Key Science Drivers for MICHI (未知), A MIR Instrument Concept for the *TMT*

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A mid-infrared (MIR) imager and spectrometer is being investigated for possible construction in the early operation of the *Thirty Meter Telescope* (*TMT*). Combined with the MIR adaptive optics (AO) system (MIRAO), the instrument will afford ~15 times higher sensitivity and ~4 times better spatial resolution (0.07”) at 10μm compared to 8m-class telescopes. Additionally, through exploiting the large collection area of the *TMT*, the high-dispersion spectroscopy mode will be unrivaled by other ground- and space-based facilities. These combined capabilities offer the possibility for breakthrough science, as well as ‘workhorse’ observing modes of imaging and low/moderate spectral resolution. In this paper we summarize the primary science drivers that are guiding the instrument design.

Science Drivers

We identify three primary areas of astrophysics that are ideally matched to mid-IR (MIR, 7.5-25μm) observations, offering both broad and transformative science from the *TMT*. These areas are (i) star and planet formation, (ii) evolved stars and the ISM, and (iii) extragalactic and cosmology. These fields mesh extremely well with four of the six key science drivers of the *TMT* described in the Detailed Science Case, as well as those highlighted in the Astro 2010 Decadal Survey, and the aspirations of many in the Japanese astronomical community. In this poster, we highlight areas that are especially likely to offer transformative type science:

(1) High spectral resolution science
(2) Disc & planetary formation/evolution, exoplanets
(3) Extragalactic observations

1. High Spectral Resolution

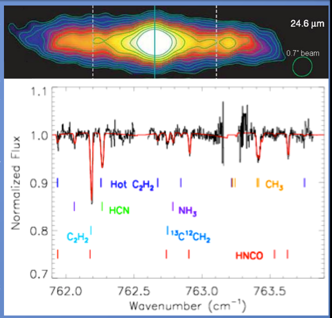
The TMT’s aperture will enable MIR high resolution spectroscopic studies to progress from the current level, where most studies concentrate on the brightest 5-10 objects of a given class, to a plane where comparative study of a hundred objects with good S/N is entirely practical. For example, a typical solar mass T Tauri star can be studied in a volume that extends past Orion as opposed to just reaching Taurus – permitting study of cluster star formation, not just formation in small aggregates. Objects ~3 mags fainter become accessible, comparable to the gain between the Bright Star Catalog (~9,000 objects) and the HD Catalog (~360,000 objects including the extensions). Surveys that required 10 hrs of integration time per target will only require 3 mins for the same S/N.

MICHI studies will be critical to completing the picture of planetary system formation. While other facilities will be better for characterizing the diversity of planetary systems, MICHI provides a uniquely powerful tool for probing planet formation environments for clues to the physical origin of this diversity. Higher excitation energy tracers, common in the MIR, will provide a direct view of the inner disc regions (<5AU region) where terrestrial and giant planets form.

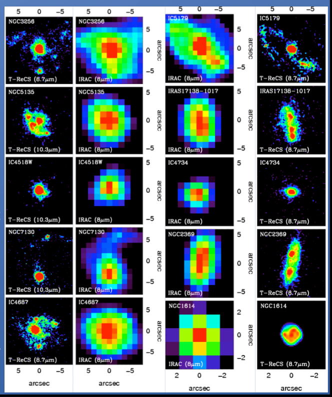
Through observations of gas in discs, the interstellar medium, comets, and other environments, MICHI offers the opportunity to investigate the abundance of prebiotic compounds that led to the emergence of life on Earth.

2. Disc & Planetary Formation/Evolution, Exoplanets

The *TMT* will have sufficient point source sensitivity to permit direct detection of gas giants, achieving a ‘tipping’ point in sensitivity to achieve this exciting goal. If a gas giant is in thermal equilibrium with irradiation by the central star, *TMT*/MICHI will be capable of detecting such giants at a distance of a few AU from nearby (~10pc) early type (AFG type) stars. If a young (~1Gyr) planet’s temperature is determined by its own internal heating (Burrows et al. 2004), detectability is easier. *TMT*/MICHI observations of gas giants holds the promise of the characterization ~5 times closer to the central star than MIR space-based facilities due to the superior spatial resolution.



MIR imaging of the Beta Pictoris debris disc (top), which with spectroscopic data hints at a planetesimal collision or breakup. Portion of the data observed by Knez et al. (2009) toward NGC 7538 IRS 1 illustrates that a small part of the spectrum can be used to measure C_2H_2, $^{13}C^{12}CH_2$, HCN, CH_3, HNCO, and NH3 (above). 8m and *Spitzer* images of AGN (below), showing the criticality of extragalactic diffraction-limited observations.



2. Disc & Planetary Formation/Evolution, Exoplanets (contd.)

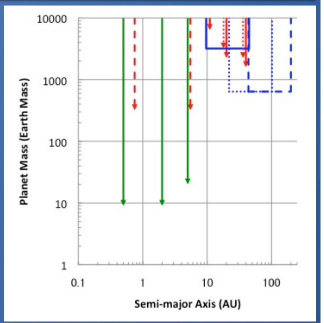
MIR molecular absorption bands and lines (i.e. NH_3 and CH_4) can be detected with low- and high-resolution spectroscopy, and in particular, the 10.5μm NH_3 absorption band is a unique indicator of low effective temperature (T<~1,000K) planets, only accessible in the MIR. Such information has extremely valuable information on planetary atmospheres

Existing near- and mid-IR observations of planet forming regions, protoplanetary and debris discs, have revealed astonishing pictures of planet forming discs such as spirals, gaps, holes, and dips, which strongly imply that planets are forming there. Further, the evolution of dust, the key ingredient of planets, such as grain growth and crystallization has been observed. However, these are challenging observations for 8m class observatories. The spatial resolution and sensitivity of *TMT*/MICHI will be crucial to dramatically increase the number of available sources, conduct statistically significant surveys, and probe the disc chemistry.

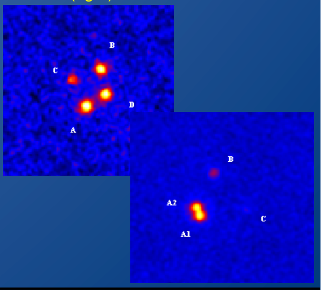
3. Extragalactic Observations

The Decadal Survey stressed the importance of extragalactic SMBH to both astrophysics and cosmology. There is a clear connection between the SMBH and galaxy properties, as shown through the famous M_{BH} vs. M_{bulge} and M_{BH}-σ relationships, demonstrating that the galaxy bulge mass (M_{bulge}) and the stellar velocity dispersion (σ) are tightly correlated with the SMBH (M_{BH}), despite being spatially on widely different scales. This correlation strongly implies some form of coevolution between the SMBH growth and the growth of the galaxy bulge, but the precise nature of this relationship remains uncertain. Understanding the precise nature of this relationship will help to address two crucial questions in cosmology: (1) which formed first, the SMBH or the galaxy, and (2) how did SMBHs form so shortly after the big bang? The SMBH will often show a level of ‘activity’ arising through accretion of gas and dust, leading to an AGN. The study of AGN has recently been invigorated through 8m MIR observations of the torus, which have shown a complex, clumpy, and probabilistic unification scheme, with tentative hints that the torus structure is (partially) dependent on the level AGN activity. Possible other effects could be the level of radio emission (radio loud/quiet AGN) and that of the host galaxy, as well the precise fuelling of AGN. The complex interplay between the host galaxy and AGN remains poorly constrained, and is a goal of the Decadal Survey.

In summary, the lives of galaxies and SMBHs seem to be strongly linked in a poorly understood manner, and the interaction of the AGN with the torus and host galaxy remains unclear. Observations of the AGN, torus, black hole growth, starburst/AGN connection, and gravitationally lensed QSOs will help elucidate these connections, and through use of *JWST/SPICA*, will help to characterize the evolution of the SMBH, AGN, and distribution of matter within galaxies versus time, activity level, and the effect of and on the host galaxy on these parameters.



Limiting performance for planet detection (above) around old (5Gyr) A stars with MICHI at 9μm (green solid line), the SCI at 4.4μm (blue solid line), 11.4μm (blue dotted line), and 20μm (blue dashed line), the FGS-TFI/NRM at 4.4μm (red dashed line), NIRCam coronagraph at 4.4μm (red solid line), and the MIRI/FQPM at 11.4μm (red dotted line), based on models from Burrows et al. (2003). 11.7μm images of Q2237+030 (bottom left) and MG0414+0534 (bottom right) taken from Subaru (Minezaki et al. 2009) showing multiply lensed images, indicative of microlensing (left) and the subhalo (right).



Further Information & Acknowledgements

The science drivers and flow down was discussed in Okamoto, Packham, Tokunaga et al. (2010, SPIE, 7735, 77355O) and the design by Tokunaga, Packham, Okamoto et al. (2010, SPIE, 7735, 77352C). This work was supported by NSF grant number 0947189 (2009-11), and the JSPS (2012). We gratefully acknowledge the support of the *TMT* project office of the National Astronomical Observatory of Japan (NAOJ). CP thanks the Astronomy department at the University of Tokyo for their support.