Exoplanet ISDT Activity Report:
TMT’s Prospects for Exoplanets

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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
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 featuring the 2.4-m telescope, two modular instruments and a modular spacecraft bus.

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-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 2001;
- Snellen+2013

$O_2$ Earth transmission around M5V star

- M8, 760 nm
- M8, 1270 nm

Rodler+Lopez-Morales 2014
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-Saturn 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

- 1 Re rocky planets in HZ for stars within 30pc (6041 stars)
- Around about 50 stars (M type), rocky planets in habitable zone could be imaged and their spectra acquired [assumes 1e-8 contrast limit, 1 \( \lambda/D \) IWA]
Key Program Ideas: MICHIMICHI (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