Unveiling the dynamic infrared sky

Palomar Gattini-IR is the first of a number of infrared transient surveyors that will search the skies nightly, looking for ephemeral phenomena such as novae, supernovae and neutron star merger events, explain Co-lead Researchers Anna Moore and Mansi Kasliwal.

The transient infrared sky remains virtually unexplored. The cataclysmic fates of many stars shine the brightest in the infrared due to opacity or dust or temperature. For instance, emission from neutron star mergers is longest lived and ubiquitous in the infrared as the bound–bound opacity of heavy elements pushes the peak of the emission to redder wavebands[1]. Emission from exploding massive stars that experienced many, copious mass-loss episodes could be self-obscured and better studied in the infrared[2]. Emission from a Galactic supernova deep in the disk of the Milky Way may also be brightest in the infrared wavebands on account of line-of-sight extinction[3].

Despite the obvious value in pursuing observations in the infrared, the fundamental roadblocks to studying the infrared sky have been the blindingly bright sky background from the ground (up to 250 times brighter than in optical wavelengths) and the narrow field-of-view of infrared cameras. Infrared sensors are historically much more expensive than their optical CCD counterparts, and require lower operating temperatures, and thus sophisticated cooling methods. However, recent commercially available infrared sensor packages, combined with state-of-the-art software techniques, have enabled our international team to leap ahead with a series of experiments planned for operation.

The first instalment in the series is called Palomar Gattini-IR: a fully automated, ultra-wide infrared telescope located at the historic Palomar Observatory in California (Fig. 1). The telescope has an aperture size of 300 mm and a single capture field of 25 square degrees (ref. [4]). The system operates in the astronomical J band at a wavelength of 1.25 μm, where the near-infrared sky is darkest from Gattini-IR's temperate location. Fast access to the sky was enabled by the availability of two critical in-house components: an engineering-grade infrared detector from Teledyne (the Hawaii 2RG), with 2,048 × 2,048 active pixels, and a commercially available optical telescope assembly from Telescope Engineering Inc.

Palomar Gattini-IR is robotically surveying the accessible night sky (15,000 square degrees) to a depth of 16 mag (AB magnitudes) every night, with a survey open-shutter efficiency of 75%. This survey repeats continuously with each new epoch adding to survey sensitivity, creating a dynamic history of the infrared night sky and J-band light curves for more than 10 million sources with nearly nightly cadence. Agile software continually drizzles[5], subtracts[6] and mines the dataset in real-time for new transient signals. The experiment will begin science observations in January 2019 after a three-month commissioning period.

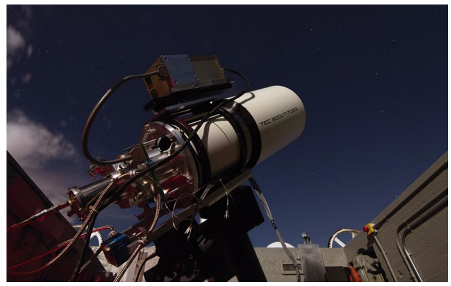

Fig. 1 | The Palomar Gattini-IR telescope. Credit: Palomar Gattini-IR team

Palomar Gattini-IR will complete our census of classical novae in the Milky Way as well as enshrouded supernovae in the local Universe. Discovering and characterizing the infrared emission of novae will reveal whether shocks in novae are accompanied by dust formation[7]. Finding infrared supernovae missed by traditional optical surveys could help us resolve the long-standing discrepancy between the supernova rate and the cosmic star formation rate[8]. The survey can reveal variable stars in some of the most enshrouded dusty regions in the Milky Way.

Palomar Gattini-IR paves the way for a series of even more ambitious infrared transient surveyors. In the Northern Hemisphere, the Wide-field Infrared Transient Explorer (WINTER), also located at Palomar Observatory, will be a fully robotic 1-m aperture telescope with a 1 square degree field-of-view infrared camera. In the Southern Hemisphere, the Dynamic REd All-sky Monitoring Survey (DREAMS), located at Siding Spring Observatory in Australia, will be a fully automated, 0.5-m aperture, custom-designed telescope and camera combination. Both WINTER and DREAMS exploit the benefits of a modular, commercially available InGaAs system[9]. Together, WINTER and DREAMS will survey the entire sky every three nights to a depth equivalent to the 2MASS survey (17.8 mag_{AB}). Both WINTER and DREAMS are designed to be sensitive enough to discover the electromagnetic counterpart to a neutron star–black hole merger as far out as the LIGO/Virgo gravitational wave horizon of 200 Mpc.

Looking further into the future, to take advantage of the remarkably lower (50 times) sky background at 2.35 μm from the cold polar regions — such as the high Antarctic plateau bases at the South Pole, Dome A and Dome C — Turbo Gattini-IR will survey the accessible sky to a staggering depth of 20 mag_{AB}, the same depth as the VISTA Hemisphere Survey, but every two hours with a survey efficiency of 97%.

We thank the Gattini-IR Science and Engineering teams, the Australian National University, California Institute of Technology, Heising-Simons Foundation, Massachusetts Institute of Technology, Mount Cuba Foundation, National Science Foundation, Packard Foundation, and the United States–Israel Binational Science Foundation for their support. ❐

Anna M. Moore[1]* and Mansi M. Kasliwal[2]

[1]*Research School of Astronomy and Astrophysics, Australian National University, Canberra, Australia.*
[2]*Division of Physics, Math and Astronomy, California Institute of Technology, Pasadena, CA, USA.*
**e-mail: Anna.Moore@anu.edu.au*

Published online: 8 January 2019
https://doi.org/10.1038/s41550-018-0675-x

References

1. Kasen, D. et al. *Nature* **551**, 80–84 (2017).
2. Jencson, J. E., Bond, H. E., Adams, S. M. & Kasliwal, M. M. *The Astronomer's Telegram* 11577 (2018).
3. Adams, S. et al. *Astrophys. J.* **778**, 164 (2013).
4. Moore, A. M. et al. *Proc. SPIE* **9906**, 99062C (2016).
5. Fruchter, A. S. & Hook, R. M. *Publ. Astron. Soc. Pacific* **114**, 144–152 (2002).
6. Zackay, B., Ofek, E. O. & Gal-Yam, A. *Astrophys. J.* **830**, 27 (2016).
7. Derdzinski, A. M., Metzger, B. D. & Lazzati, D. *Mon. Not. R. Astron. Soc.* **469**, 1314–1329 (2017).
8. Horiuchi, S. et al. *Astrophys. J.* **738**, 154 (2011).
9. Simcoe, R. A. et al. Preprint at https://arxiv.org/abs/1805.08791 (2018).