2009/3/10

南極における赤外線天文学

Transit observations of Exoplanets

NAOJ・ELT project
Takuya Yamashita

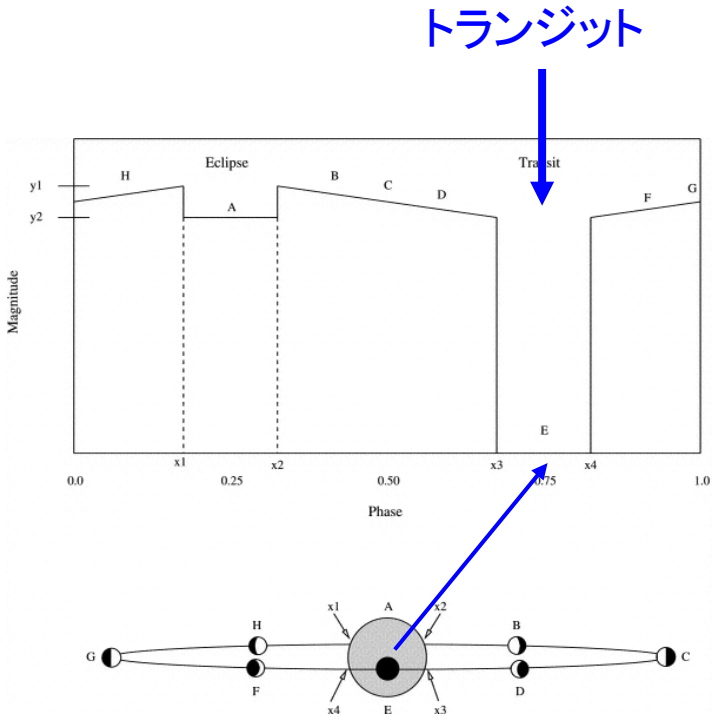
Outline

- Planetary Transit？
- 2ry Eclipse
- Atmosphere of Exoplanets
- Benefit of Antarctica
- Proposed Observations
  - New exoplanets survey for known transiting objects
  - 2ry Eclipse of known transiting exoplanets
- Summary

Planetary Transits？

- Exoplanets come across in front of host stars
  - Mercury and Venus show transits
  - It is observed as very small extinction of fluxes of host stars
- Chance coincidence is needed that a planetary orbit is seen nearly edge-on

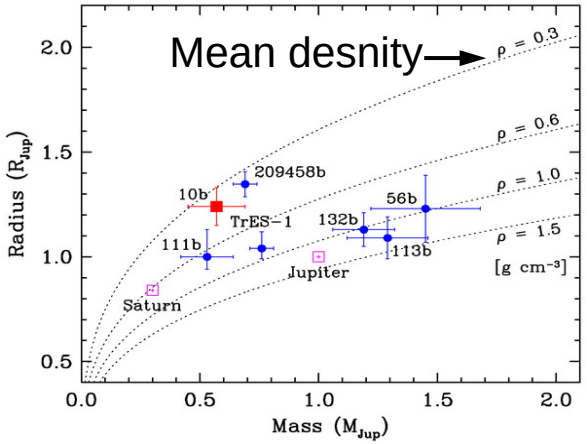
Transit of Venus



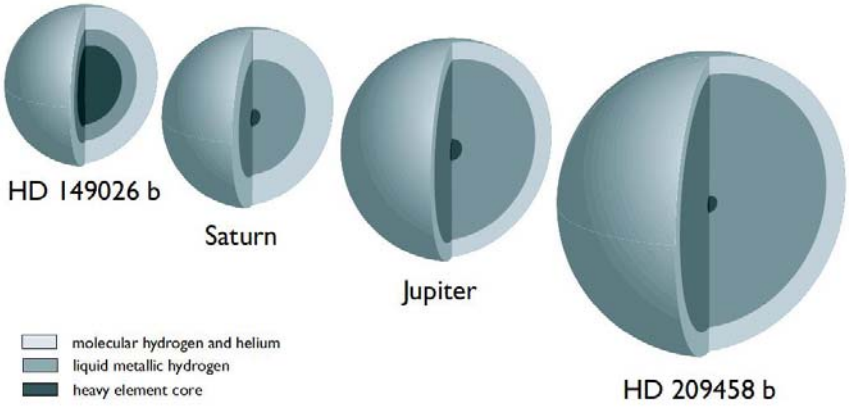
Rowe et al. 2006

Planetary Transits？

- What is known from transits?
  - Diameter of the planet
  - Inclination of Planetary Orbit
    - Resolves uncertainty of planetary mass derived from RV method
  - → Planetary density
- What is known from the density?
  - Composition
    - Gas giant (Jupiter-type)?
    - Rocky Planet（Earth-like）?
    - Ice Planet（Uranus-type）?
  - Interior structure
    - E.g., Interior of gas giants
      - Mass ratio of a core
    - Important for planet formation



Konacki et al. 2005

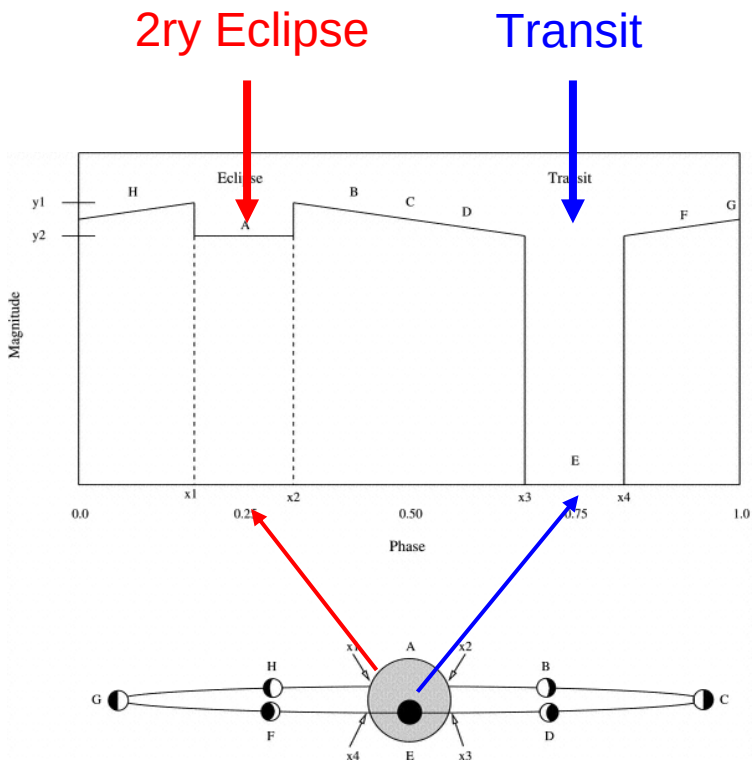


Current Status of Transit Observations

- Transit Survey
  - Small dedicated telescope
    - TrES, HATnet, XO, SuperWASP
    - 10cm class camera lens
    - Short period (1-10days) gas giants are found
  - Intermediate Telescope
    - OGLE(Optical Gravitational Lensing Experiment): 1.3m
      - Mainly for micro lensing event
      - Difficult to follow up due to faint targets
  - Dedicated Space missions
    - CoRoT: 2006/12/27 launch
      - 27cm、150days×5 field、Rocky Planets
    - Kepler: 2009/3/6 launch
      - 95cm、4 years 1field、Earth-like Planets

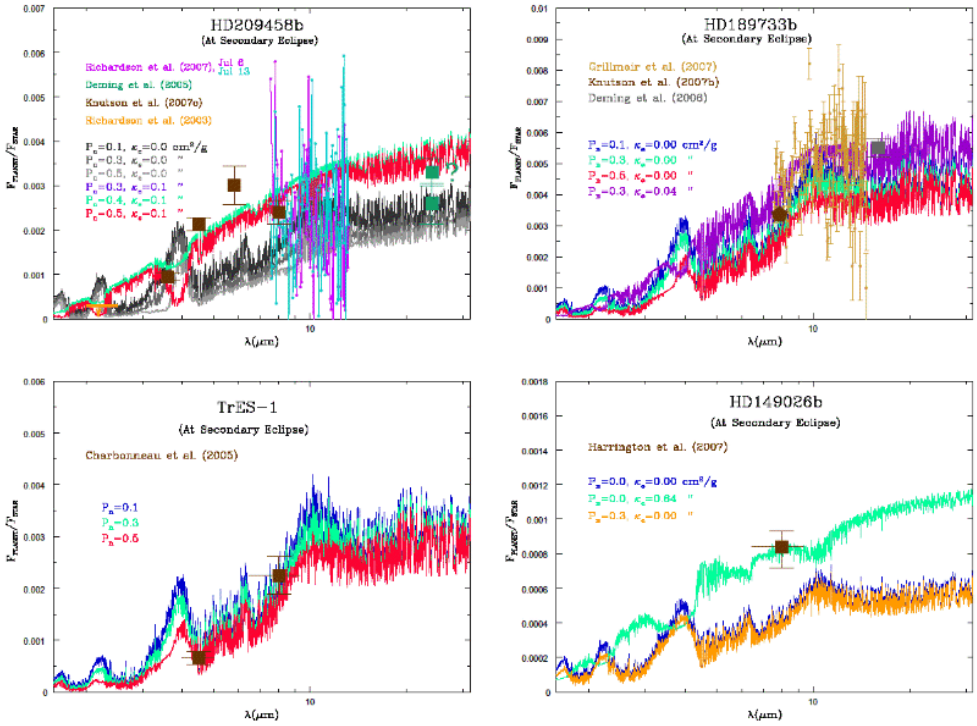
2ry Eclipse

- A planet is hidden by a host star
  - Inverse process to transit
    - Radiation from planets are dimmed during this process
      - Thermal emission (IR)
      - Scattered light (Optical)
  - Extinction is extremely small
- What is known ?
  - Planetary Surface
    - Thermal emission form the ground and atmosphere (IR）
    - Reflected spectrum by the ground and the atmosphere (Opt)
    - Absorption due to the atmosphere(Opt, IR)

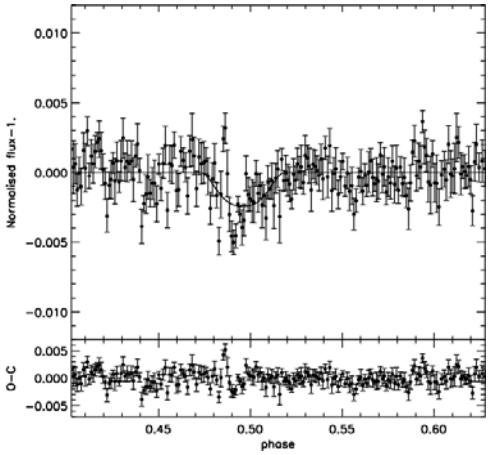


Current Status of 2ry Eclipse Observations

- Spitzer（longer than 3.5 μ m）
  - Left figure（Comparison with models）
- Ground based observation
  - Recently detected（Right figure）



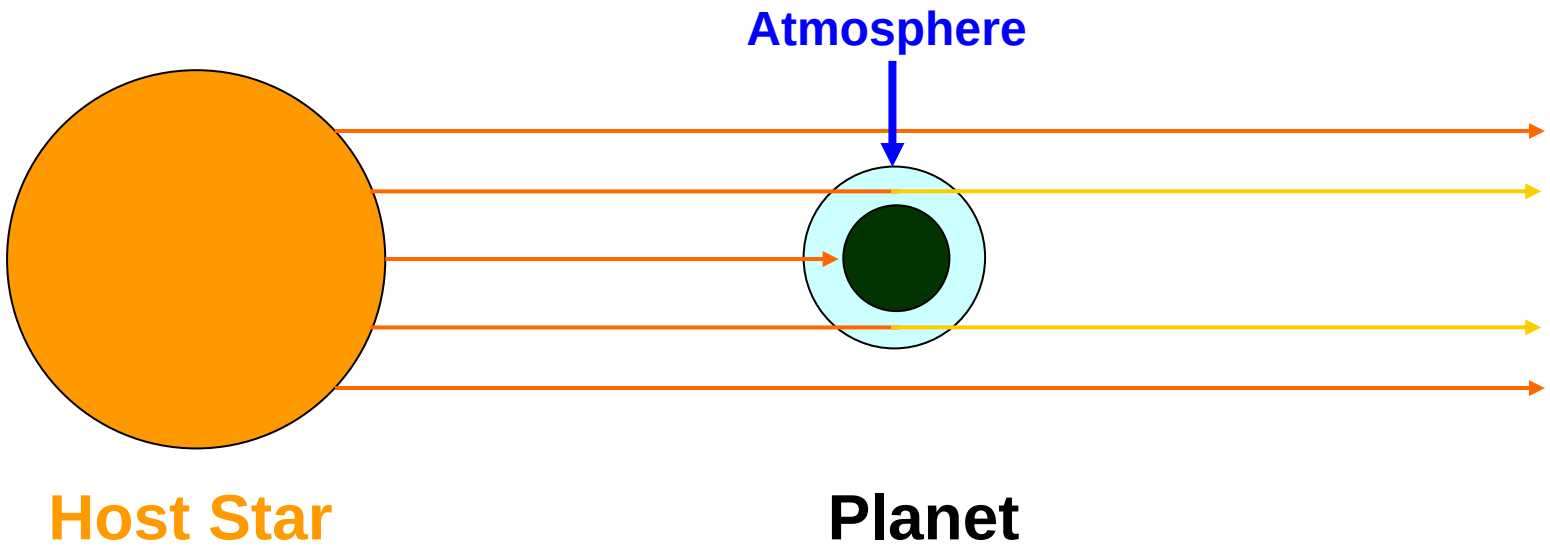
Burrows et al. (2007)



TrES-3; de Mooij et al. (2009)

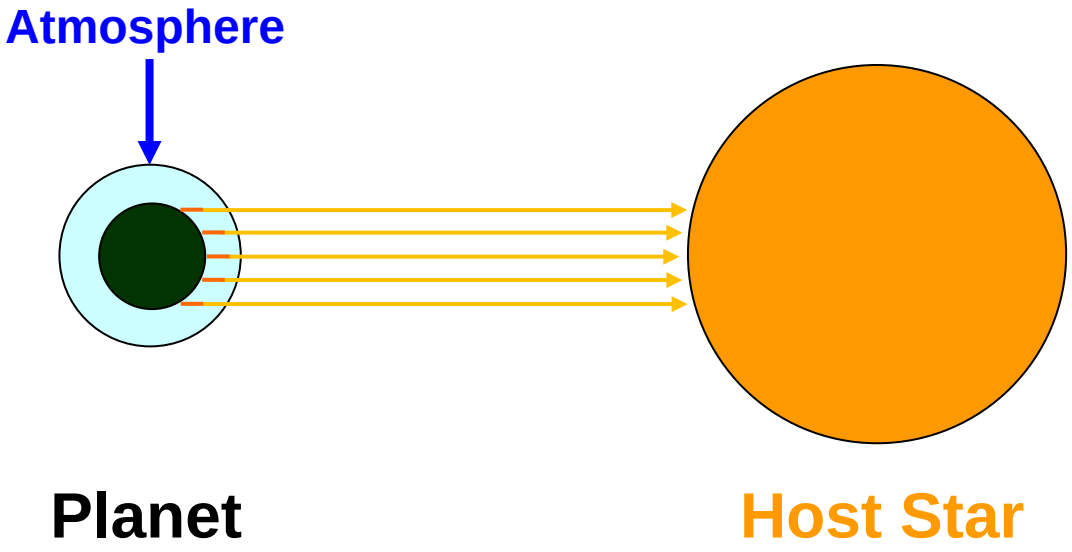
Planetary Atmosphere (Transit)

- Planetary atmosphere can be studied during the transit
  - Light from a host star is absorbed by the planetary atmosphere
  - Atmospheric gas has their specific absorption features
  - Planetary gas components are known by spectroscopy



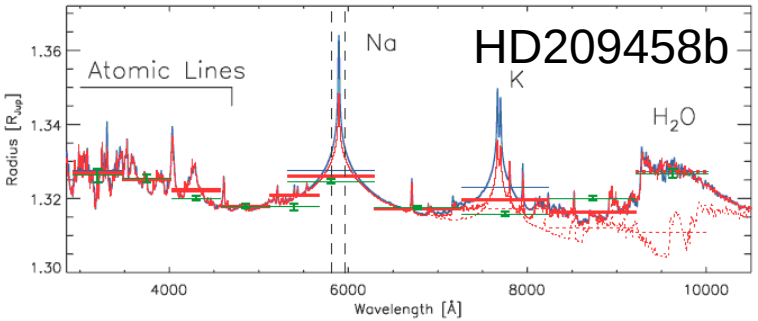
Planetary Atmosphere (2ry Eclipse)

- We can measure planetary atmosphere at the 2ry Eclipse
  - Light from the ground (or lower atmosphere) is absorbed by the atmosphere
  - Thermal emission from planetary atmosphere can be observed depending on the thermal structure
  - Planetary gas components are known by spectroscopy

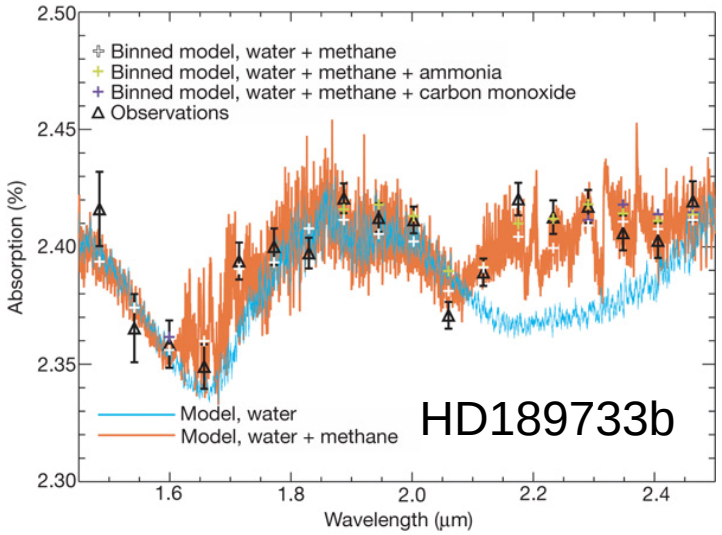


Current Status of Atmospheric Studies

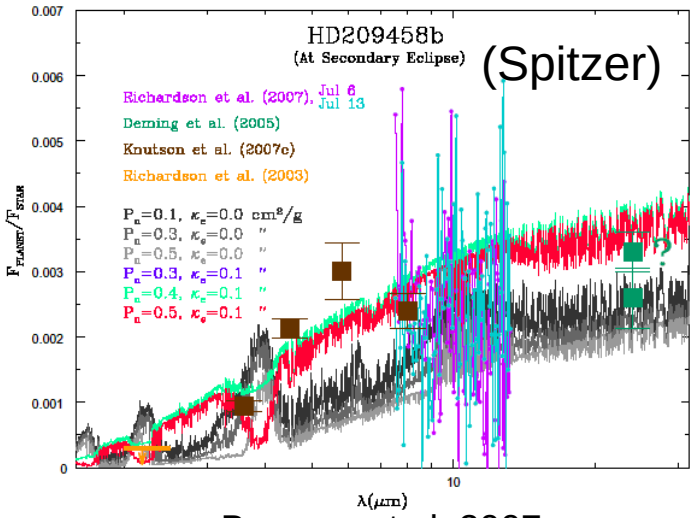
- Transmission Spec. at Transits
  - Lower Atm.：Na
  - Upper ouflowing Atm：Lyα、OI, CII
  - Water vapor, Methane
- Emission Spec. at 2ry Eclipses
  - No successful spectroscopy
  - Photometric data are used



HST STIS: Barman et al. 2007



HST NICMOS: Swain et al.2008



Burrows et al. 2007

Benefits at Antrctica

- Long lasting nights
  - Continuous Observation
    - Do not miss long period transit phenomena
    - Currently detected transits have peridos between 3-10 days a= 0.03 - 0.1AU（Mercury：P=87days, a=0.39AU）
- Little change in object altitude, and small water vapor, and stable condition
  - High photometric accuracy
    - Even a small extinction can be detected
    - Small transiting planets can be discovered
- Low temperature and small water vapor
  - High sensitivity in the Infrared
    - Small telescope can attain high sensitivity

What observations can be benefitted?

- Survey for new transiting planets (Cont)
  - Long period transit can be targeted (v.s. space mission)
    - ASTEP (Antarctic Search for Transiting Extrasolar Planets)
      - Dome C, 10cm fixed telescope, 4k×4k CCD, 4° ×4° FOV

- Transit phenomena for known long period RV planets (Cont)
  - Proposed by Dr. Takato

- New transiting planets for known transiting systems
  - Other planetary orbits are expected to be alighned
  - Long period and/or small planets (Cont) (Hi Acc.)

What observations can be benefitted?

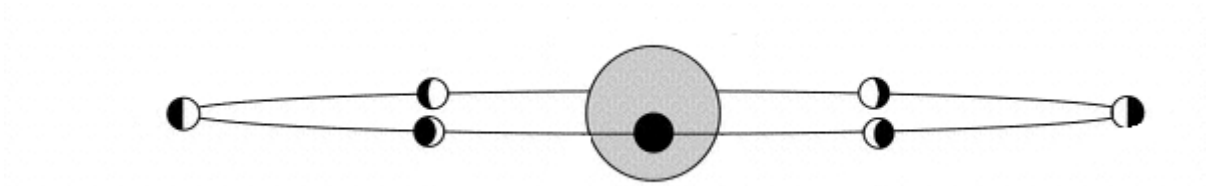
- 2ry Eclipse Hi Acc.
  - 2ry Eclipse of known transiting planets
    - Detect thermal emission fromexoplanets

- TTV (Transit Timing Variation) Cont
  - The presence of exo-moon, ring and other planets

- Spectroscopy of planetary Atmosphere Hi Acc.
  - May be difficult with 40cm ?

New planets for know transiting systems

- Target：known transiting systems
  - Long period and/or small planets
    - Currently known transiting planets are very short-period
      - » P = 1 – 10 (17) days, a = 0.02 – 0.1 AU
      - » P = 88 days, a = 0.39 AU (Mercury)
    - Most are Jupiter sized ones
    - More like solar system → Longer period and/or small planets
  - Why known transiting systems?
  - Orbits of other planets are expected to be along the line of sight
    - For our solar system $\Delta i < 2^\circ$ (Except for Mercury)



New planets for know transiting systems

- Method
  - Optical (IR is also OK、Opt. sensitivity is better?）1band
  - Interval is less than transiting event（3hr）
  - Comparison star is available within the same field
    - For photometric accuracy
  - Depth of the transits
    - Jupiter size：1%
    - Neptune size：～0.1%
    - Earth size：～0.01%

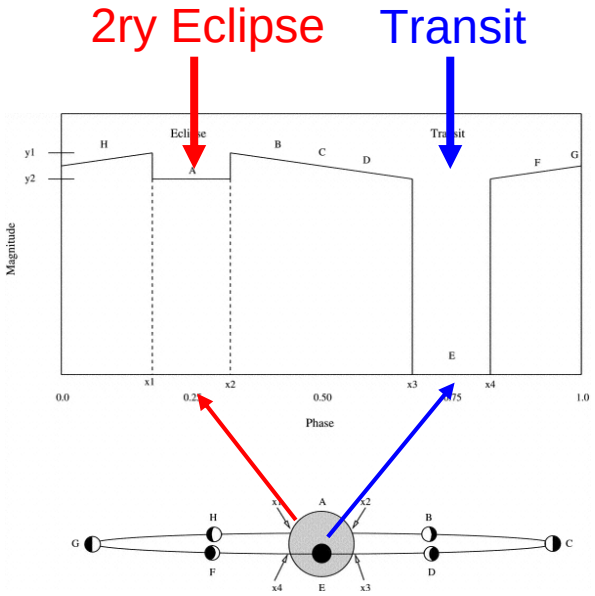
    } Targets
  - High system stability and also stability of the target is important

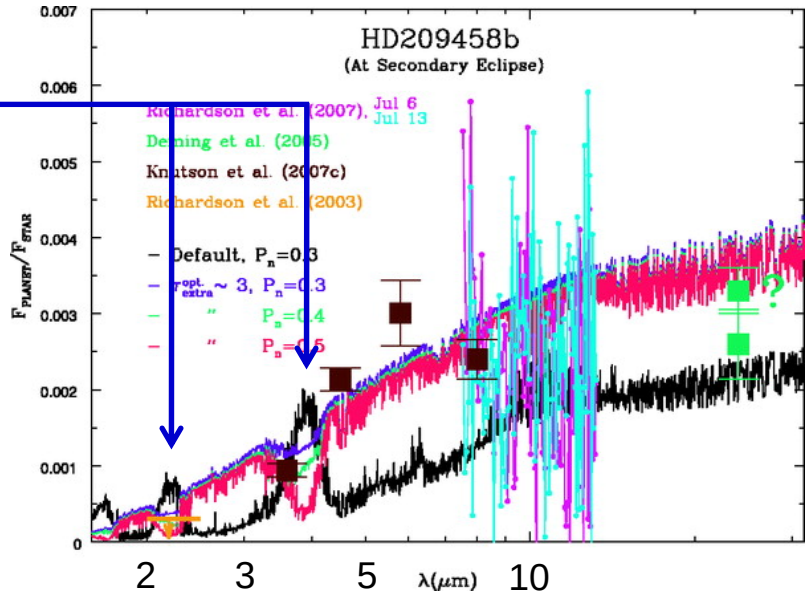
New planets for know transiting systems

- Candidate conditions
  - Decl. < -30°
  - V > 12.5 mag (S/N > 1000 for 200sec integration)
    - 0.1 % → R ～ $0.3 \times R_{Jup} \sim 1 \times R_{Nep} \sim 3 \times R_{Earth}$
- Currently available targets
  - WASP-4b,-5b, 7b, 15b
- Small number of targets !
  - Transit surveys are not active for southern sky
    - HAT-South will be added to Super WASP
  - Space mission will provide new transiting system but already done

2ry Eclipse of known transiting planets

- What will be revealed?
  - Hot Jupiter
    - Thermal emission from the atmosphere: Surface temperature
  - Atmospheric structure: Not yet revealed with Spitzer
    - Low S/N ratio for spectroscopy
    - Weak features among Spitzer wavelength coverage
    - Inversed layer？
  - 2 μ m band flux can offer important information
  - Without other wavelength data, NBF (3 parts in the K band) is preferable (also good for transits)





2ry Eclipse of known transiting planets

- Targets: Known transiting planets
- Method
  - Near Infrared
  - Photometric observation around expected 2ry Eclipse time
  - Comparison star is available within the same field
    - For photometric accuracy
  - Typical depth of 2ry Eclipse
    - Less than 0.1%
  - High system stability and also stability of the target is important

2ry Eclipse of known transiting planets

- Candidate conditions
  - Decl. < -30°
  - K > 10.0 mag (S/N > 1000 for 200sec integration)
    - Typical depth for 2ry Eclipse ～ 0.1%
- Currently available targets
  - WASP-4b,-5b, 7b, 15b (same as pthe revious proposal)
- Small numbers of targets
  - HAT-South will be added to Super WASP
  - Space mission will also provide new transiting system
  - However, until JWST will be launched

Summary

- Proposed transit observations
  - New transiting planets for known transiting system
    - V.s. dedicated space mission
      - Different targets but the same science
  - 2ry Eclipse of known transiting systems
    - Before JWST will be launched (2013?)
- Currently only 4 targets are available
  - On-going survey will add more
  - Most of the transiting system found with small telescope can be the targets
    - Super WASP, HAT-South
- It is better, if prism spectroscopy (over NIR) is available
  - For both transmission and emission spectroscopy