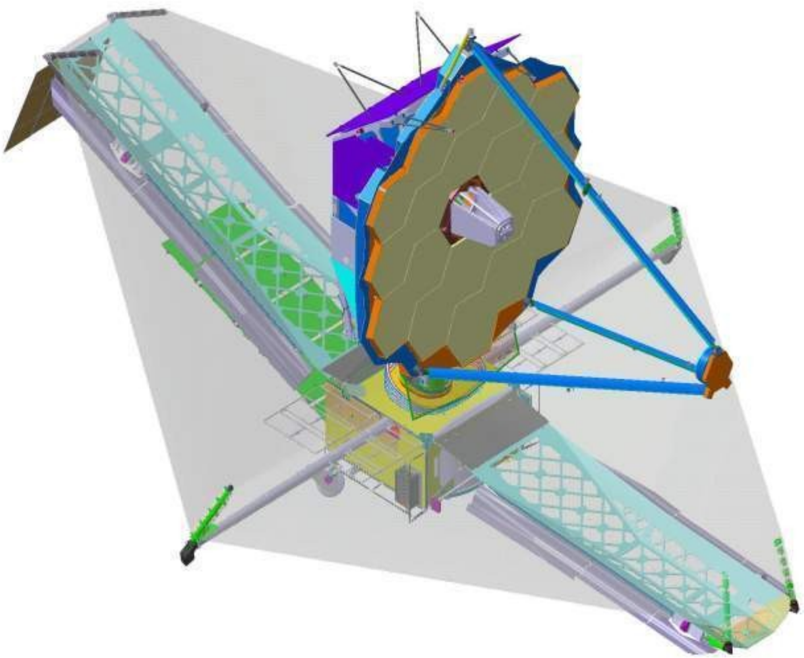

# Exoplanets with the James Webb Space Telescope

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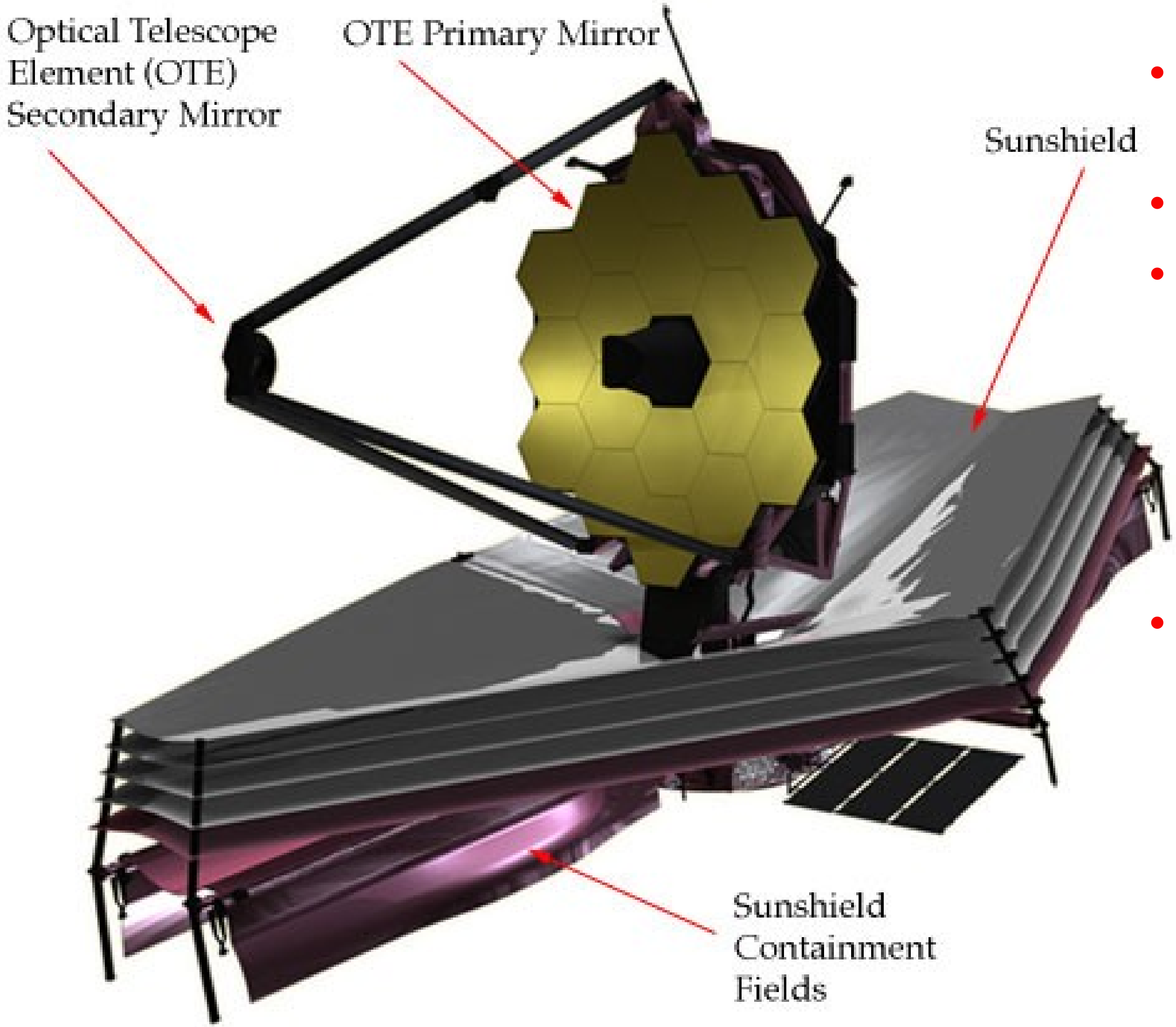
# Exoplanet Landscape in 2014 – JWST Launch

- Likely over 750 RV exoplanets known
  - HARPS-N, APF, IR RV(?), other facilities online
  - Maybe some ~1$M_{Earth}$ planets around M dwarfs (~1-4 m/s; IR)
  - Perhaps >100 bright transiting planets with RV
- Spitzer warm IRAC & HST (WFC3 / STIS / NICMOS) will have observed all bright transiting planets known as of 2010+
- Kepler & Corot surveys complete: planet number & size statistics
  - Perhaps > 1000 new exoplanets over 100 sq deq FOV; most 12 < V < 15 (Johnson mags), short period, gas giants; > 100 small ones ?
- Super-Earths in habitable zones around M dwarfs may be discovered by ground-based transit surveys (e.g., Charbonneau Mearth)
- Many transiting planets around bright stars (accessible via RV) could be found if a small dedicated space mission has flown (too bad re. TESS)
    - Ground-based searches limited to ~0.5% depths and short periods
- Some information about exozodiacal dust from Keck & LBT-I
  - Numerous large planets imaged from ground (GPI)

# JWST in a nutshell

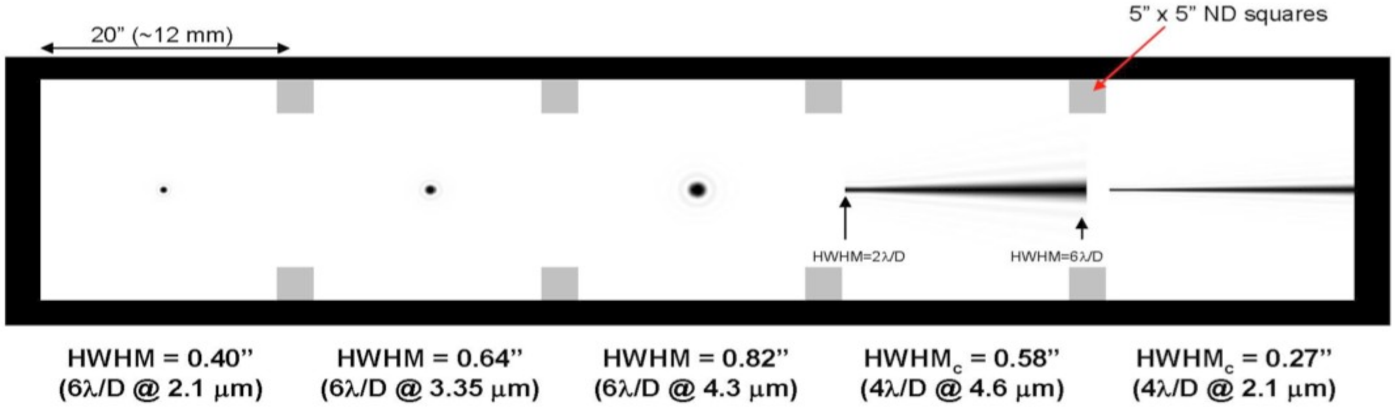



- 6.5-m primary mirror; 18 segments
- λ ~1 - 28 μm
- Instruments:
  - NIRCam
  - NIRSpec
  - MIRI (cam + spec)
  - FGS w/TF & NRM
- 2014 launch
  - Arianne V to L2
  - 5 yr req life
  - 10 yr goal
  - No cryogens

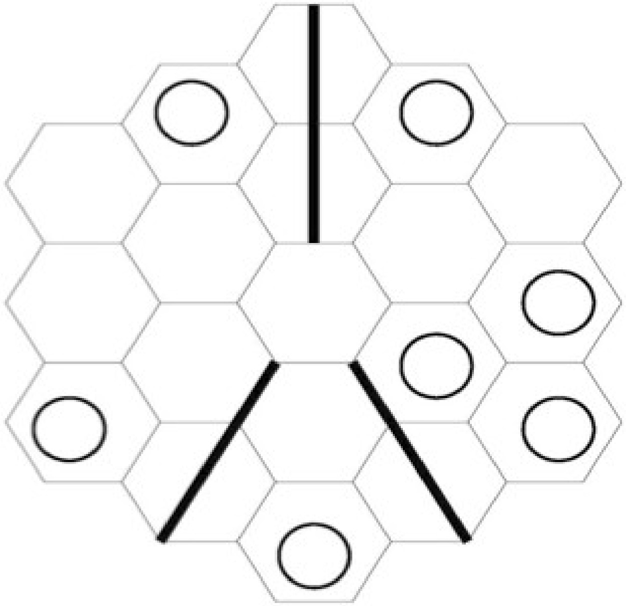
# JWST Transit Capabilities: Instruments (2)

- **NIRCam:** 1 – 5 μm images & some spectra
  - Images over 0.7 – 5 μm Nyquist sampled at 2 and 4 μm
  - R ~ 1700 spectra 3 – 5 μm (not continuous)
  - K ~ 5 - 8 bright limit via subarrays, weak lenses, spectra
- **NIRSpec:** 1 – 5 μm spectra
  - R=100 (1 setting) and R=2700 (3 settings) spectroscopy with coarse (100 mas) spatial sampling for single or multiple objects
  - Implementing a very wide slit (1.6 arcsec) to eliminate slit modulation
- **MIRI:** 5 – 28 μm images & spectra
  - 5 – 28 μm Imager Nyquist sampled at 7 μm
  - Low Res Spectrograph R~100 λ = 5 – 10 (14) μm
  - Med Res R=3000 Integral Field image slicer spectrograph
- **Fine Guidance Sensor** Tunable Filter (FGS TFI)
  - 1 – 5 μm images @ R~100
  - Has a non-redundant mask interferometer

# NIRCam Coronagraphic Masks & TFI NRM




NIRCam Coronagraph Masks



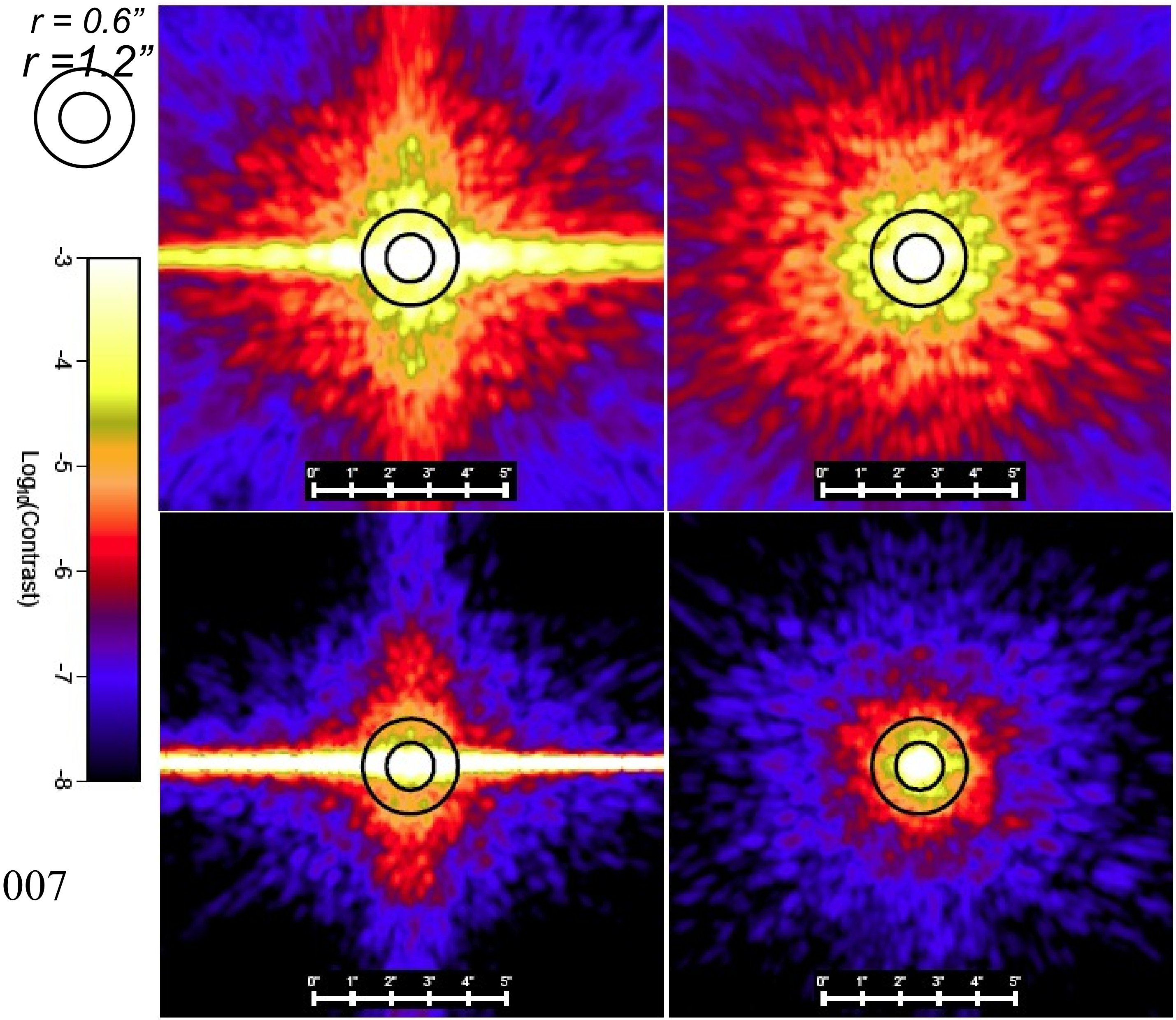
TFI Non-redundant (pupil) mask interferometer apertures
(Sivaramakrishnan et al. 2009)

# JWST/NIRCAM CORONAGRAPHIC CONTRASTS

4λ/D Sinc² Wedge    6λ/D Sombrero² Spot

Raw

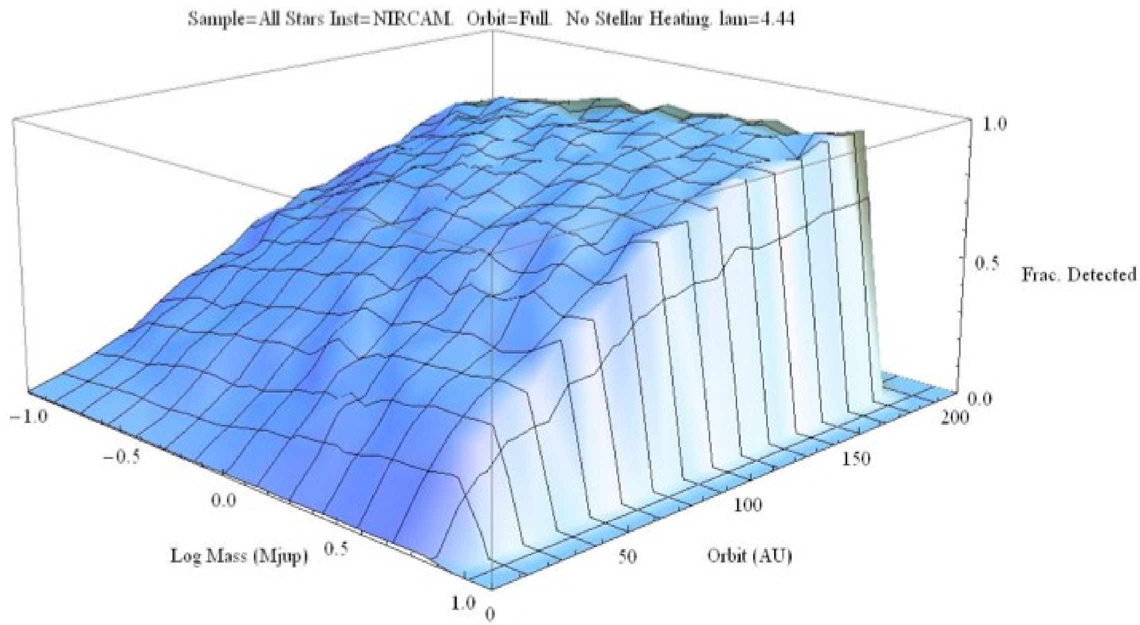
Rolled

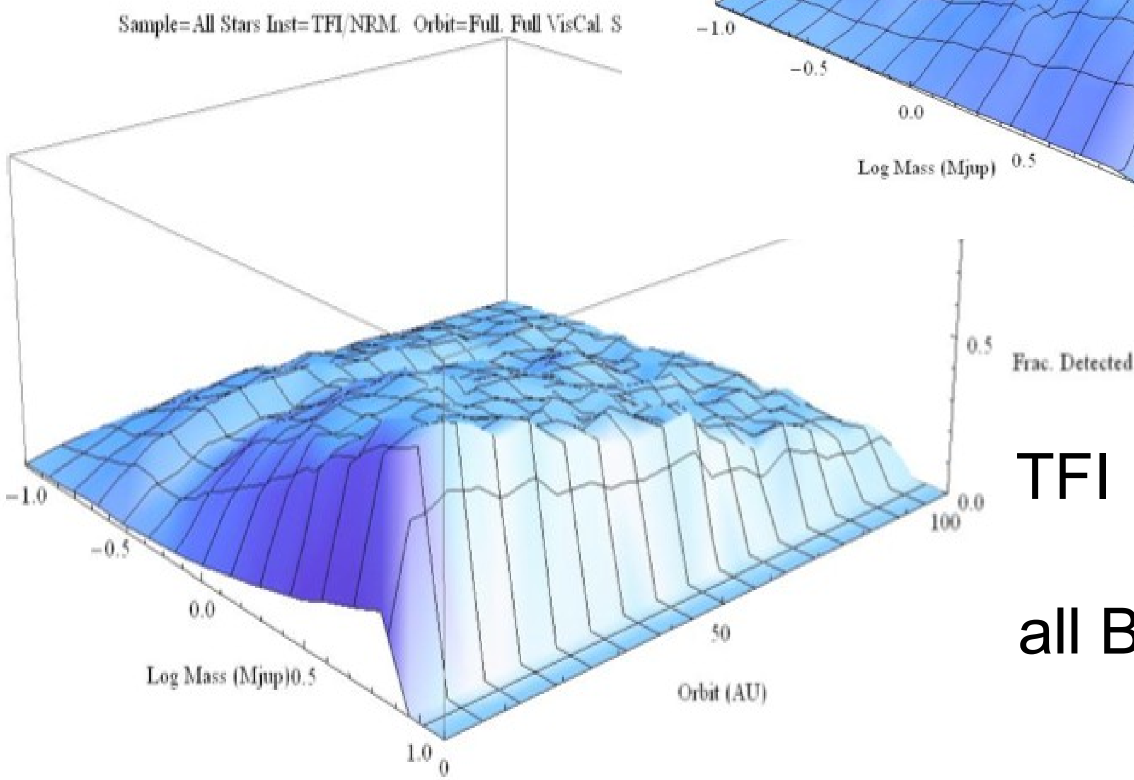



Krist et al 2007 (SPIE)

# NIRCam & TFI planet imaging detectability

NIRCam

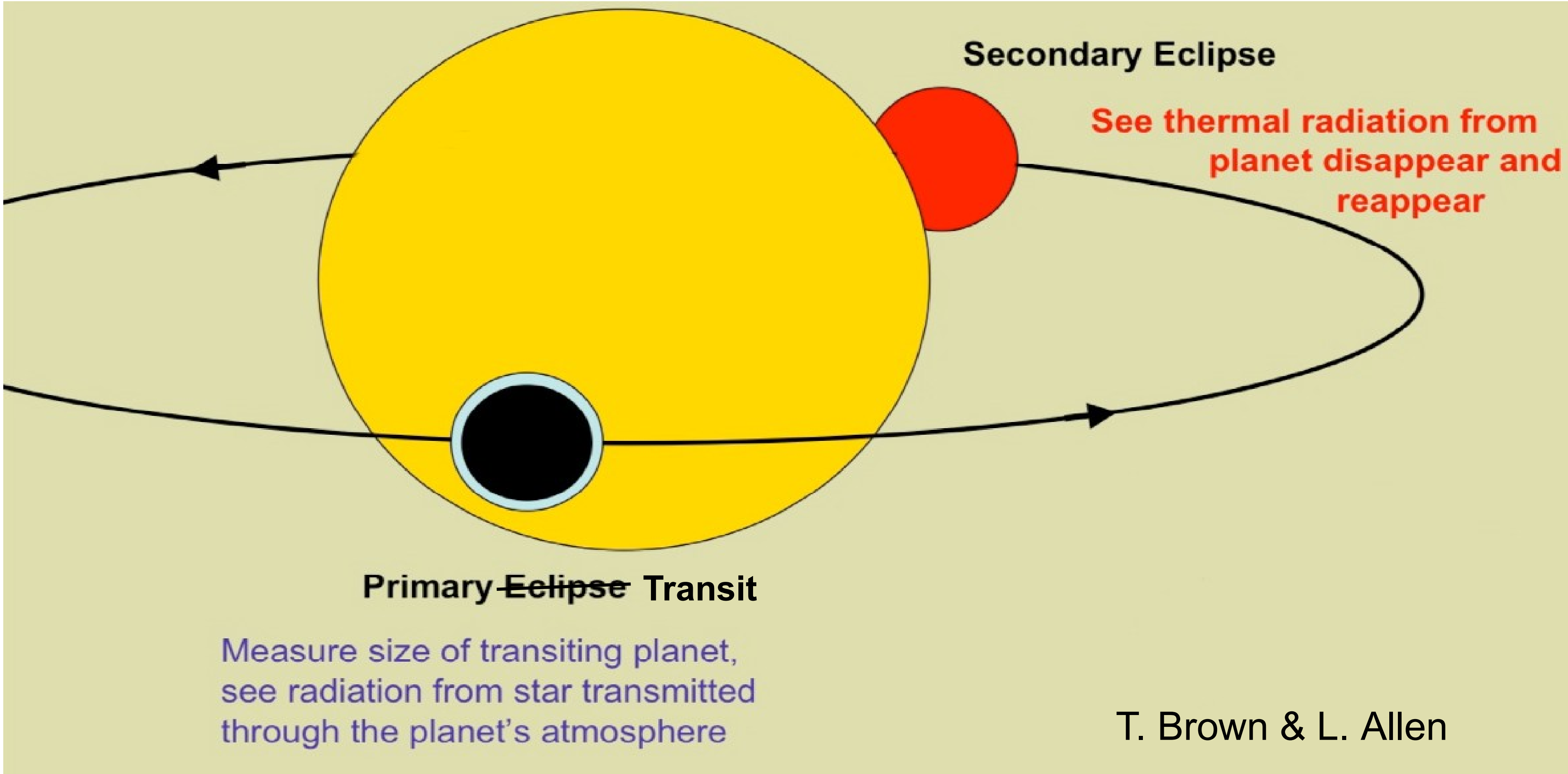


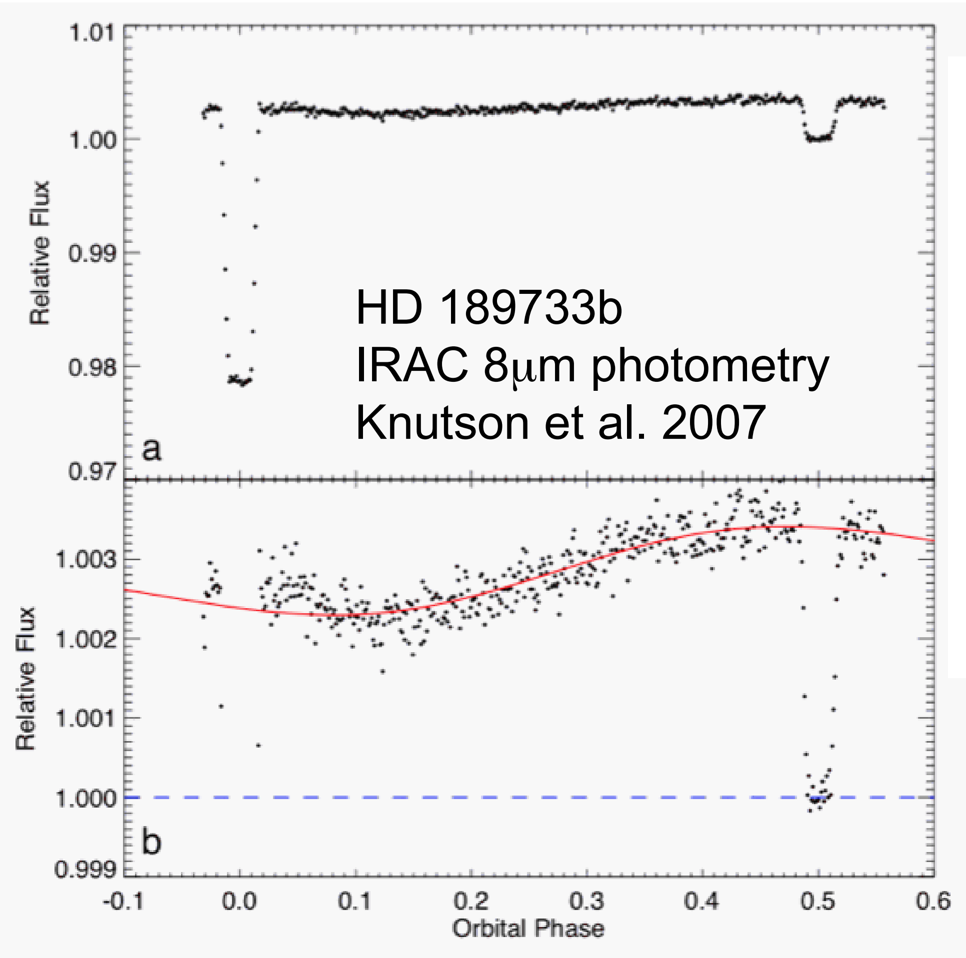

TFI NRM

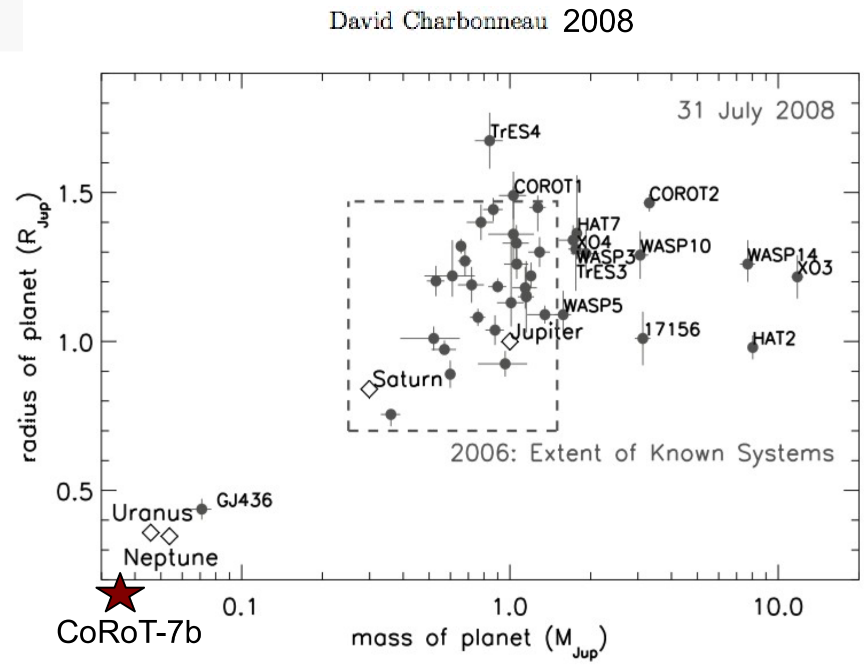
all Beichman et al. 2009

# Transit & Eclipse Geometries



# Exoplanet transit observations 2008/9



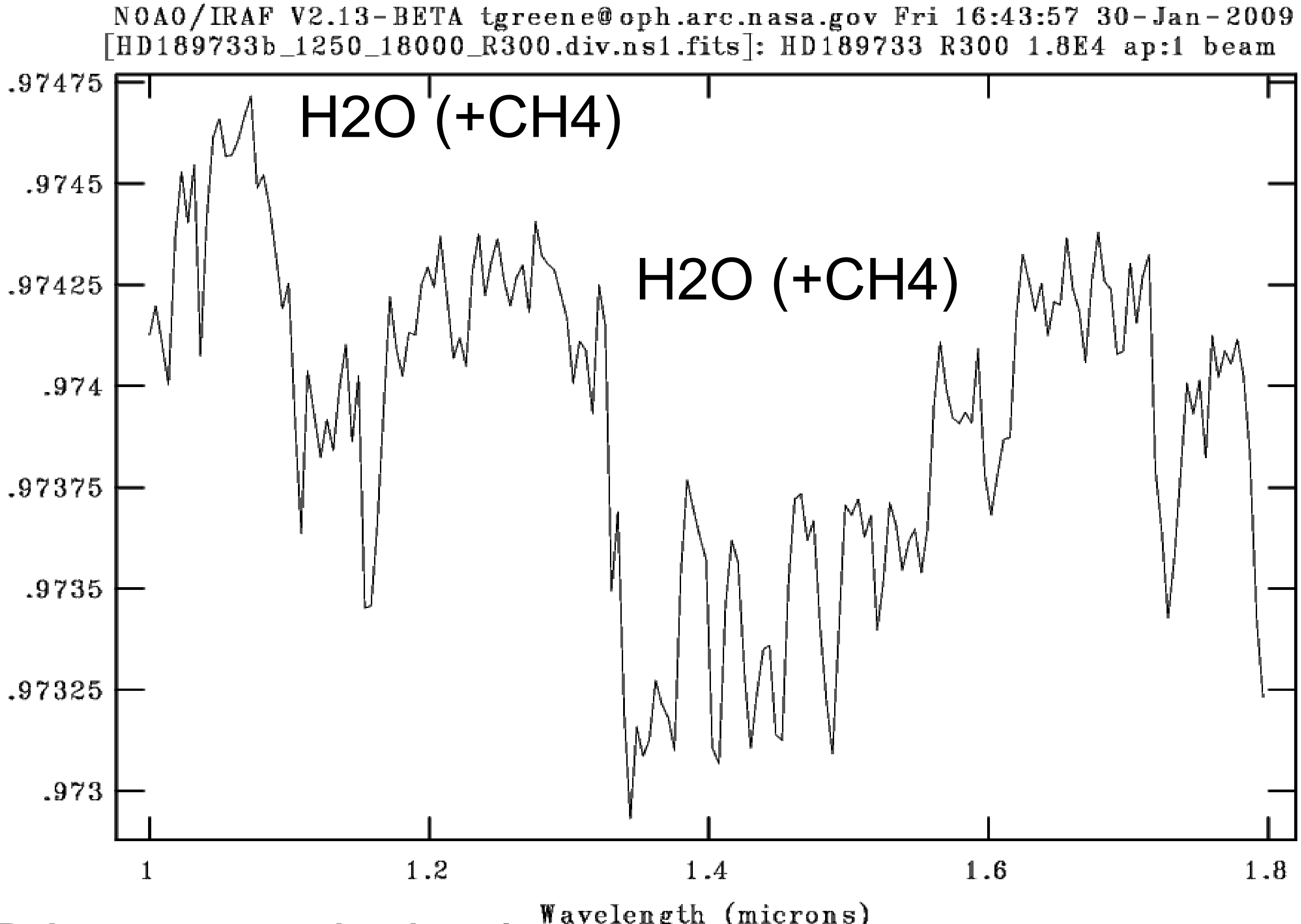




- Over 50 exoplanets characterized via both transits and RV (only 11 in 2007); numerous Spitzer secondary eclipse observations)
- About half are ~ Jovian mass & size

# JWST Transit Capabilities (1)

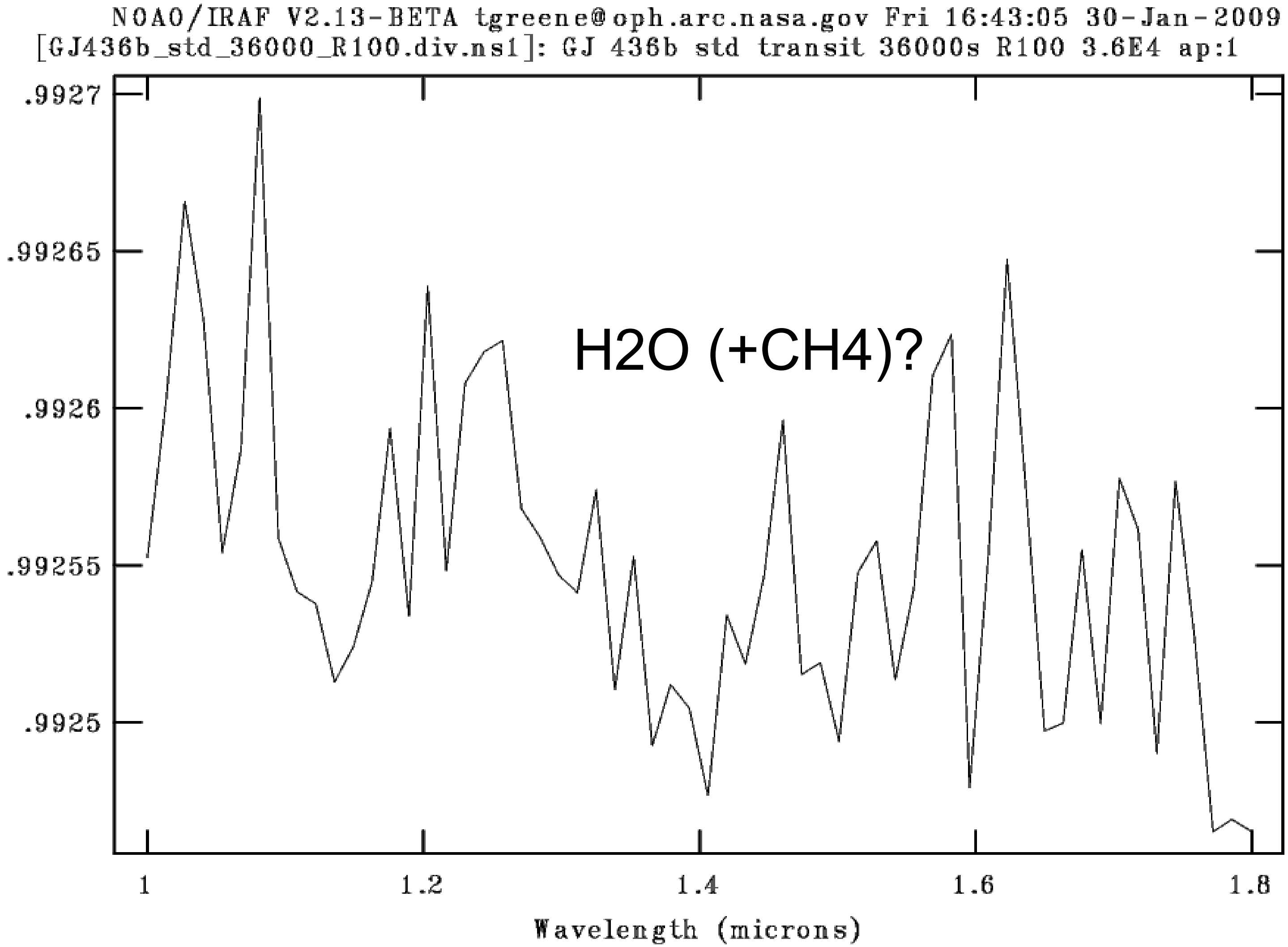
- ***How much better will JWST be than Spitzer or Hubble that are producing such great results today?***
  - Two major improvements
- Larger aperture has more area (25 vs 0.5 m^2) for collecting light - about 7x the effective diameter of Spitzer:
  - S/N should be 7x more than Spiter in same time
  - 50 x less integration time for Spitzer S/N
- We are still modifying the instruments to optimize them for transit observations!
  - Better near- and mid-IR capabilities overall
  - Reduce / eliminate slit losses in spectrographs
  - Studying spect. precision limits (Clampin, Deming, Lindler)
  - Optimize operation & calibration strategies (precision, bright limits)

# Simulation: HD 189733b should be great!



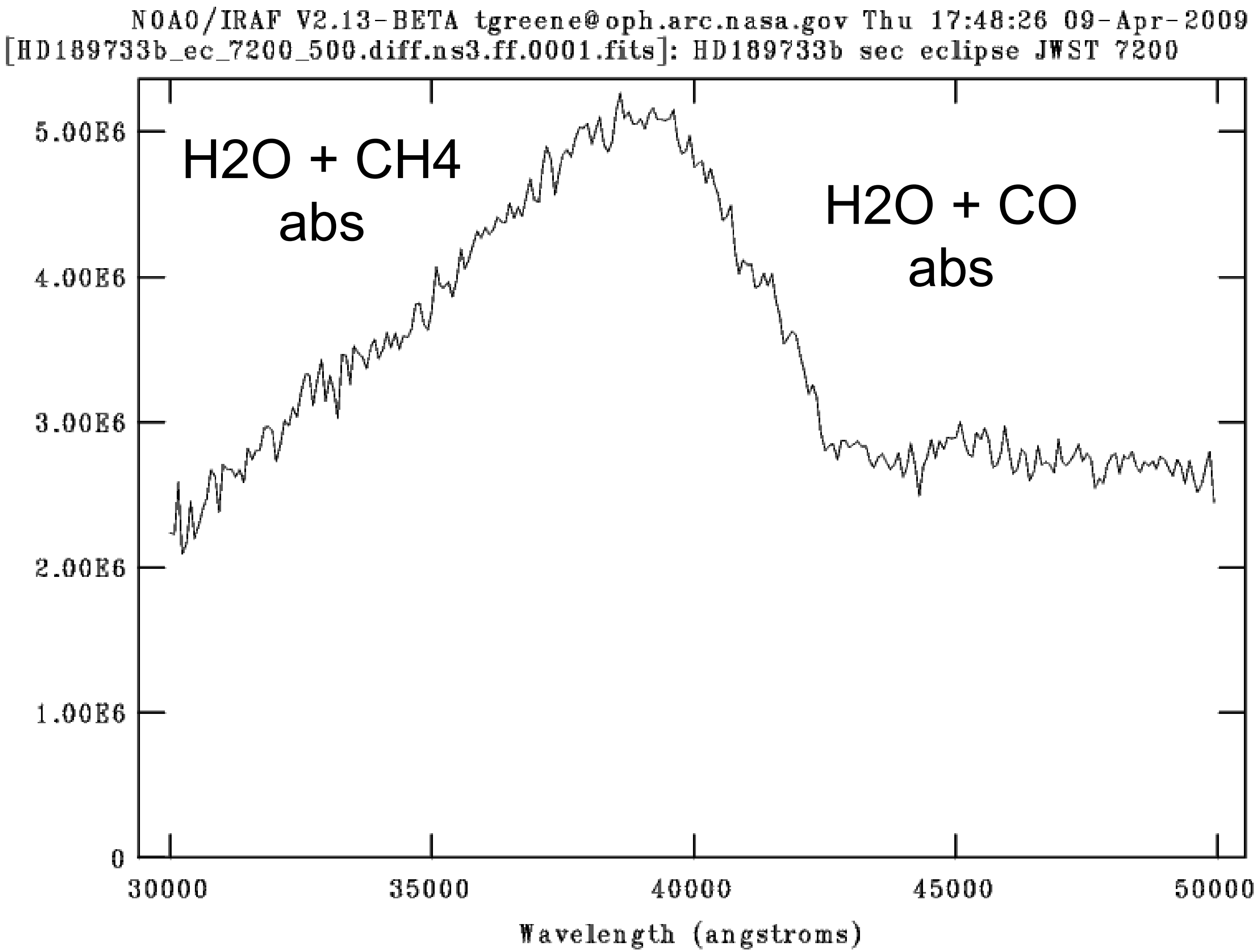

– Primary transit simulation
– Using T=1250K model from J. Fortney (10 hr )

# GJ 436b will be tough! (small & cold)

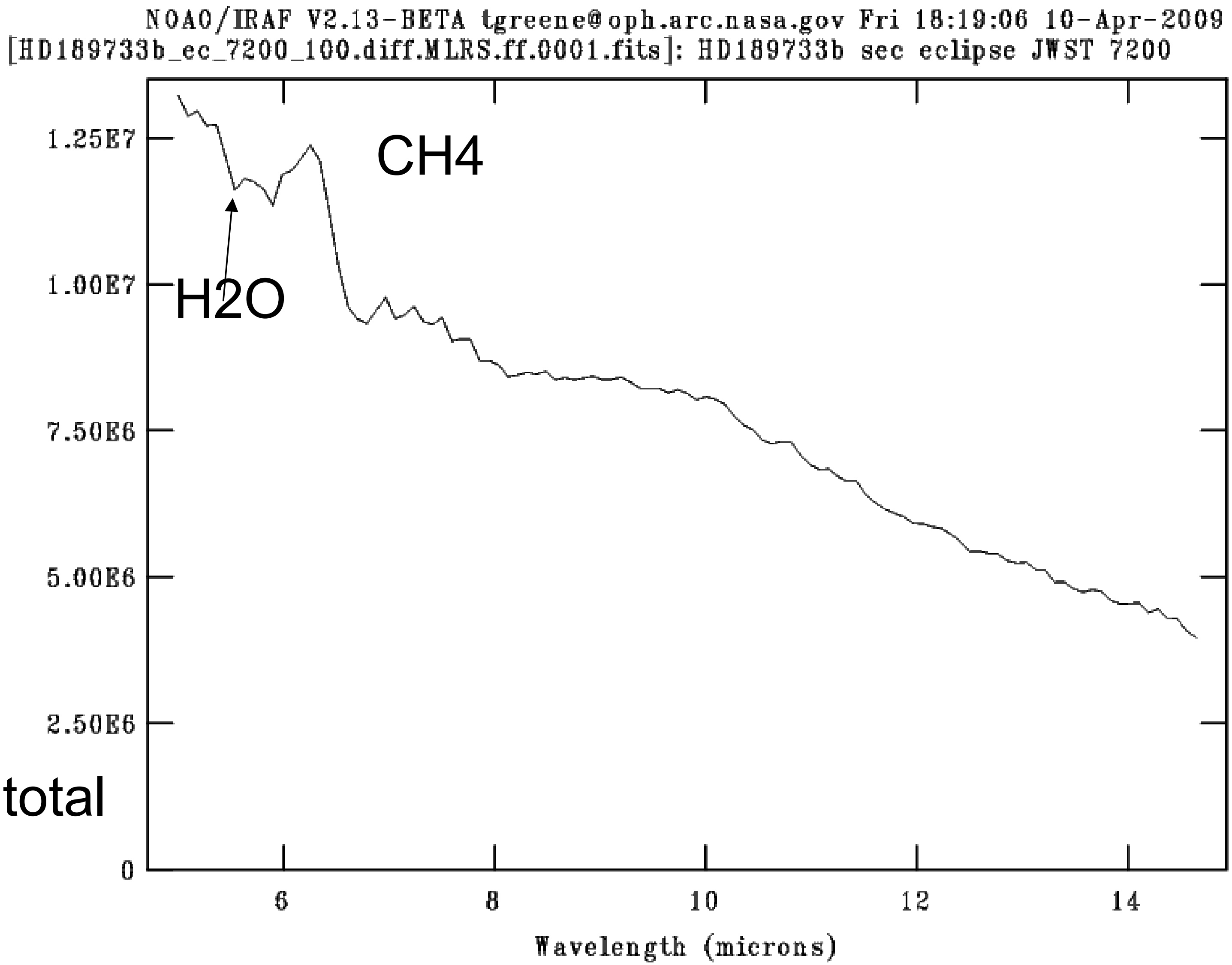



– Transit simulation using J. Fortney 1X solar model (20 hr)

# HD 189733b nIR Sec. Eclipse

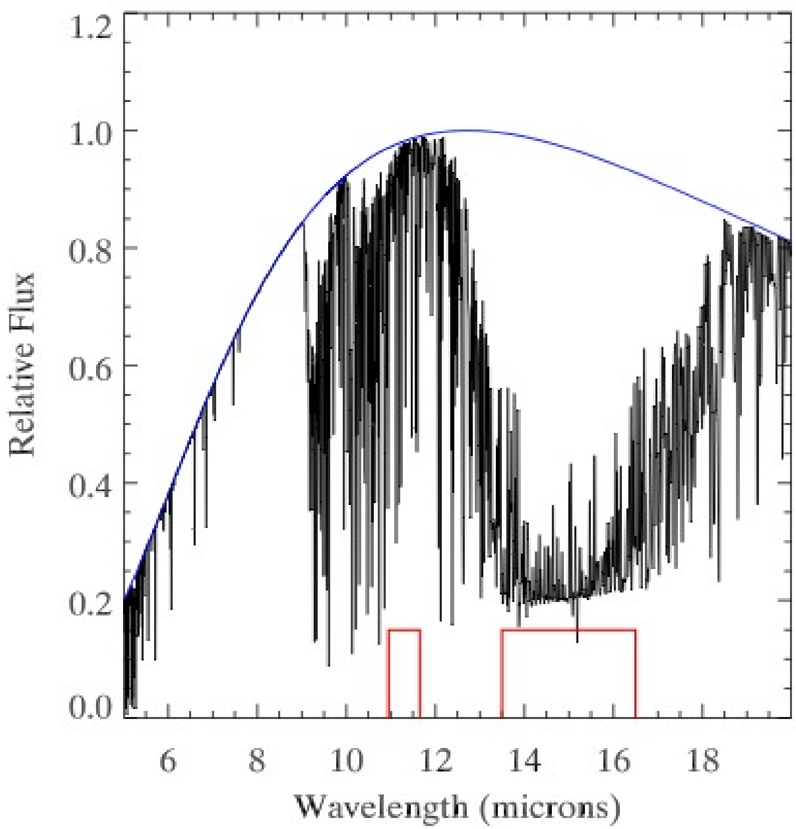


# HD189733b MIRI LRS R=100 simulation




t = 4 hr total

# MIRI detection of $CO_2$ abs. in Super-Earths




Deming et al. (2009) showing Miller-Ricci Super-Earth (2009) and MIRI filters

- JWST MIRI filters (red boxes, left) can be used to detect deep CO2 absorption in Super-Earth atmospheres (Miller-Ricci 2009 model, left)
- Modelling shows that modest S/N detections possible on several M star planets (Deming et al. 2009).

# JWST Exoplanet Summary

- NIRCam and TFI/NRM can image / characterize planets with a wide range of masses and separations
- JWST will *characterize hot giant planets* with high S/N and at R=100 – 500 spectral resolution with near-IR and mid-IR transit and secondary eclipse observations
  - Planet features detectable in a single transit @ R=500!
- Thermal emission from super-Earth transiting planets in habitable zones of M stars *can be detected* in a few transits in a broad-band 20 $\mu$m filter
- Characterization of some small planet atmsopheres possible
  - Exotic Super Earths (low gravity, H dominated atmospheres) possible!
  - Atmospheres of strict Earth analogs cannot be characterized
  - Stars produce too much photon noise