Exoplanet ISDT Activity Report: TMT's Prospects for Exoplanets

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on behalf of Exoplanet ISDT

Agenda

We have received 28 key program ideas from ISDT!

- Necessary Instruments for exoplanet key programs
- Summary of proposed key programs by instruments
- Some matters to be noted

Necessary Instruments for Exoplanet Studies

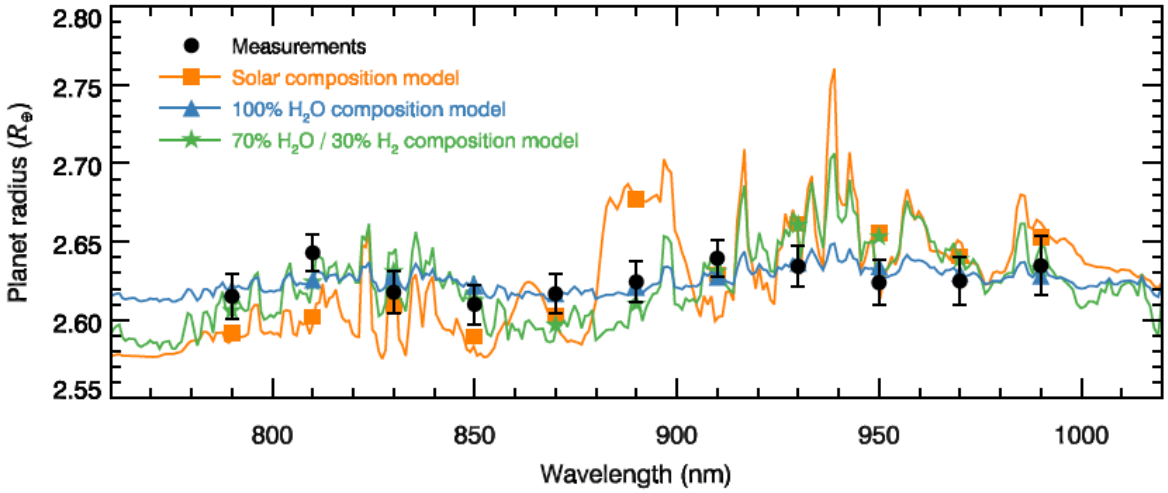
- First Light Instruments (WFOS, IRMS, IRIS+NFIRAOS)
- High Dispersion Spectrographs
  - NIRES
  - HROS
- High Contrast Imagers
  - PSI
  - MICHI

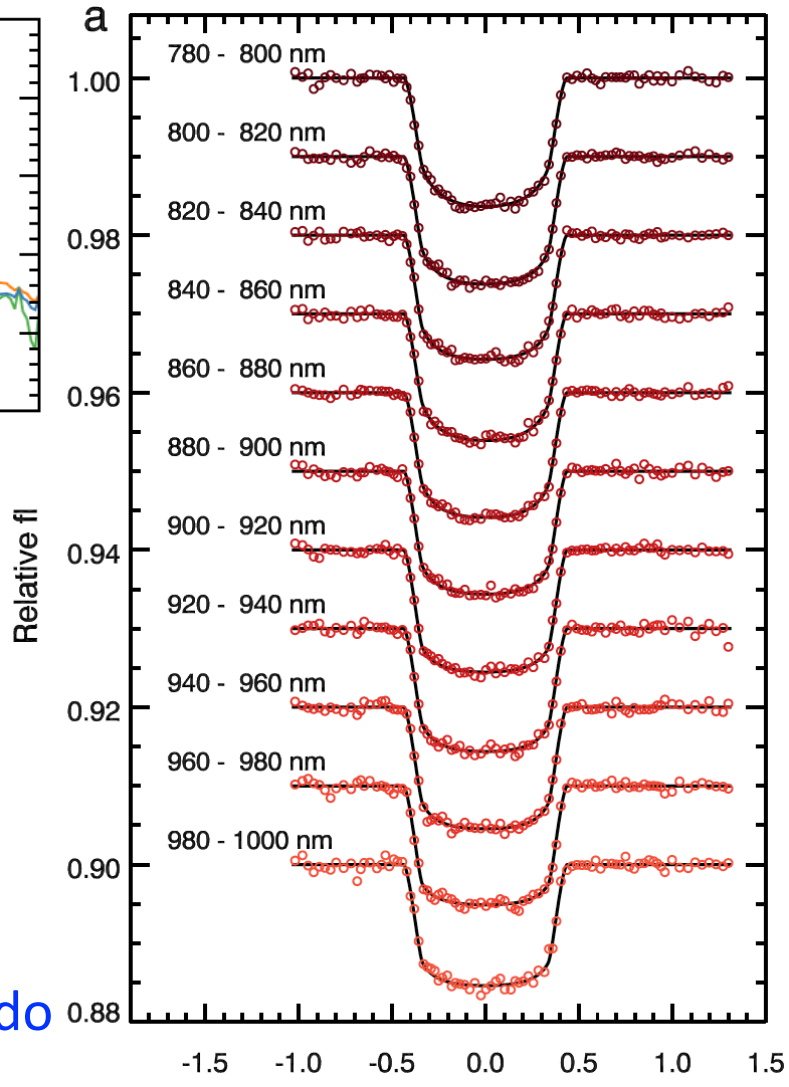
Key Program Ideas: WFOS & IRMS

- MOS capability of WFOS and IRMS are useful for transmission spectroscopy of transiting exoplanets

- Probing atmospheres of transiting exoplanets discovered by K2 and TESS

MOS is a powerful tool for this purpose





- Instrument: VLT/FORS2
- Target: GJ1214b (V=14.7)
- Integration: 20 nm (R ~ 30)
- Precision: ~400 ppm
- TMT's FL instruments (MOBIE, IRMS) can do

Key Program Ideas: WFOS & IRMS

- WFOS (optical)
  - planets in super-Earth / mini-Neptune boundary
  - disintegrating (evaporating) planets
- IRMS (NIR)
  - secondary eclipse mapping for hot planets
    - ✓but may overlap with JWST science
- TMT's merits
  - narrower wavelength binning (higher spectral resolution)
  - higher SNR for faint host stars
  - better time resolution

Key Program Ideas: IRIS+NFIRAOS

- Microlensing follow-up to resolve source and lens stars
- Astrometric search for planets around brown dwarfs

Ground & Space Microlens Survey

2.4m WFIRST-AFTA

- Existing Hardware: high quality mirror and optical system
- Easily used in Three Mirror Anastigmat
  - Wide field of view
  - 3rd mirror in Wide-Field Imager primary instrument

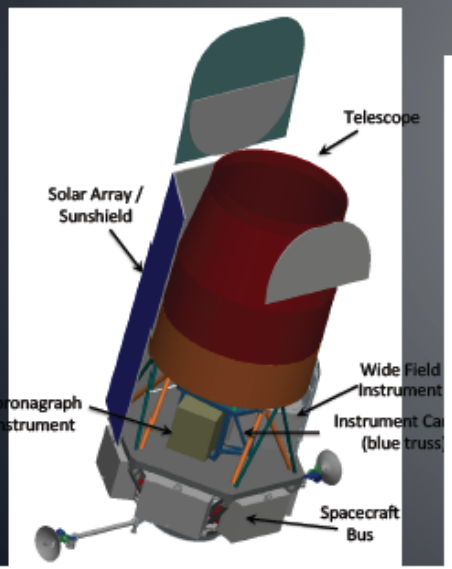
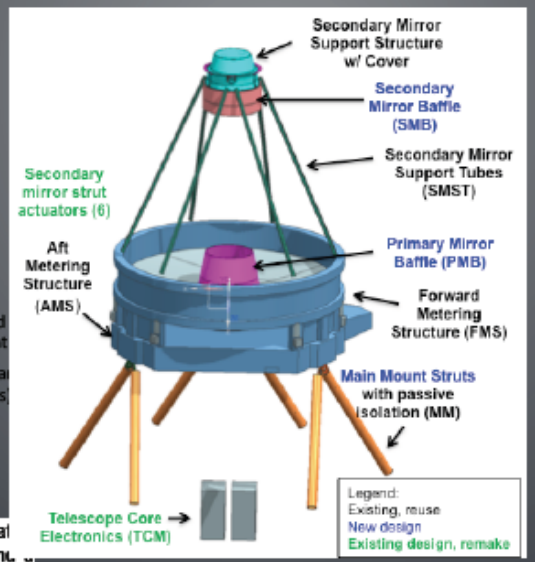


Figure 3-3: WFIRST-2.4 Observatory configuration feat ing the 2.4-m telescope, two modular instruments and modular spacecraft. bus



The telescope entrance pupil

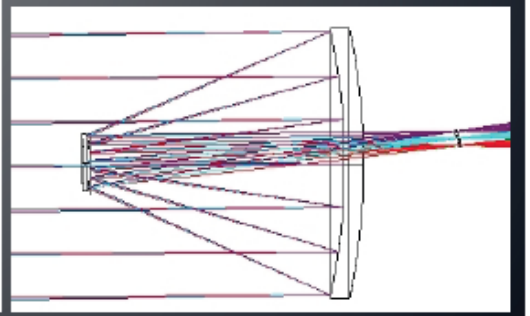
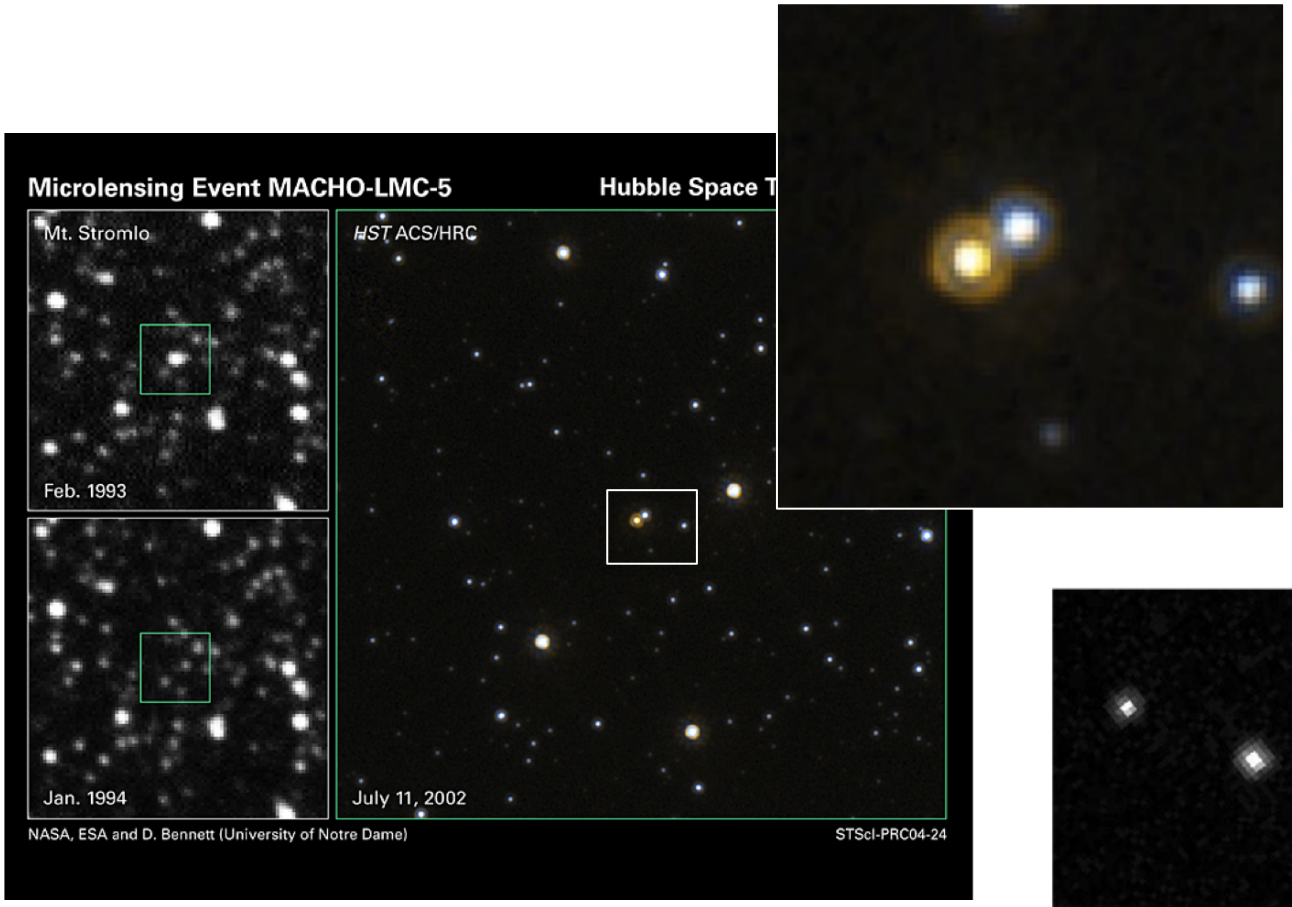


Figure 3-6: Ray trace through the telescope to the wide field channel intermediate focus.

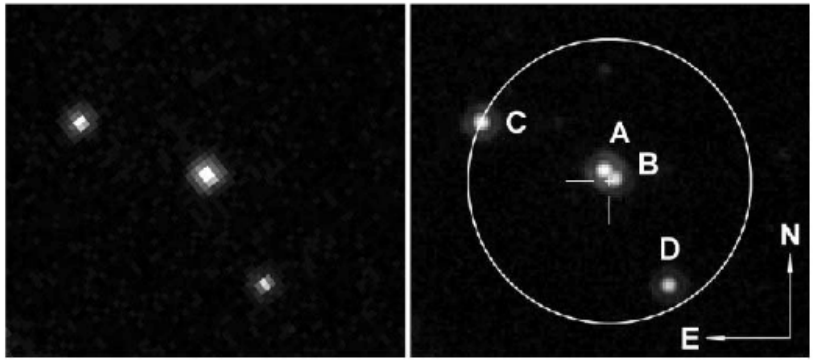
Planet host mass and distance need follow-ups

- So far lens and source have been separately resolved for only two (non-planetary) microlensing events.



MACHO-LMC-5:
Alcock et al (2001);
Drake et al (2004)
[exceptional large proper motion:
~20 mas/yr]

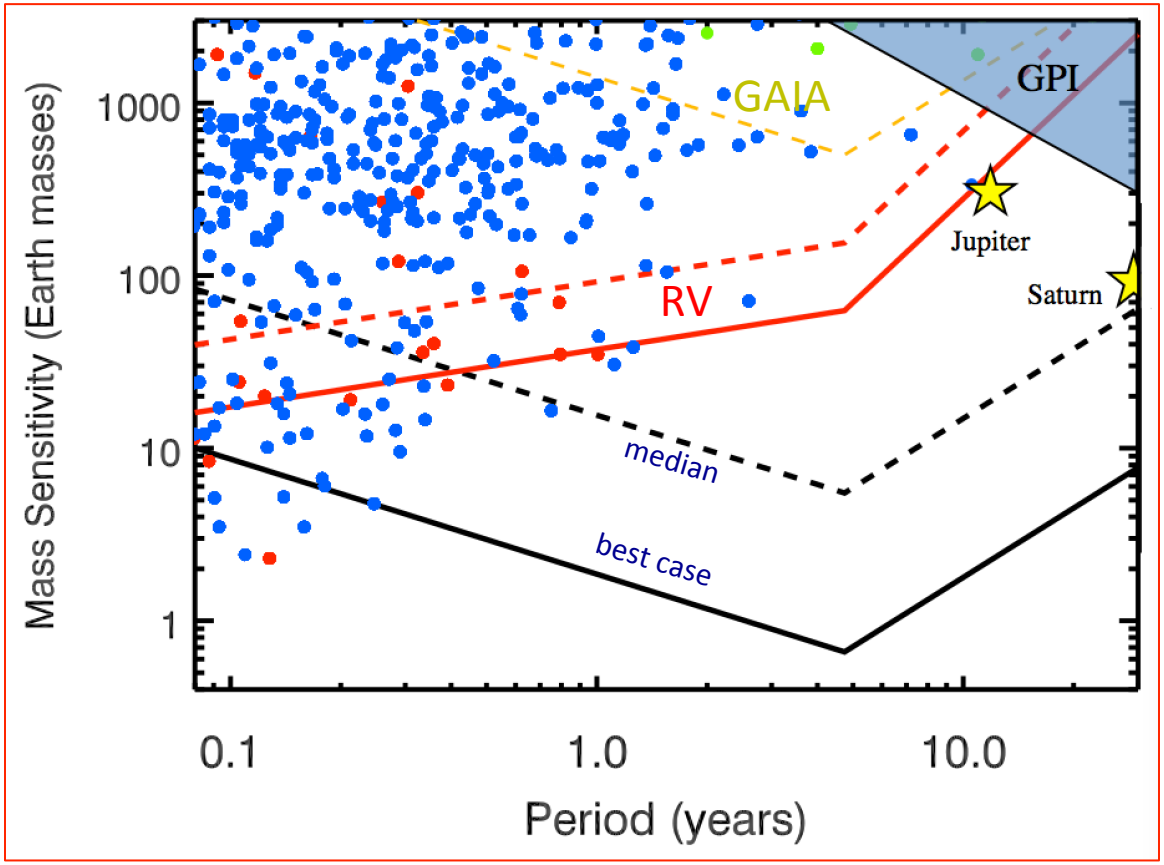
MACHO-95-BLG-37:
Kozlowski et al. (2007)
[~11 mas/yr]



TMT IRIS+NFIRAOS will critically enhance the science values of microlensing discoveries

- Host mass and distance measurements will enable:
  - Accurate determination of planet mass function
  - Many target: WFIRST-AFTA will discover ~3000 planets within 0.3-30 AU down to 2 Moon mass + free-floating Mars.
  - Studying planet distribution for different stellar environments:
    - ✓ Dependency as a function of stellar mass
    - ✓ Bulge vs. Disk
    - ✓ Metal Rich vs. Metal poor

Precision Astrometry with TMT+IRIS Enables Astrometric Surveys of Brown Dwarfs for Orbiting Exoplanets

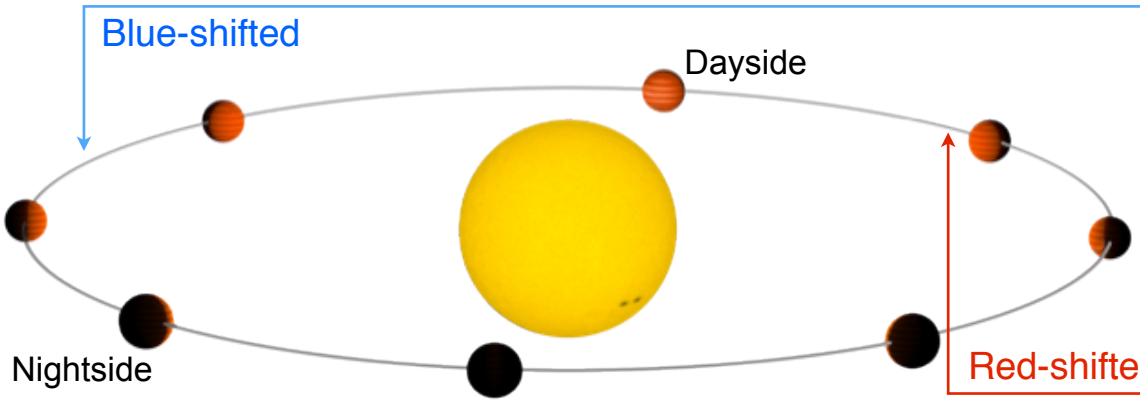


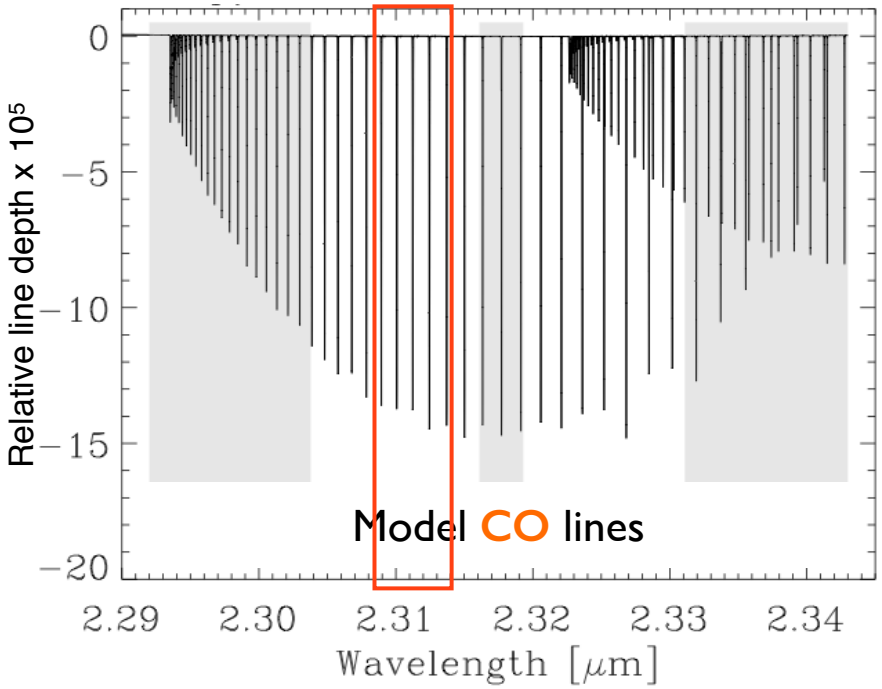
- Exoplanet mass sensitivity curves (5-sigma) for a 5-year astrometric survey for exoplanets orbiting L/T brown dwarfs
- Distance = 2-20 pc
- 0.02 – 0.04 mas TMT+IRIS precision
- 200 m/s RV precision (brown dwarf hosts)

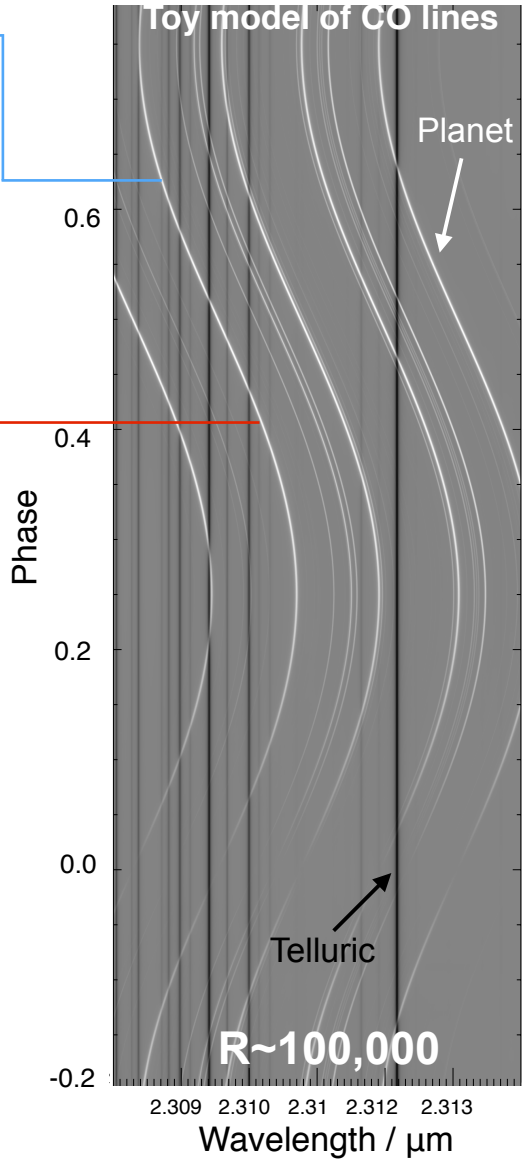
Key Program Ideas: NIRES & HROS (I)

- Probing atmospheres and dynamics of planets
- Search for oxygen molecule on habitable planets
- Doppler imaging and mapping of directly imaged and short-period planets

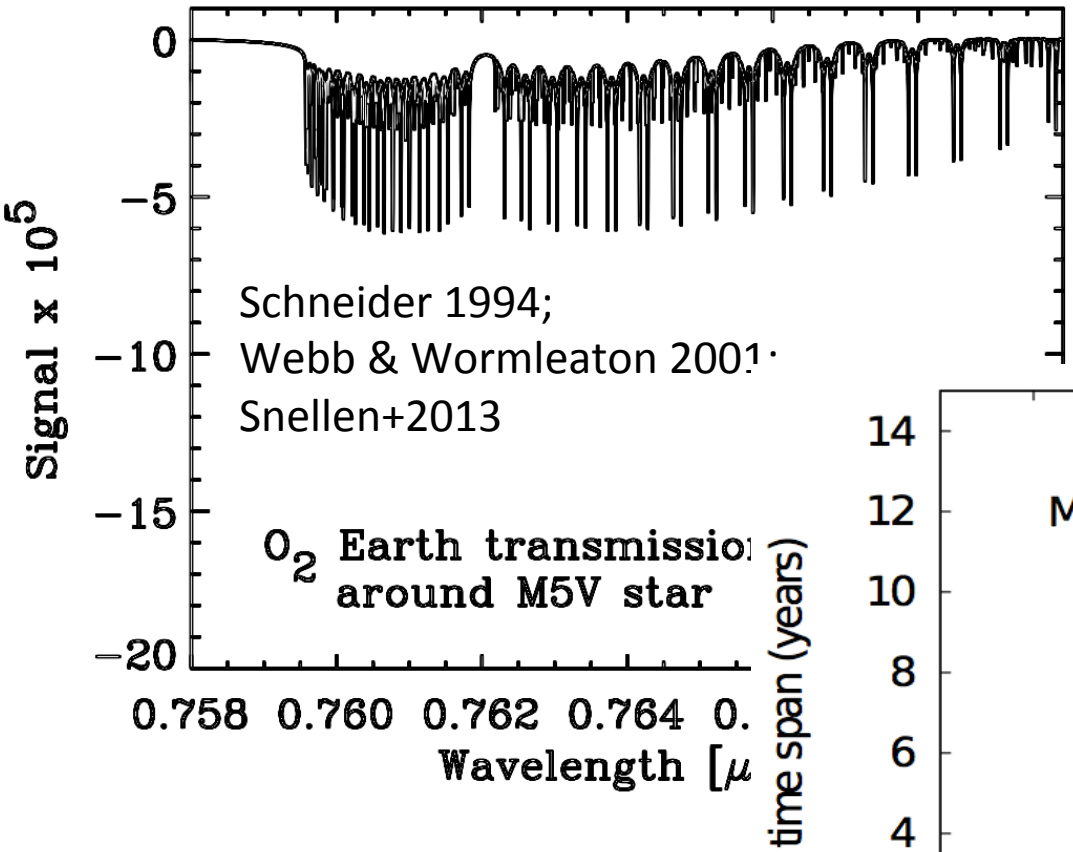
NIRES/HROS can probe planetary atmospheres and dynamics



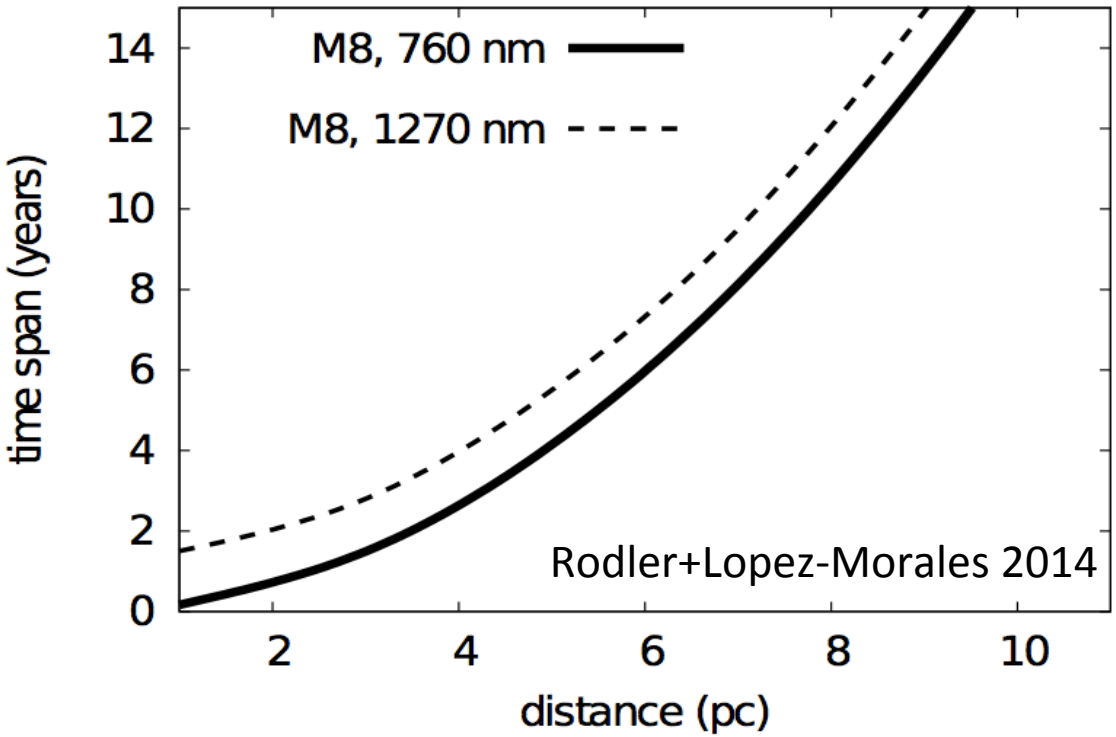




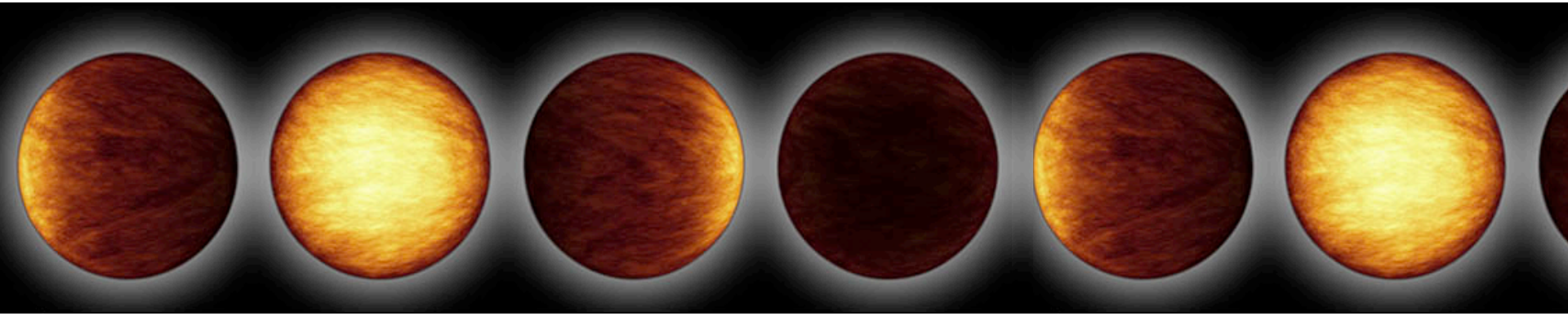
HROS/NIRES: Detecting O_2 with high-dispersion Doppler spectroscopy

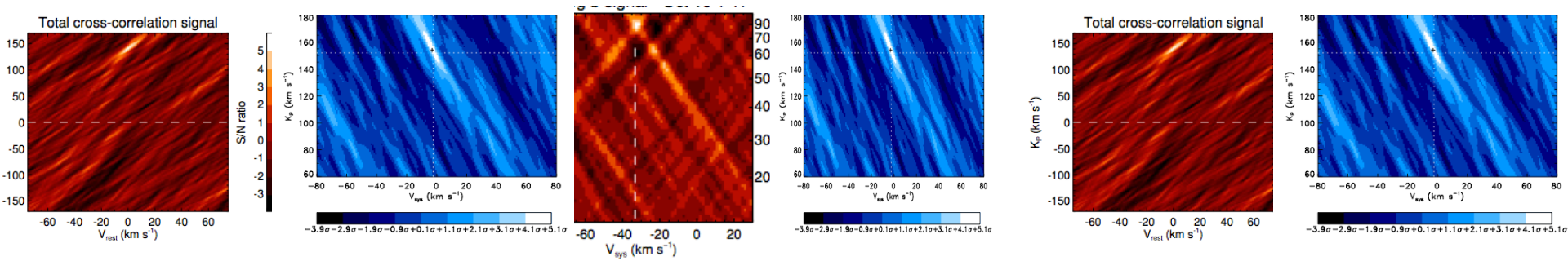


Schneider 1994;
Webb & Wormleaton 200
Snellen+2013



NIRES can probe compositions, orbital motion, atmospheric dynamics and thermal structure of (non-)transiting planets **as a function of longitude**





Brogi+2013, 2014, Birkby+2014, de Kok+2013, Rodler+2013a, b

Key Program Ideas: NIRES & HROS (II)

- Search and characterization of planets around white dwarfs, brown dwarfs, and young stars
- RV follow-ups of especially interesting targets discovered by Kepler, K2, TESS, PLATO

Requests for NIRES & HROS

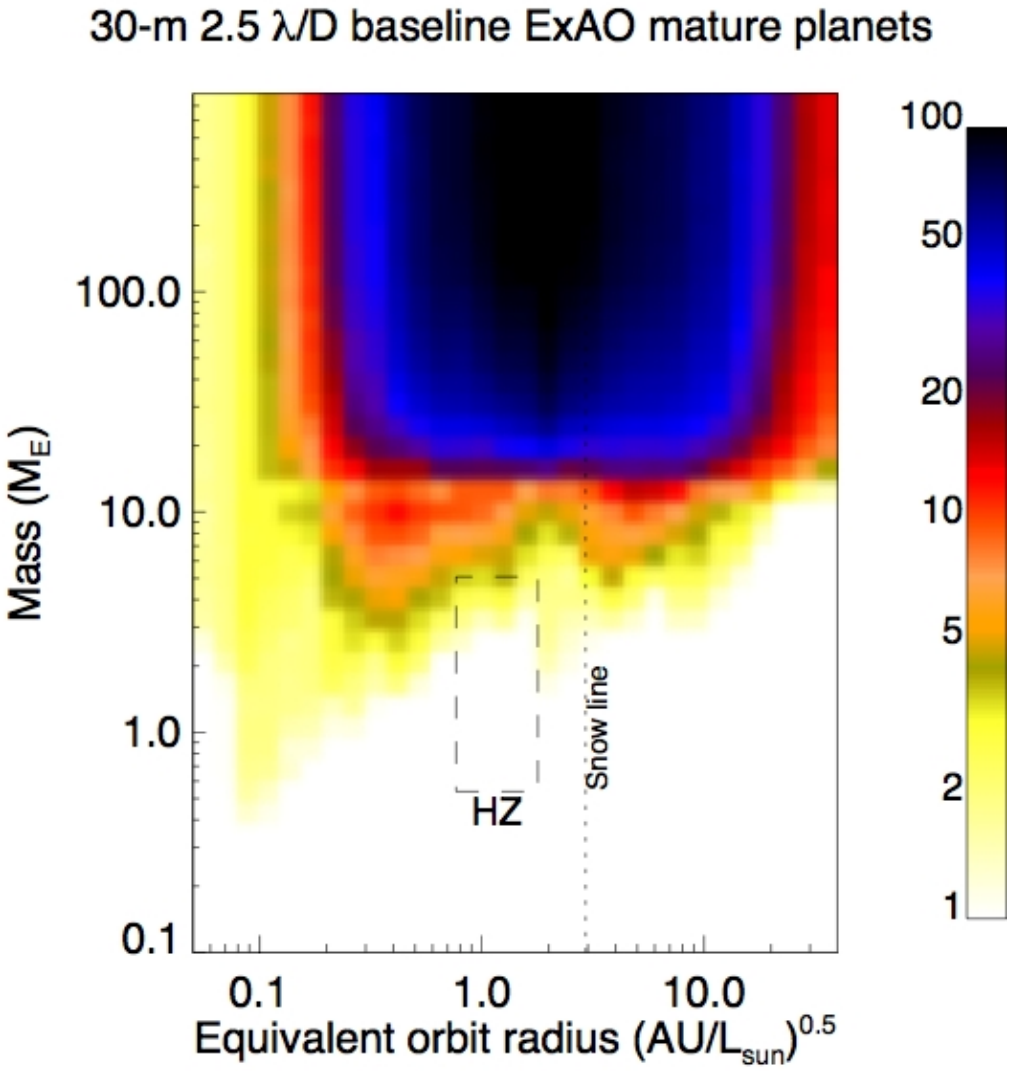
- Spectral resolution: ~100,000 is desirable (~50000 minimum)
- RV measurement capability: astro-comb, stable environment
- Simultaneous capability: NIRES+HROS can be the most efficient, can reduce systematic errors

Key Program Ideas: PSI

Note: PSI = PFI + SCExAO + SEIT

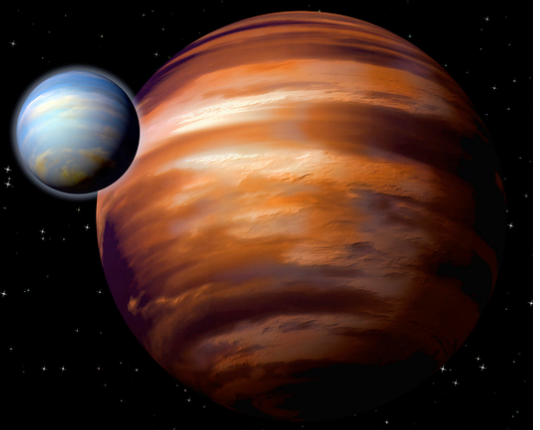
- Search for young planets in planet forming regions
- Search for exomoons around directly imaged planets
- Detect small planets in HZ around nearby M dwarfs
- HCI + NIRES for probing directly imaged planetary atmospheres

PSI is capable to detect sub-Suturn mass planets in planet forming regions



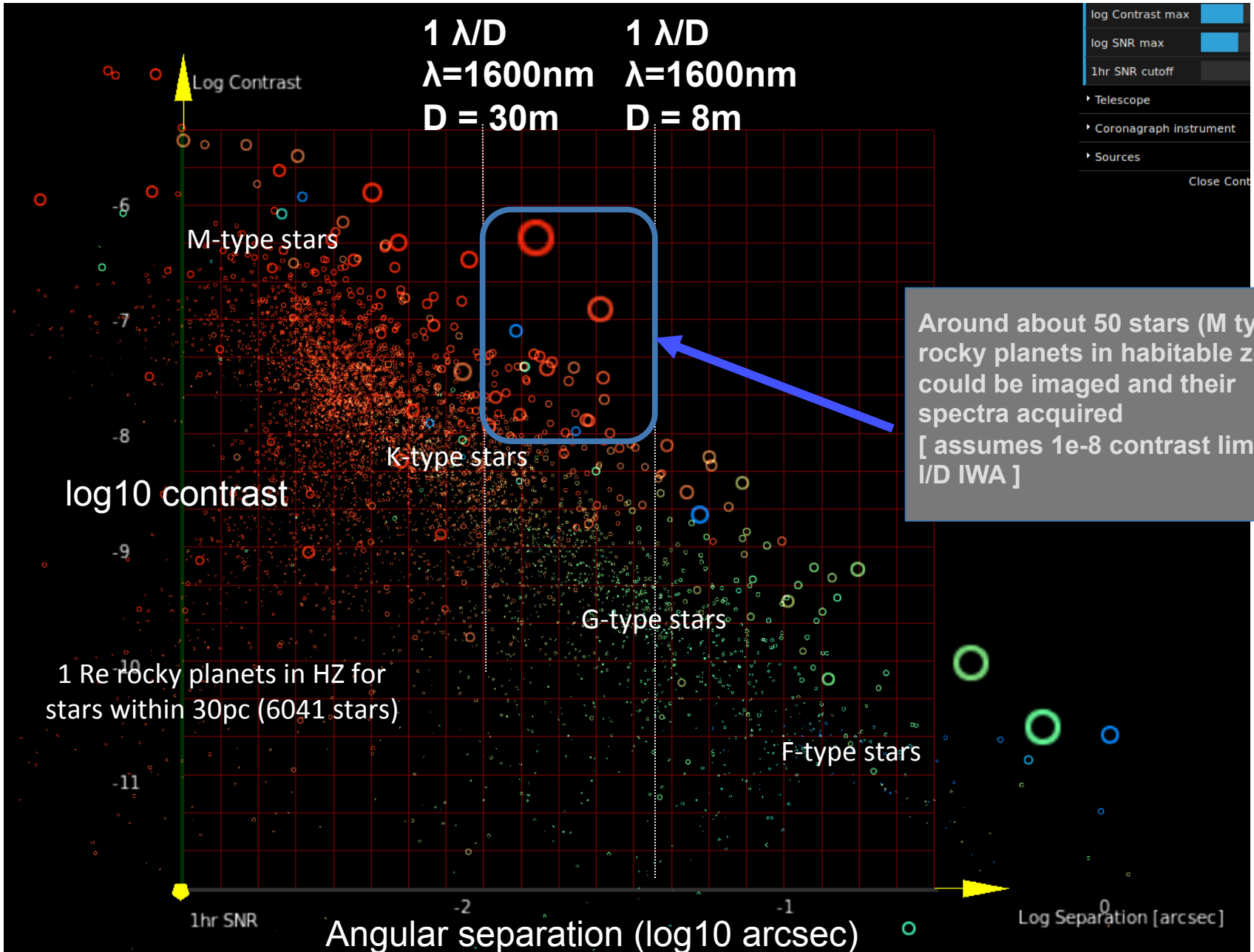
Search for exomoons around directly imaged Jovian planets

ExoMoons PRV



- NIR High-contrast imaging instrument + PRV NIR spectrograph?
- An Earth-mass planet around a few Jupiter mass planet has an RV of ~10 m/s

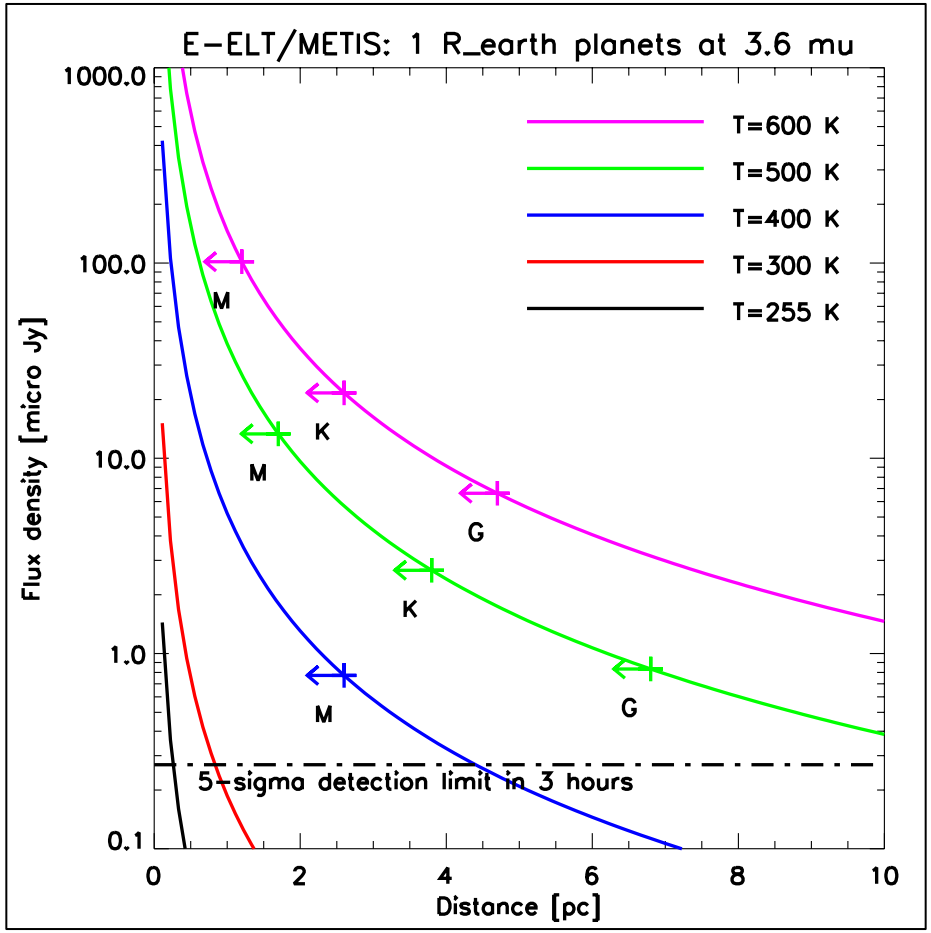
Earth-like planets around nearby M dwarfs: characterization of Earth-sized planets with TMT

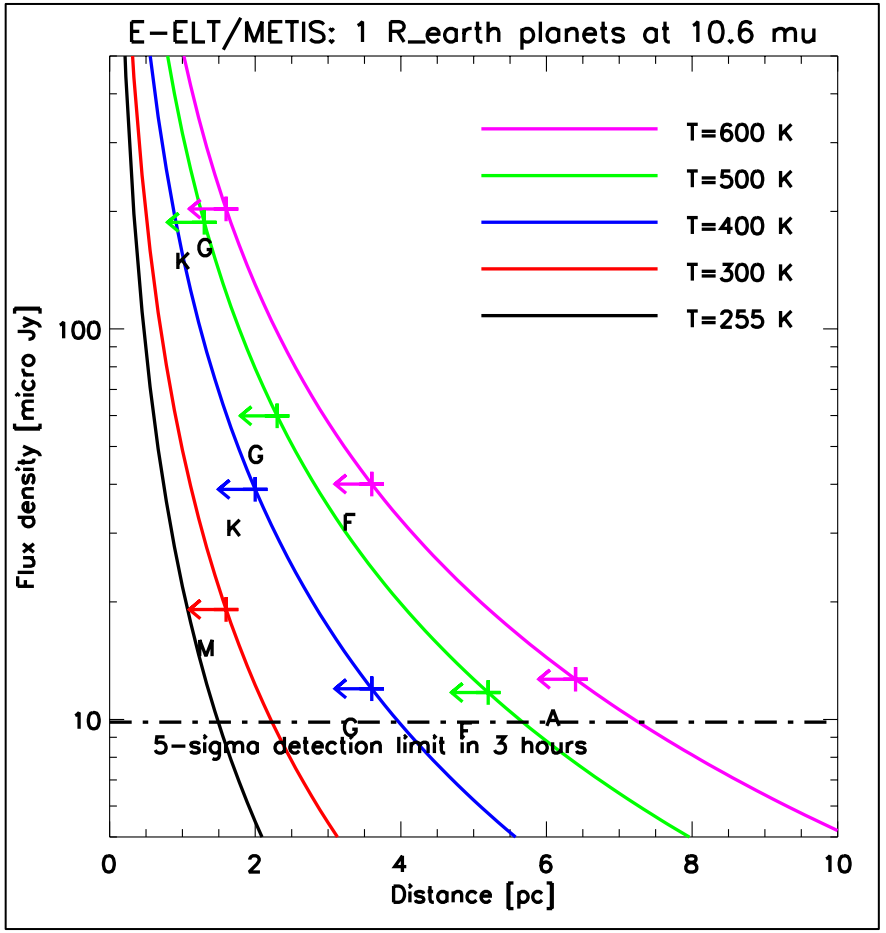


Key Program Ideas: MICHI

- MICHI (L & M & mid-infrared) for small planets around nearby M dwarfs

L, M, Mid-IR bands are also capable to detect Earth-sized planets around nearby M dwarfs





Quanz et al. 2014

Summary

- Exoplanet ISDT requires all FL instruments and 2nd generation instruments
  - High dispersion spectrographs (NIRES, HROS)
  - High contrast imager (PSI, MICHI)
- NIRES received the highest demand
- Precise RV capability is requested
- Simultaneous capabilities of NIRES+HROS and NIRES +PSI are also requested