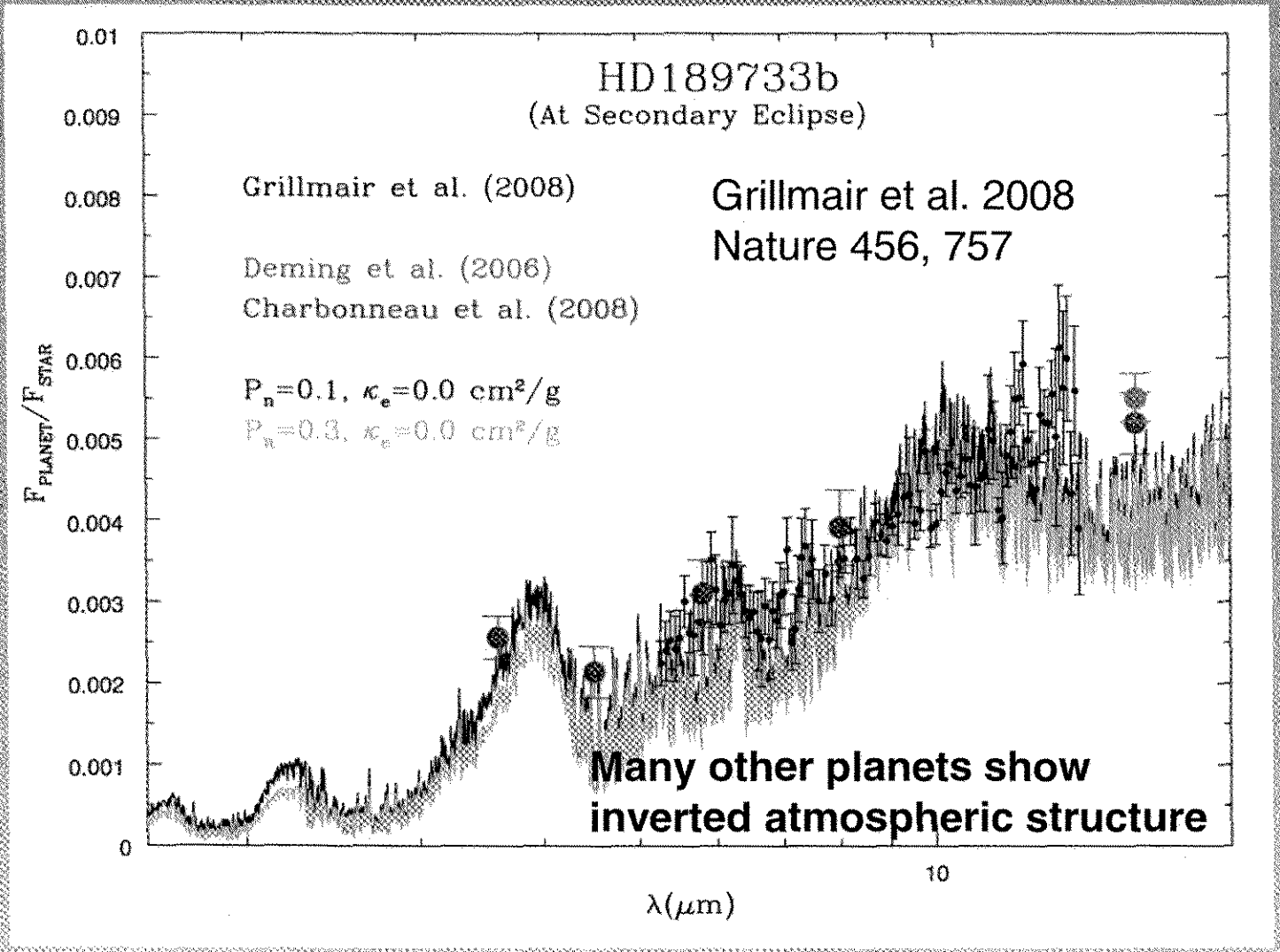
HD 189733b (K3V)

32σ detection at 16 μm

Deming et al. 2006, ApJ 644, 560

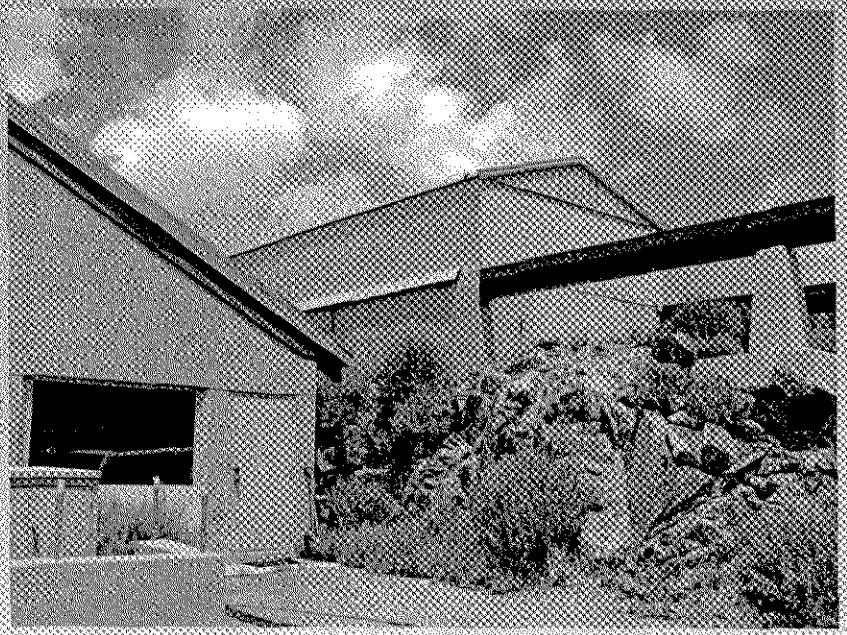


An Exoplanet Spectrum (R ~ 100)

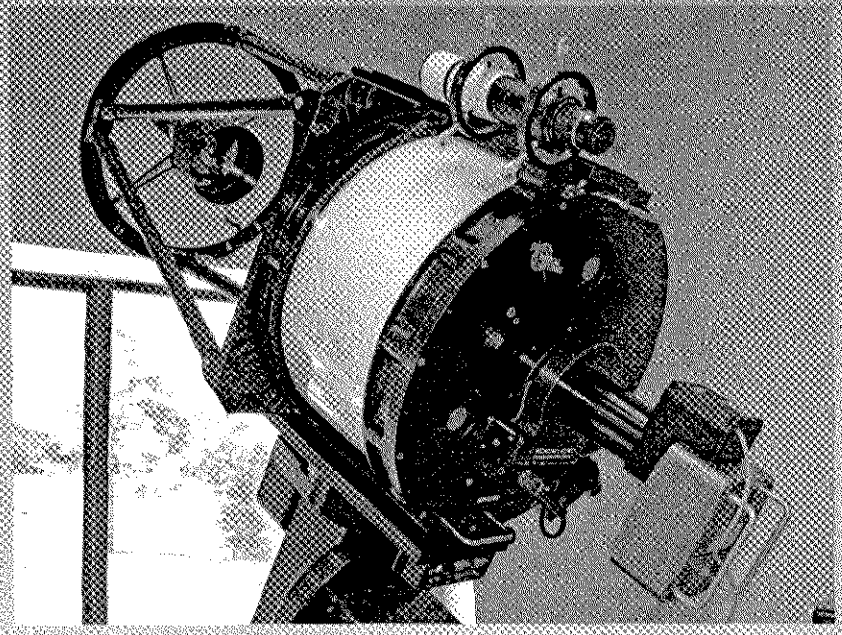


The MEarth Project

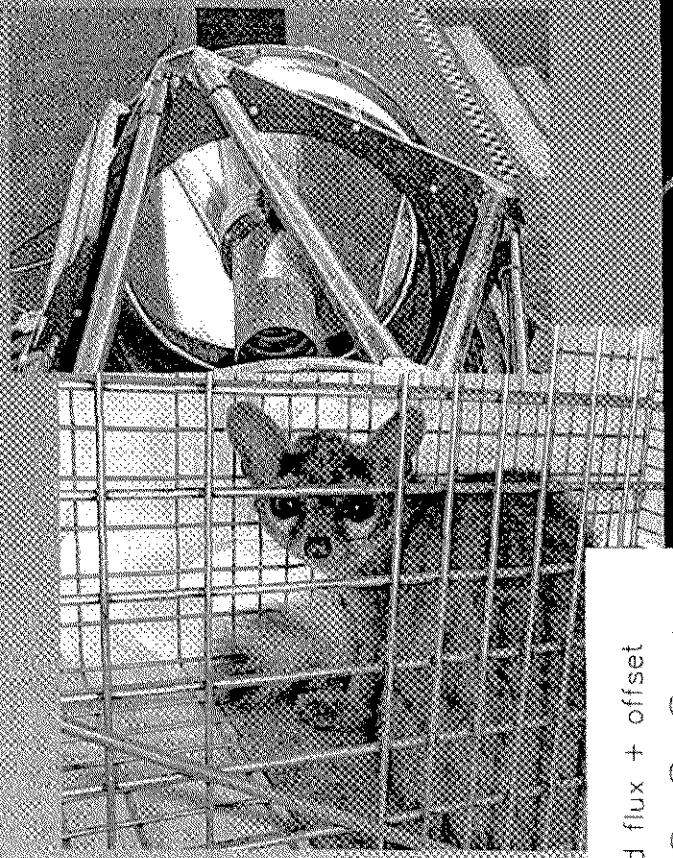
Charbonneau et al.

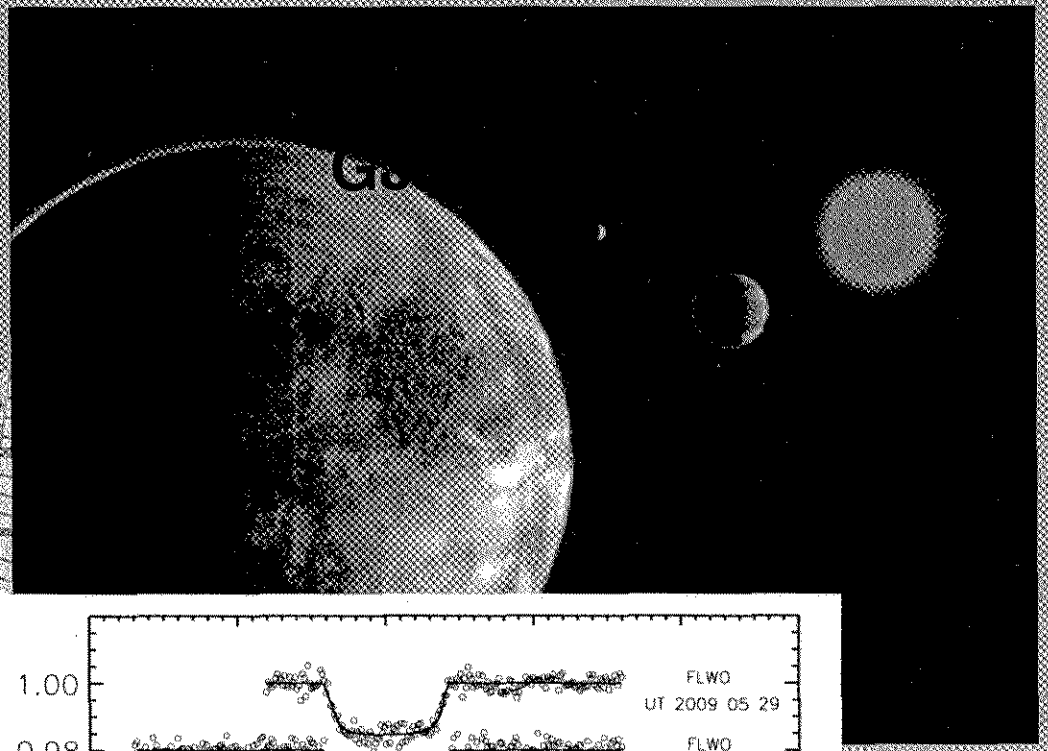


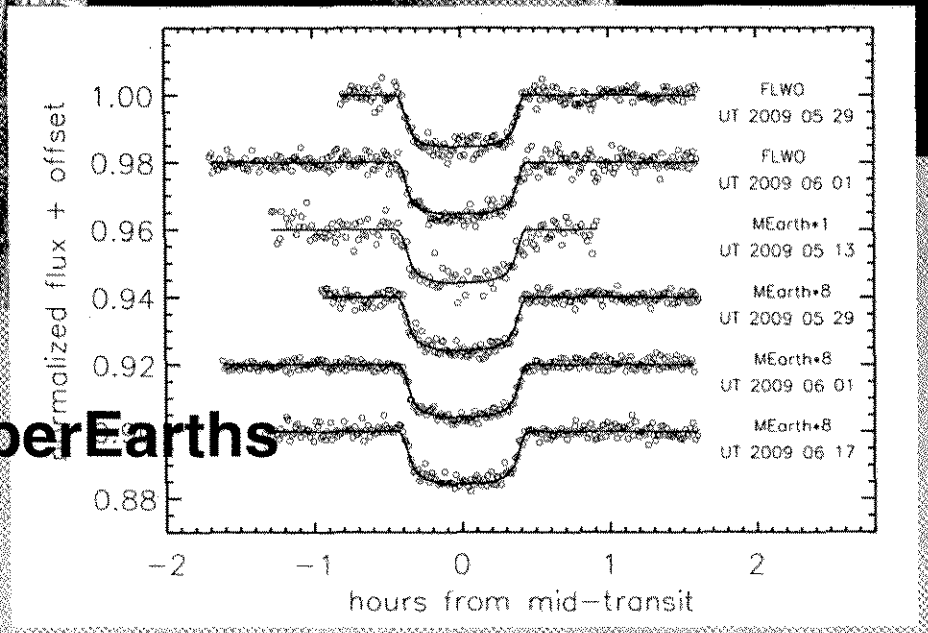
- Using 8 X 16-inch telescopes to survey the 2000 nearest M-dwarfs for rocky planets in their habitable zones
- Converted an existing abandoned building on Mt Hopkins, AZ
- Fully operational; southern version planned
- **These planets will be amenable to spectroscopic follow-up to search for atmospheric biomarkers**



The First MEarth Super-Earth

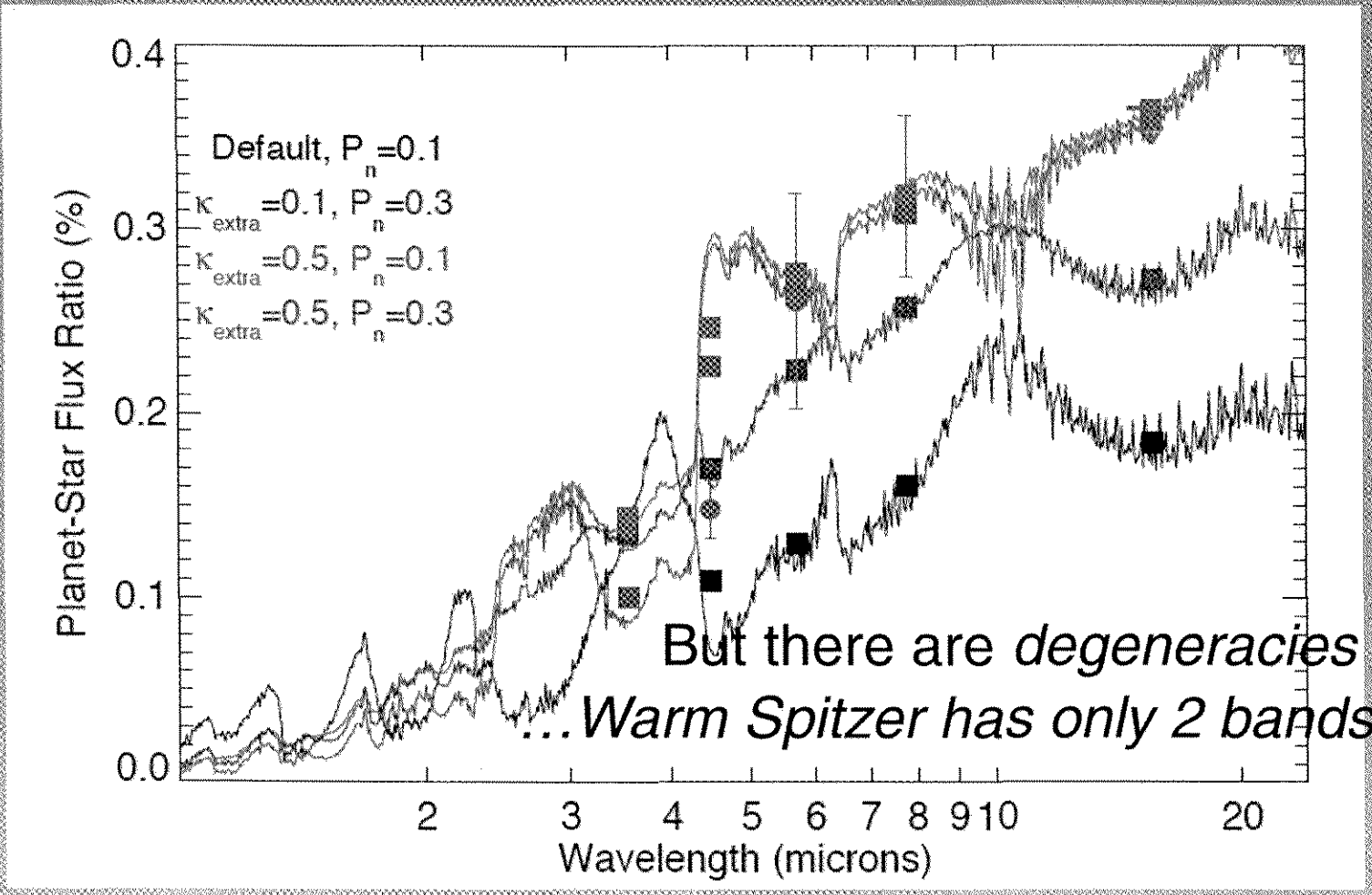




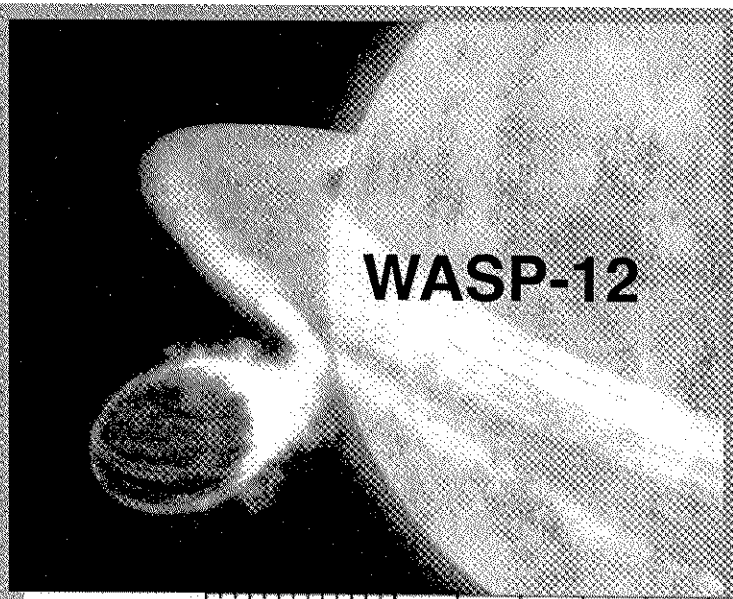


Nearby, hotter superEarths to come

TrEs-4 – apparently an inverted atmosphere



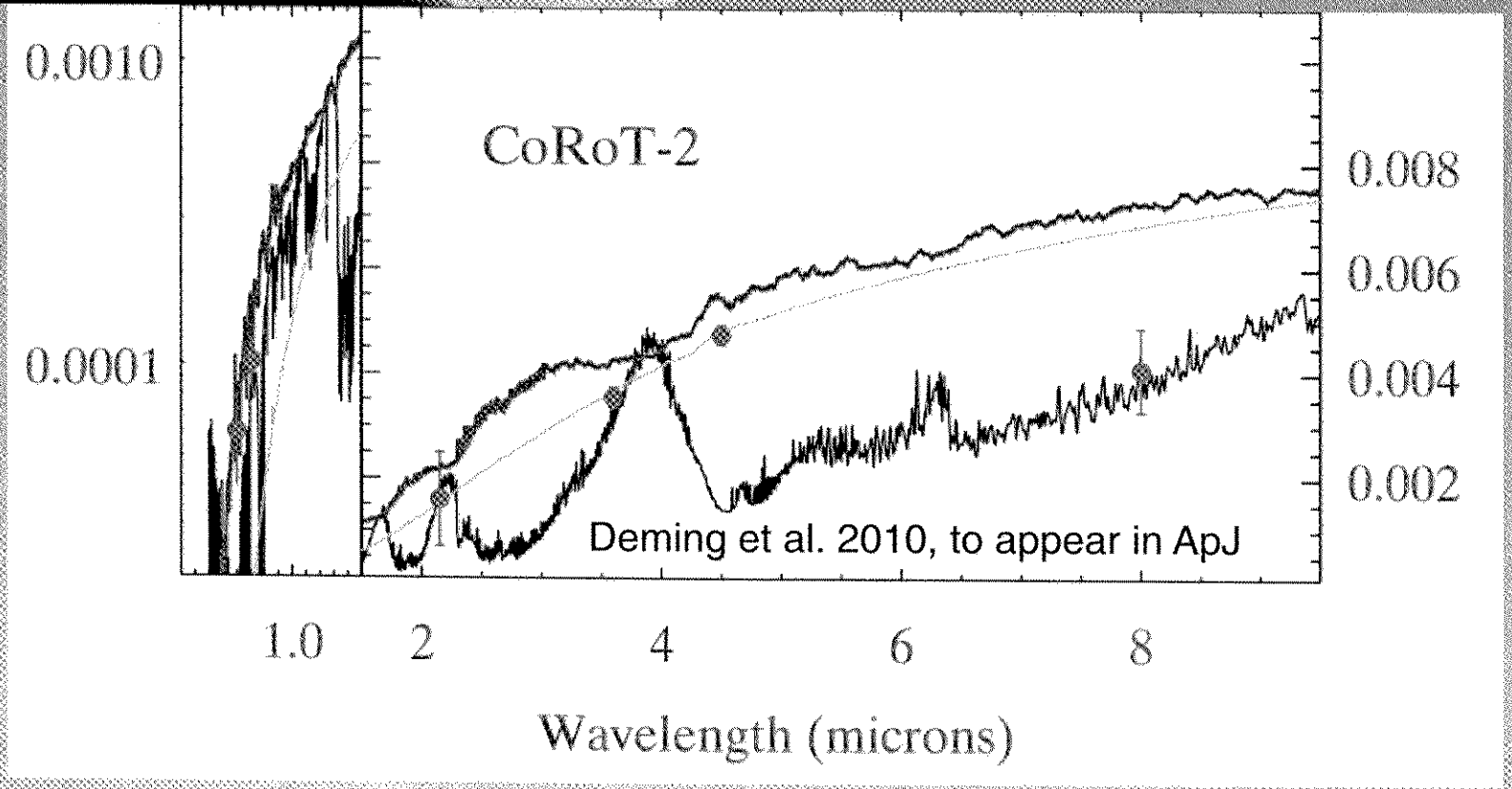
Knutson et al. ApJ 691, 866 (2009)



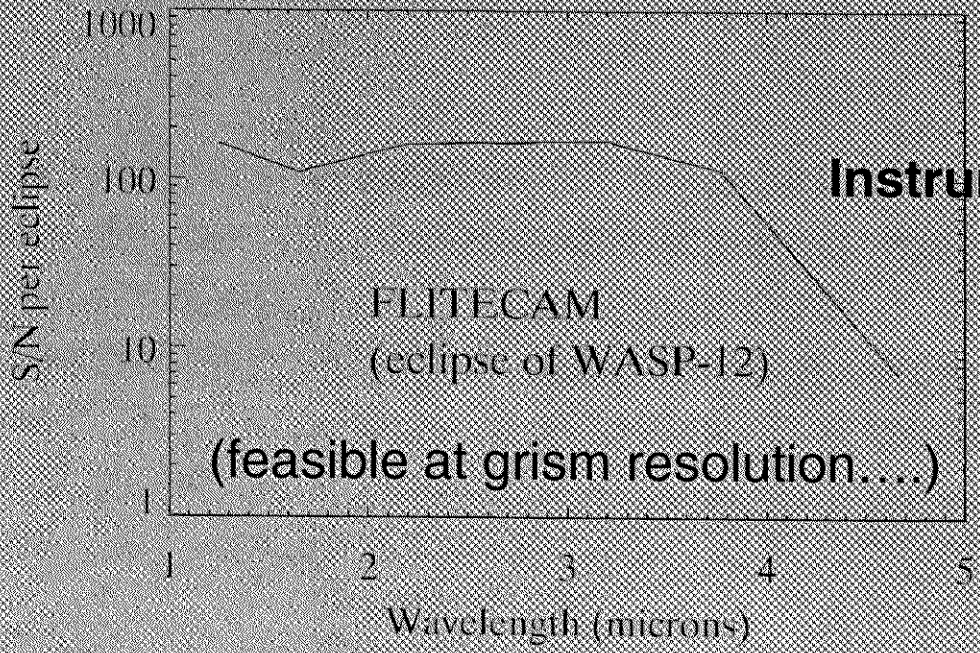
The *very hot* Jupiters

atmospheres perturbed by strong irradiation?

losing mass by tidal stripping?



High S/N for WASP-12 at filter resolution



Instrument considerations:
maximize the spectral range
R ~ 100 is OK
maximize stability
consider λ-dithering

hot super-Earths?

Conclusions and comments

- SOFIA with current instruments can make significant progress on the science of transiting exoplanets
  - Mass loss and atmospheric structure of very hot Jupiters
  - Complementary to Warm Spitzer
  - possibly can characterize hot M-dwarf super-Earths

- Instrument enhancements should concentrate on stable 1 -5 μm spectroscopy, maximizing the spectral range at relatively low spectral resolution