Evaluating the fraction of obscured supernovae in LIRGs

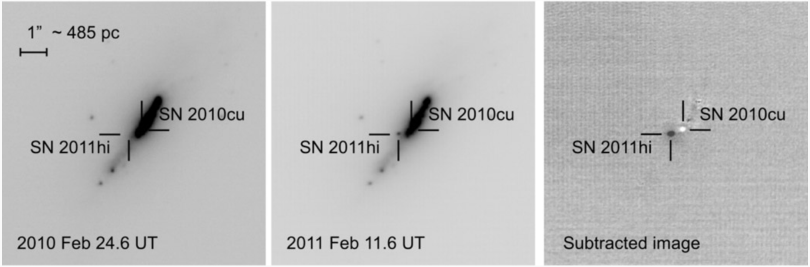
November 20, 2017

Introduction

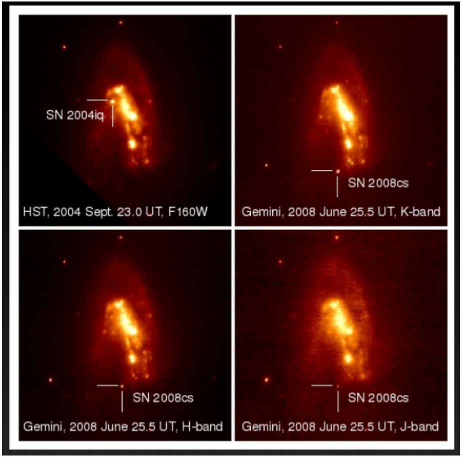
- The SUNBIRD+ Sample: 4 major datasets of LIRGS
- Detecting supernovae (SNe): What is our ability to detect SNe in the sample?
- Simulation: given the SNe in the sample and our detection efficiency, how many should we detect?

LIRG observations: Gemini/Niri

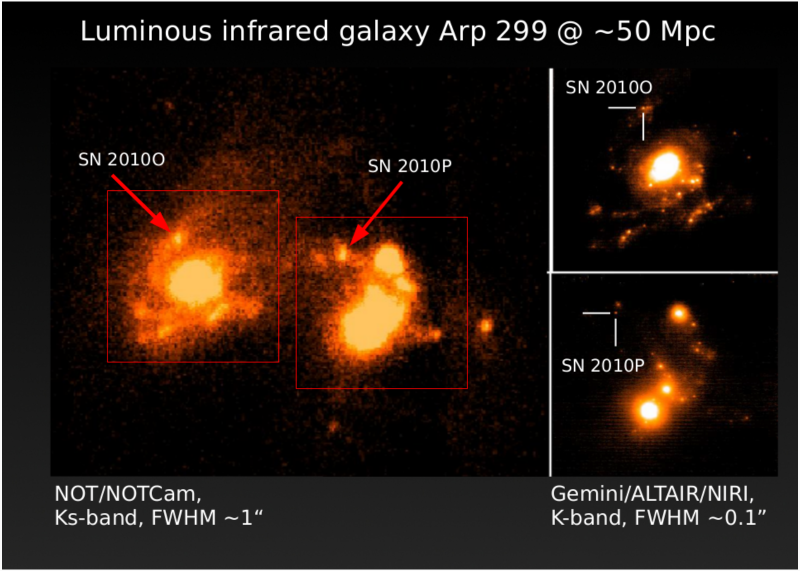
- Observations taken with Near InfraRed Imager (NIRI) and single-conjugate adaptive optics (AO) system ALTAIR on Gemini North
- 8 LIRGs were monitored between 2008-2011
- Discovery of 6 SNe



NIRI SNe


SN 2004iq
HST, 2004 Sept. 23.0 UT, F160W
SN 2008cs
Gemini, 2008 June 25.5 UT, K-band
SN 2008cs
Gemini, 2008 June 25.5 UT, H-band
SN 2008cs
Gemini, 2008 June 25.5 UT, J-band

NIRI SNe

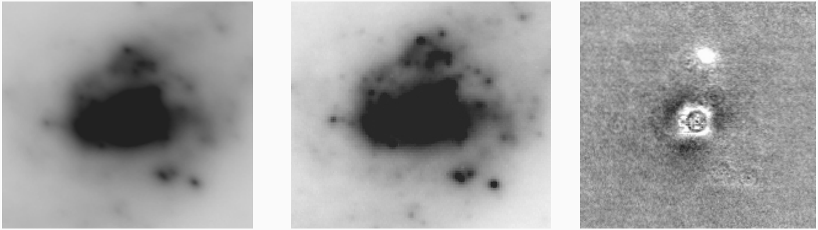

Luminous infrared galaxy Arp 299 @ ~50 Mpc
SN 2010O
SN 2010P
SN 2010O
SN 2010P
NOT/NOTCam,
Ks-band, FWHM ~1"
Gemini/ALTAIR/NIRI,
K-band, FWHM ~0.1"

LIRG observations: VLT/NACO

- Observations taken with NAOS CONICA adaptive optics system on ESO VLT in the near-IR Ks band
- 2-3 epochs of observation of 26 LIRGs in the period 2010-2013
- 4 SNe found

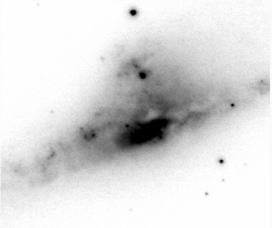
SNe in IRAS18293-3413: 2012

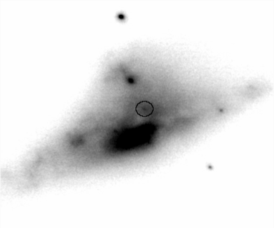
- SN detected first in 2012: 0.2" West and 1.5" North ($\approx$ 600pc)
- 3 epochs of H and K band imaging

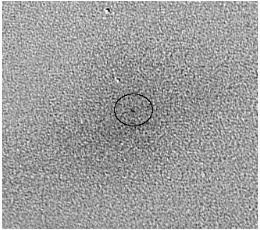


SN in IRAS17578-0400

- SN detected 2012/07/04
- SN is $\approx$ 320pc from host nucleus
- 2 K and 2 H band observations

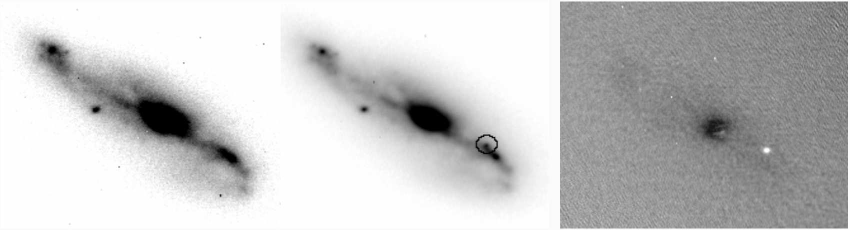






SN in ESO440-058

- SN detected 2012/07/17
- SN is ≈ 1.2Kpc from host nucleus
- Single K band epoch for the SN



LIRG observations: GEMS & KECK

- Observations with Gemini South Adaptive Optics Imager (GSAOI), Gemini Multi-Conjugate Adaptive Optics System (GeMS)
- 13 LIRGs were observed with Gemini South GeMS/GSAOI between 2013-2016. A total of 38 K band images were taken with laser guide star multiple conjugate AO
- 21 LIRGs have been observed with KECK NIRC2. Observations began in 2016 and are ongoing, with 43 K band images taken so far with laser guide star AO.

SN Detections

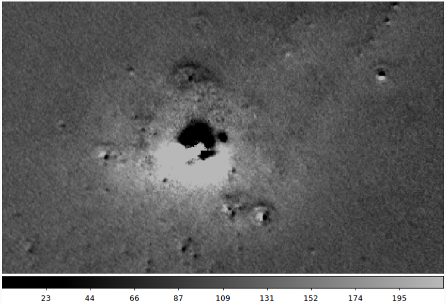
	Host Galaxy	SN rate (yr^{-1})	Facility	Type	Reference	Extinction (mag)	Projected distance (Kpc)
SN2004ip	IRAS 18293-3413	1.74	VLT/NACO	II	Mattila et al. (2007)	5-40	0.5
SN2004iq	IRAS 17138-1017	0.71	NICMOS/HST	II	Kankare et al (2008)	0-4	0.66
SN2008cs	IRAS 17138-1017	0.71	Gemini-N/ALTAIR	II	Kankare et al (2008)	17-19	1.5
SN2010cu	IC 883	1.26	Gemini-N/ALTAIR	II	Kankare et al (2012)	0-1	0.18
SN2011hi	IC 883	1.26	Gemini-N/ALTAIR	II	Kankare et al (2012)	5-7	0.38
SN2013if	IRAS 18293-3413	1.74	Gemini-S/GSAOI	IIP	Kool et al. (2017)	0-3	0.2
SN2015ca	NGC 3110	0.55	Gemini-S/GSAOI	IIP	Kool et al. (2017)	3	3.5
SN2015cb	IRAS 17138-1017	0.71	Gemini-S/GSAOI	II	Kool et al. (2017)	4.5	0.6
AT2015cf	NGC 3110	0.55	Gemini-S/GSAOI	II?	Kool et al. (2017)	2-5	3.5
SN2010O	Arp 299	2.05	Gemini-N/ALTAIR	Ib	Kankare et al (2014)	2	1.6
SN2010P	Arp 299	2.05	Gemini-N/ALTAIR	IIb	Kankare et al (2014)	7	1.2
AT2012xx	IRAS 18293-3413	1.74	VLT/NACO	II?	Reynolds et al (in prep)	?	0.6
AT2012xx	IRAS 17578-0400	0.60	VLT/NACO	II?	Reynolds et al (in prep)	?	0.32
AT2012xx	ESO 440-058	0.62	VLT/NACO	II?	Reynolds et al (in prep	?	1.2

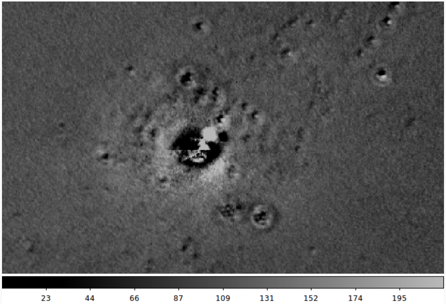
The overall sample

- 10 years of observations with a highly variable cadence
- Typical FWHM was 0.05" – 0.15": natural seeing surveys have had 0.35" at best, usually more like 0.7"
- Most observed LIRGs have 20 epochs of observations, least have 2
- Multiple instruments create difficulties in comparison
- Simple estimate of SN rate from IR luminosity: 100+ SNe should have occured in these LIRGs during the observation period!
- How many should we have seen?
- Note, Mattila et al found 83% missed in Arp299, quite similar

SN detection efficiency

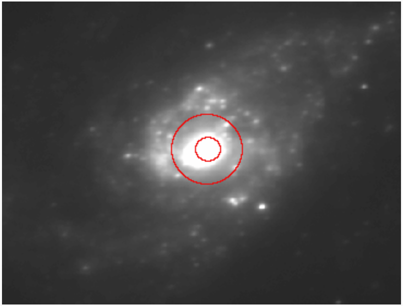
To find our ability to detect SNe in our data, simulate sources and recover. The sources effect the subtractions.

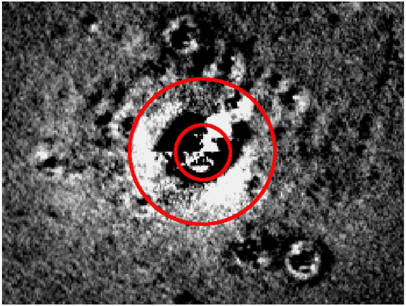




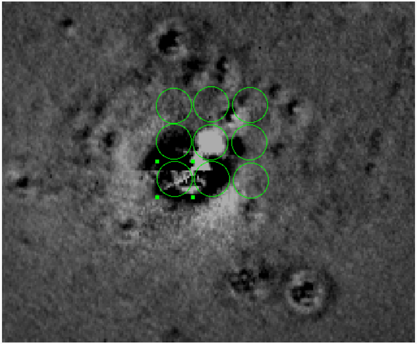
SN detection efficiency

Can define regions, or use a grid.

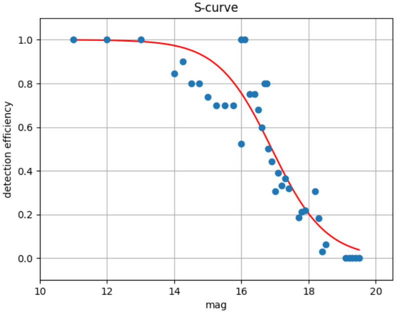


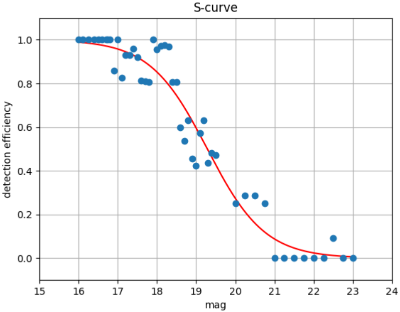


- Construct PSF using field stars and model using single best fitting function
- AO PSFs can be difficult: spatially variable as you move from the guide star, and have narrow and broad component
- Detection by comparing aperture (forced phot) at SN location with σ taken from a surrounding grid of apertures



Fitting an "S-curve" gives an estimate of 50% detection efficiency: 16.7, 19.3 for the inner and outer regions shown respectively. (cf. Seppo's comments on Miluzio)

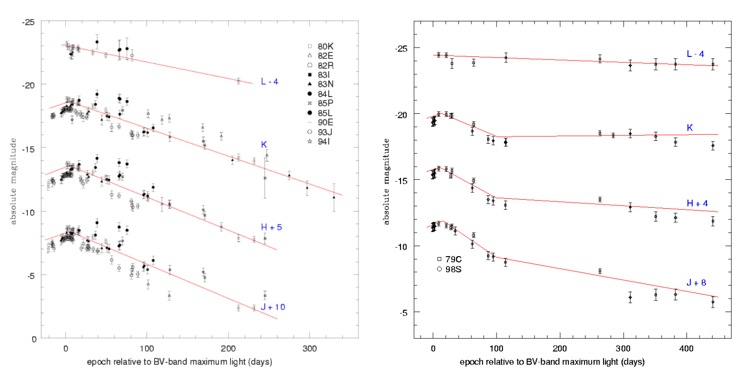




Simulations

- With detection efficiency curves calculated for our data, can run a Monte Carlo simulation
- Randomly sample various distributions to generate SNe
- "Explode" them in individual galaxies to compare to cadence and detection efficiency
- Multiple parameters to understand/fit, notably:
  - Light curve evolution and peak magnitudes
  - Star formation rate in the host galaxy
  - Extinction of the SNe
  - Spatial distribution of the SN (cf. Radio SNe)

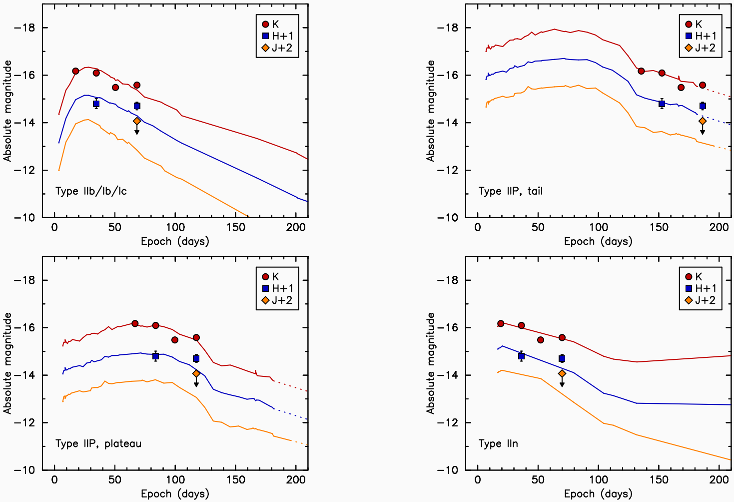
Supernova models



"type II" model

"slowly declining" model

Mattila & Meikle, 2001


K
H+1
J+2
Type IIb/Ib/Ic
Type IIP, tail
Type IIP, plateau
Type IIn
Absolute magnitude
Epoch (days)
−18
−16
−14
−12
−10
0
50
100
150
200

Conclusions

- Taking the light curves and typical peak magnitudes from above and combining with measured detection efficiency moderately close to the nucleus, find that a ”typical” SN might be visible for about 130 days.
- With our cadence, expect perhaps 45 SNe in our sample with these parameters
- This implies we expect many nuclear or heavily extincted SNe
- With complete simulation, can analyse our sensitivity to the various parameters
- With bayesian approach, can constrain SFR in the LIRGs and other attributes of SNe

SNe in IRAS18293-3413: 2013

- Second SN detected 2013/05/08.
- SN is $\approx$ 200pc from host nucleus- close!
- Also have a H band image