First results from Project SUNBIRD: Supernovae UNmasked By Infra-Red Detection

E. C. Kool[1,2], S. Ryder[2],
E. Kankare[3], T. Reynolds[4], S. Mattila[4]
M. Pérez-Torres[5] and R. McDermid[1]

[1] Department of Physics and Astronomy, Macquarie University, NSW 2109, Australia
[2] Australian Astronomical Observatory (AAO), 105 Delhi Rd, North Ryde, NSW 2115, Australia
[3] Astrophysics Research Centre, School of Mathematics and Physics, Queen's University Belfast, Belfast BT 7 1NN, UK
[4] Tuorla Observatory, Department of Physics and Astronomy, University of Turku, Väisäläntie 20, FI-21500 Piikiö, Finland
[5] Instituto de Astrofísica de Andalucía (CSIC), Glorieta de la Astronomía s/n, E-18080 Granada, Spain

Summary

In project SUNBIRD we are monitoring more than 25 actively star forming and dusty Luminous Infrared galaxies (LIRGs) for dust-obscured core-collapse supernovae (CCSNe) in an effort to characterize the population of CCSNe exploding in dust-obscured crowded nuclear regions, as these events are missed by SN surveys but are crucial to the accurate determination of CCSN rates. We observe in the near-infrared with Gemini South in Chile and Keck in Hawai'i, making use of state-of-the-art laser guide star adaptive optics instruments to achieve a spatial resolution (< 0.1") sufficient to resolve close in to the nucleus. So far we have discovered four supernovae with nuclear offsets as small as 200 pc. Aggregating the new discoveries with the CCSNe found in previous programs employing adaptive optics (AO), we show that compared to seeing-limited surveys our method is singularly effective at uncovering nuclear CCSNe in LIRGs.

Introduction

A star with a mass more than 8 times that of the Sun ends its life in an explosion that can briefly outshine its host galaxy: a core collapse supernova (CCSN). Because massive stars have short life times, CCSNe can act as a direct tracer of massive star formation, even at large distances, due to their brightness. However, currently CCSN rates suffer from large uncertainties, likely due to a large fraction of CCSNe exploding in crowded regions with bright background emission and significant dust extinction, where traditional SN surveys fail to detect them.

Our collaboration pioneered the use of near-infrared (NIR) laser guide star adaptive optics (LGSAO) to uncover CCSNe in the crowded regions of luminous infrared galaxies (LIRGs). The NIR is less affected by dust extinction compared to the optical and LGSAO provides a sufficient spatial resolution (<0.1") to probe close in to the nucleus. Finally LIRGs have high star formation (and thus CCSNe) rates and host bright and crowded nuclear regions, but show a distinct shortfall of CCSN discoveries relative to the predictions from the well-defined star formation history.

In project SUNBIRD (Supernovae UNmasked By Infra-Red Detection) we aim to characterize the population of CCSNe in the nuclear regions of LIRGs, and in this way improve the constraints on the fraction of CCSNe that are missed by conventional SN surveys due to large extinctions and reduced search detection efficiency.

Project SUNBIRD

SUNBIRD is a targeted search for CCSNe in LIRGs with the use of LGSAO instruments GeMS/GSAOI on Gemini South and NIRC2 on Keck. We observe in the NIR K_s-band, which is less affected by dust extinction compared with the optical, and is where LGSAO currently performs best.

Upon the discovery of a CCSN we track its light curve in NIR bands K_s, H and J. Obtaining a spectrum of a dust-obscured CCSN in a crowded region is challenging, so we typically determine the subtype of the CCSN by fitting the NIR light curve to prototypical well documented archival CCSNe:

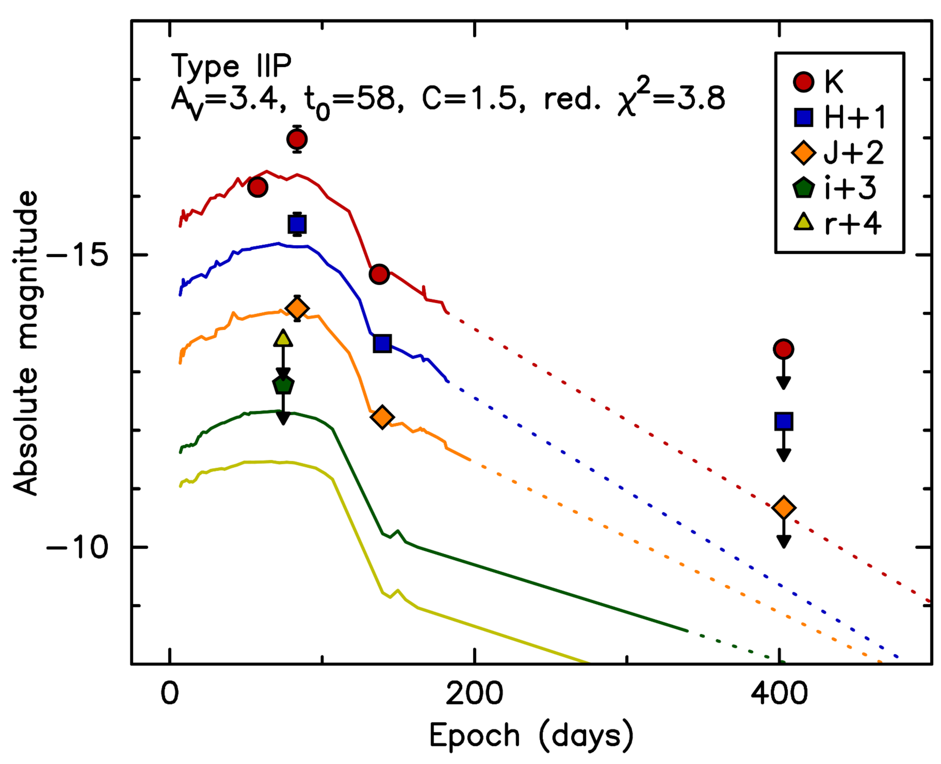

Fig 1. The best fit of the NIR lightcurve of SN 2015cb, to a Type IIP template with an extinction of A_V = 3.4 (Kool+2018)

Supernova detections

The first CCSN SN 2013if was detected in 2013 during a pilot program for SUNBIRD, shown in Fig. 2. It showcases the need for LGSAO observations, as the supernova is very close (200 pc, 0.5") to the nucleus of the galaxy and would otherwise have been missed. Three more CCSNe were discovered in the first full year of SUNBIRD in 2015, again with GeMS/GSAOI, see Fig. 3 for SN 2015cb and SN 2015ca (Kool+2018).

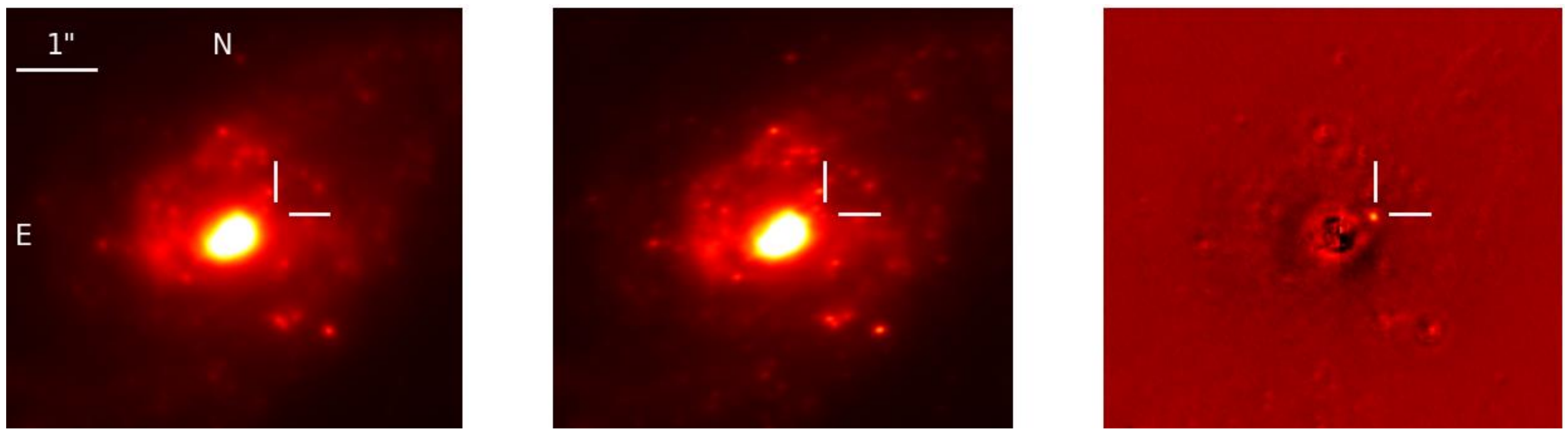

Fig. 2: SN 2013if in IRAS 18293-3413 with GeMS/GSAOI: reference image (left), discovery image (middle) and the difference of the two images (right).

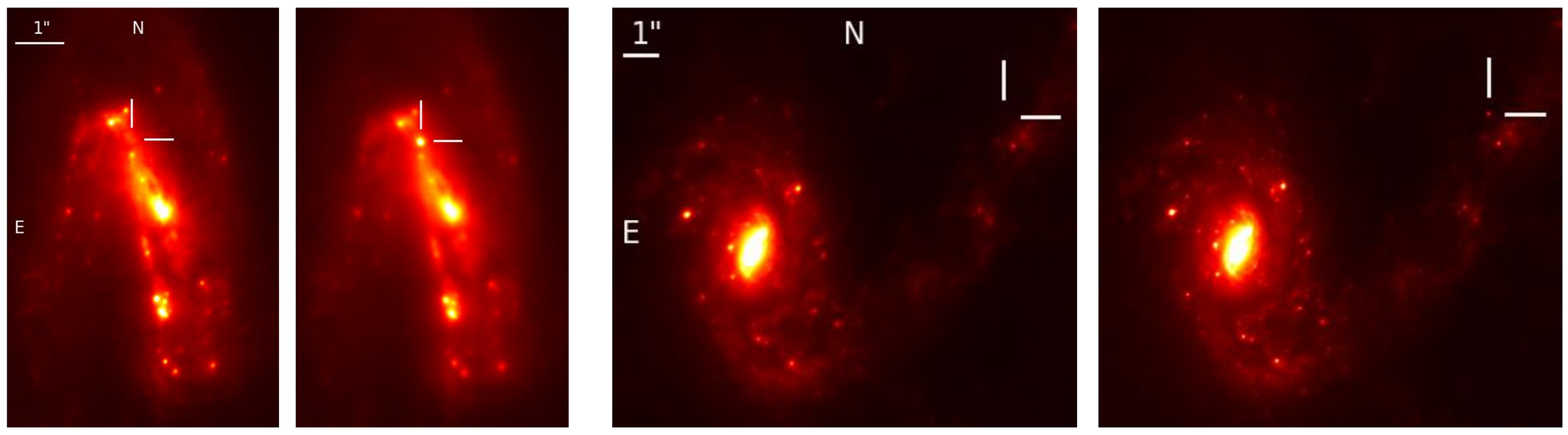

Fig. 3: GeMS/GSAOI reference and detection images of SN 2015cb in IRAS 17138-1017 (left) and SN 2015ca in NGC 3110 (right), as indicated by the tickmarks.

Impact of LGSAO on CCSN discoveries in LIRGs

With the four (and counting) CCSN discoveries from SUNBIRD, so far there have been nine CCSNe discovered in LIRGs using LGSAO in NIR (Matilla+2007, Kankare+2008,2012). In Fig 4. we show the distribution in offset from the nucleus of *all* documented CCSNe discoveries in LIRGs in the NIR and the optical. It clearly shows that our method is singularly effective at uncovering CCSNe in the nuclear regions of LIRGs and while optical surveys dominate SNe discoveries far from galaxy centres, NIR AO observations are needed to probe the regions within 1 kpc, where stellar densities are typically highest.

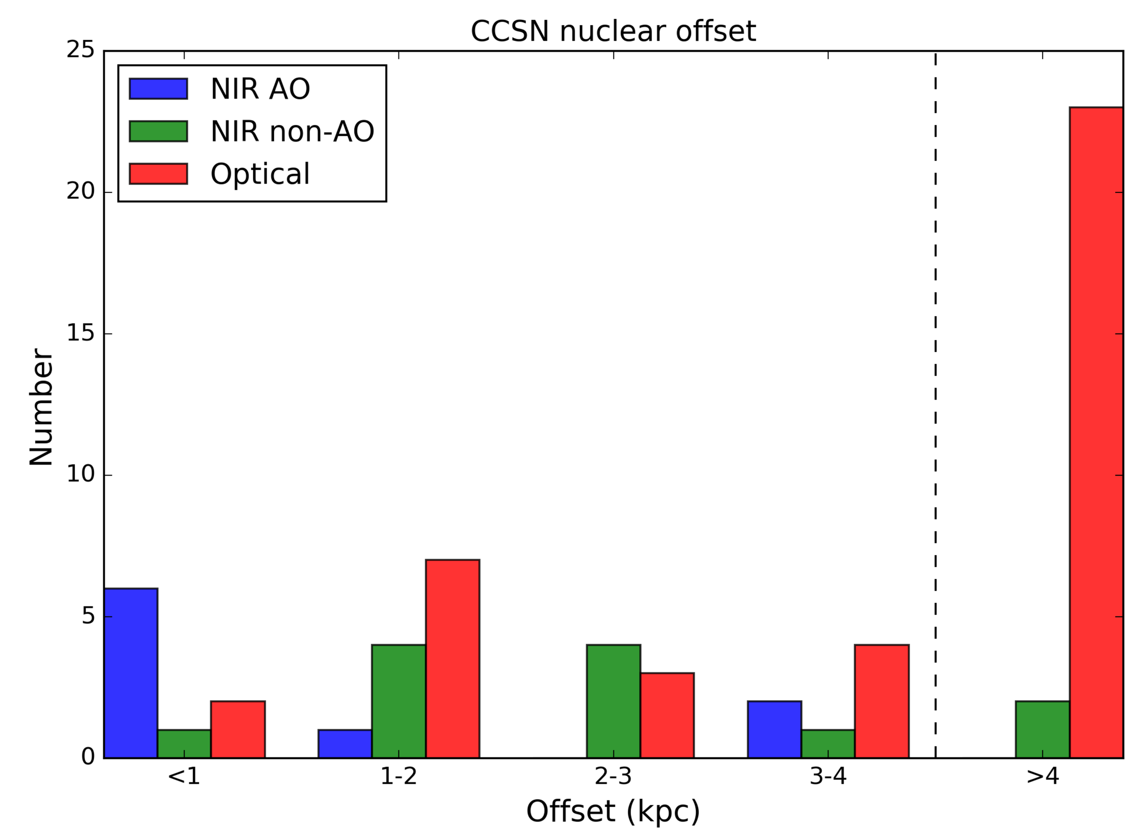

Fig 4: Nuclear offsets for all documented CCSN discoveries in LIRGs, in the optical (red) and in NIR, with (blue) or without AO (green). Note that the time coverage of all NIR AO CCSNe surveys in LIRGs in NIR is <10% of the total historical NIR coverage of LIRGs, which in turn is only a fraction of the coverage of LIRGs in the optical (Kool+2018).

References

• Kool E. C., et al, 2018, MNRAS, 473, 5641
• Kankare E., et al, 2008, ApJ, 689, L97
• Mattila S., et al, 2007, ApJ, 659, L9
• Kankare E., et al, 2012, ApJ, 744, L19