Michi (MIR) A MIR Instrument Concept for the TMT

C. Packham (Florida), X.-K. Okamoto (Ibaraki), A. Tokunaga (Hawaii), J. Cerr (NRL), M. Chiba (Tohoku U.), M. Chun (Hawaii), K. Eaya (ISAS), H. Fujiwara (ISAS), T. Fujishiro (Subaru/NAOJ), M. Honda (Kanagawa), M. Imanishi (NAOJ), Y. Ha (Tohoku), H. Kataza (ISAS/JAXA), T. Kotani (ISAS/JAXA), H. Izumiura (NAOJ), N. A. Lennon (Gemini), Y. Matsue (NAOJ), M. Matsushita (UCL), T. Minezaki (U Tokyo), J. Najita (NOAO), T. Onaka (Tokyo), E. Ootsu (Tohoku), M. Richter (UC Davis), I. Sakon (Tokyo), M. Takami (ASIAA), C. M. Telesco (Florida), C. Warner (Florida), C. M. Wright (USN), and T. Yamashita (NAOJ)

A mid-infrared (MIR) imager and spectrometer is under consideration for construction in the first decade of the Thirty Meter Telescope (TMT) operation. When combined with a MIR adaptive optics system, the instrument will afford 15 times higher sensitivity, 4 times better spatial resolution (0.08") than 8m-class telescopes, and ~4.5 times better spatial resolution than the JWST. Additionally, its huge light gathering power opens a new window of high-dispersion spectroscopy in the MIR. We discuss the key science drivers, from star and planet formation to galaxies and black holes and cosmology; science drivers which are in close synergy with the recent Decadal report. We flow down our science cases to produce fundamental and optional instrument capabilities, including imaging, long-slit and IFU spectroscopy, and polarimetry.

Science Drivers

We identify three primary areas of astrophysics that are ideally matched to mid-IR (MIR, 7.5-25 pm) 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, as described in the Detailed Science Case, as well as those highlighted in the Astro 2010 Decadal report.

Diffraction limited imaging of circumstellar disks will search for evidence of planet formation, such as percentiger growth or perturbations in the disk, and follow up low- to moderate-resolution spectroscopy will probe the rich dust chemistry which could supply seed materials for life on forming exoplanets. Observational efficiency can be dramatically improved using a modular field unit, which would make effectively impossible observations (due to time constraints) routine. High-resolution spectroscopy will afford the opportunity to make detailed chemical analyses of unachievable objects in space based platforms.

Gas and dust ejected from dying stars are key to our understanding of the chemical evolution of the Universe and the circulation of materials. A detailed low- to moderate-resolution spectroscopic study at high-spatial resolution will provide a firm statistical characterization, impossible with 8m class telescopes.

Observing in synergy with the JWST, Michi will make diffraction-limited imaging and low- to moderate resolution spectroscopic observations of various extragalactic objects. The very high-spatial resolution of the TMT will disentangle emission mechanisms in AGN, distinguish between starburst and AGN energy sources in ULIRGs, and probe CDM substructures of lensed QSOs to test CDM models of structure formation. Michi enables AGN and ULIRG observations to a much higher z than current 8m, where AGN and black hole evolution may become apparent, and permit a statically significant probe of lensed QSOs, impossible on 8m class.

TMT and Michi permit multiple cycles of scientific discovery and follow-up, whereas the much shorter lifetimes of space based observatories cannot perform such programs.

Requirements & Initial Design

From a detailed examination of the primary science cases, we found the following key requirements for the instrument, as well as possible enhancements.

1. Imaging at N (7.3-13.5 pm) & Q (16-25 pm), FOV ~30".
2. IFU at low-dispersion (R~250), ~2"x5", FOV 470 x 2350.
3. Long-slit moderate-dispersion spectroscopy at N & Q with the entire band across single array; R ~810 at N, R ~1,100 at Q.
4. High-dispersion spectroscopy with R ~200,000 at N, R ~66,000 at Q.
5. MIR AO system to enable diffraction-limited observations at N and Q.
6. Cold internal chopper to enable imaging, low- and moderate-dispersion spectroscopy.
7. Possible enhancements:
   - Coronagraph mode
   - Aperture-masking mode

As we proceed to a further development stages, the detailed trade studies associated with implementation of the various modes of Michi will be made, and the possible enhancements will only be incorporated if they are of minimal difficulty.

Our optical design answers the requirements through a modular approach, providing the capabilities listed (top right). While a complex design, each module is constructed from a collection of flexible modules that can be built separately, greatly facilitating construction and testing of the instrument. We also assume that a MIR adaptive optics system will be available, as already designed by Chun et al. (2006). We believe that all items needed for Michi are either off the shelf or require little or no R&D to produce, and hence the instrument has a low technical risk.

Further Information & Acknowledgements

The science drivers and flow down is discussed in Okamoto, Packham, Tokunaga et al. (2010, SPIE, 7735, 773550) and the design by Tokunaga, Packham, Okamoto et al. (2010, SPIE, 7735, 77352C). This work was supported by NSF grant number 0847888. We gratefully acknowledge the support of the TMT project office of National Astronomical Observatory (NAOJ). Y. Ikeda (Photozoom Inc.) and Optical Research Associates. Y.K.O. is supported by Grant-in-Aid for Young Scientists (A) (21684005) by the Ministry of Education, Culture, Sports, Science and Technology, Japan.