

# Adaptive Optics-assisted detection and study of supernovae

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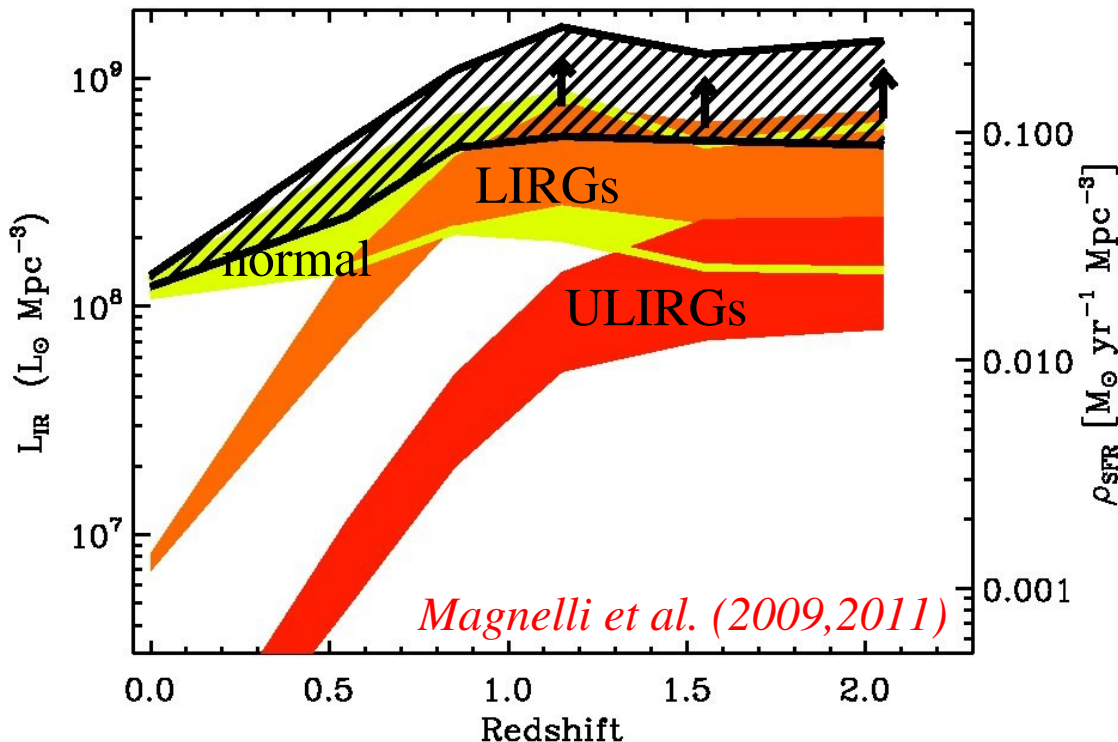
## Collaborators

Stuart Ryder (AAO), Petri Väisänen (SAAO), Franz Bauer (PUC)  
Tomas Dahlen (STScI), Erkki Kankare, Jari Kotilainen (FINCA)  
Miguel Perez-Torres (Granada), Andreas Efstathiou (Cyprus)  
Cristina Romero-Canizales (PUC), Zara Randriamanakoto (SAAO)  
Andres Escala (U. de Chile), Jens Melinder (Stockholm) ...



# Supernovae in luminous infrared galaxies (LIRGs)

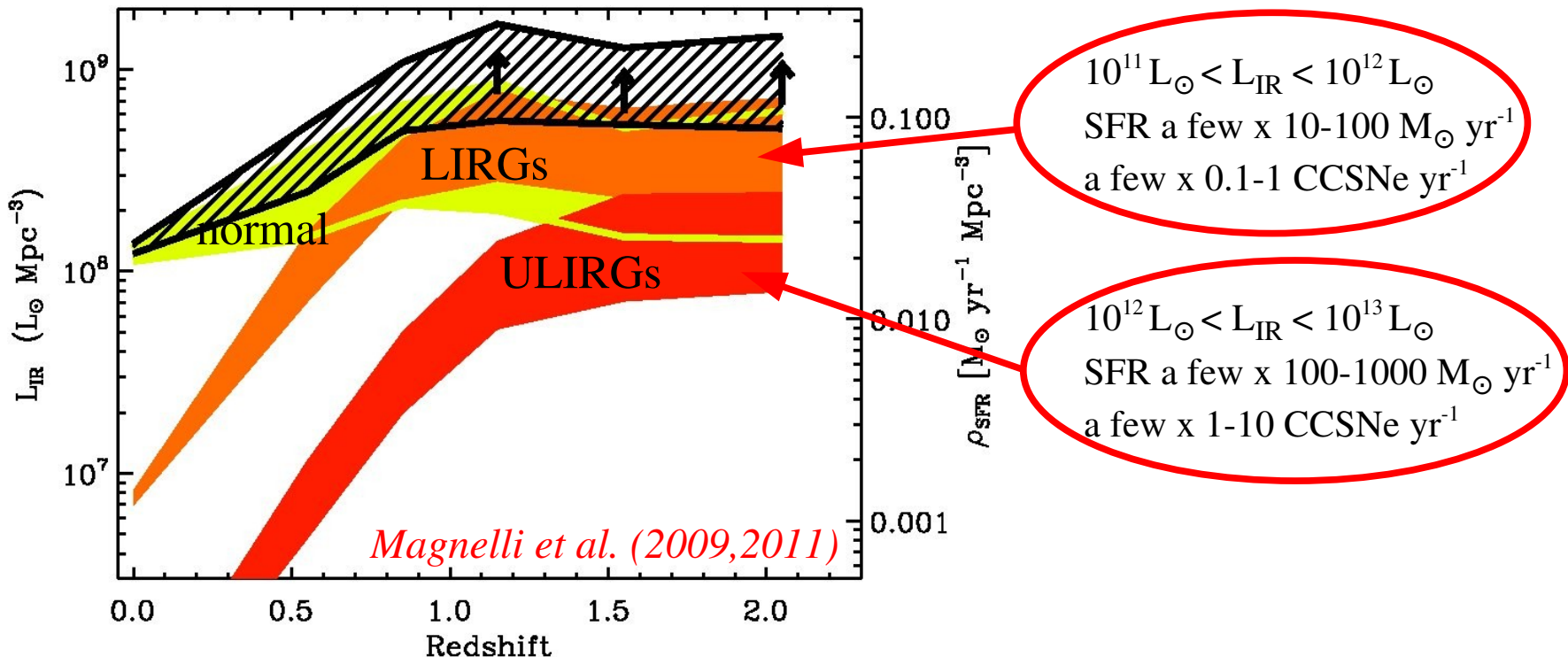
- U/LIRGs locally rare but at  $z \sim 1-2$  dominating the star formation
- Stars forming rapidly during a few  $\times 100$  Myr starburst episode in LIRGs
- Large numbers of massive short lived ( $< \text{a few } \times 10$  Myr) stars exploding as CCSNe
- Still mostly undiscovered due to large extinctions and concentration to nuclear regions
- High spatial resolution near-IR imaging required for the detection and study



The Cosmic Bird

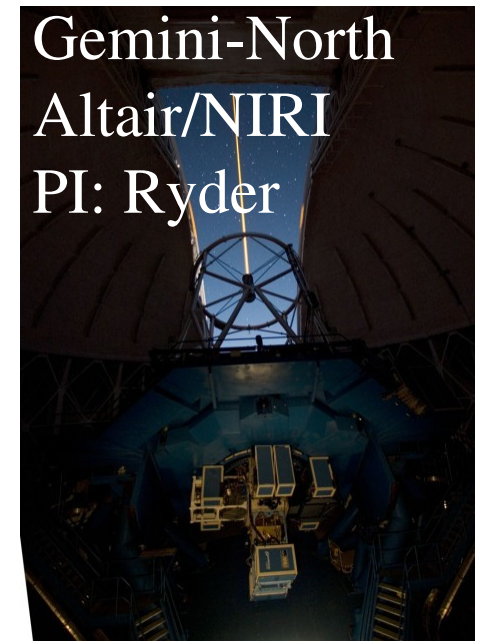
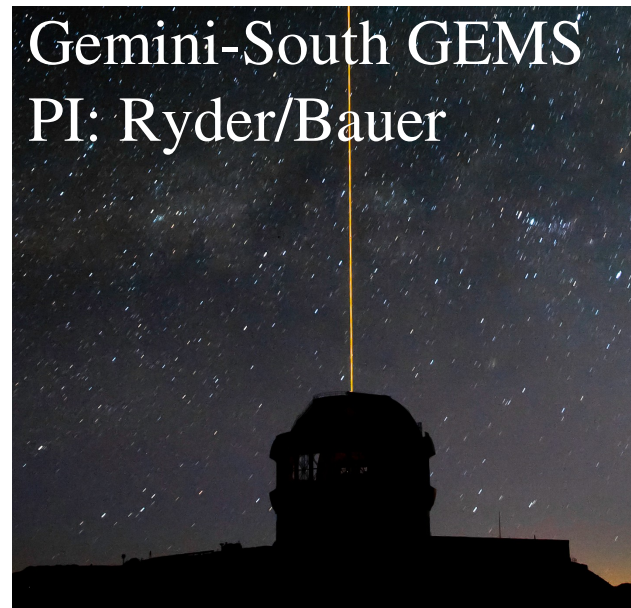
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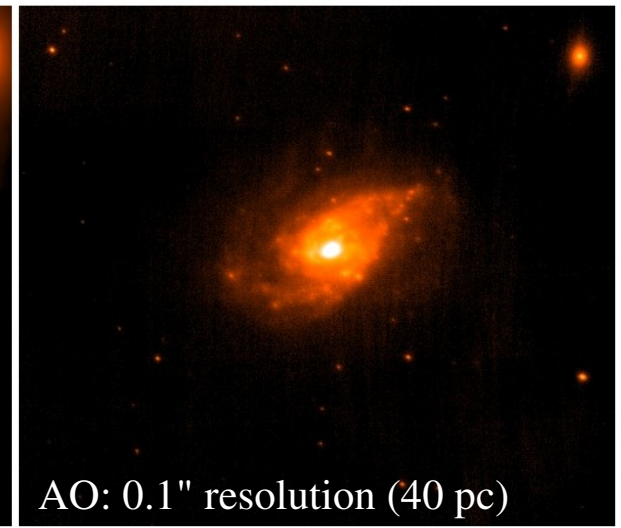
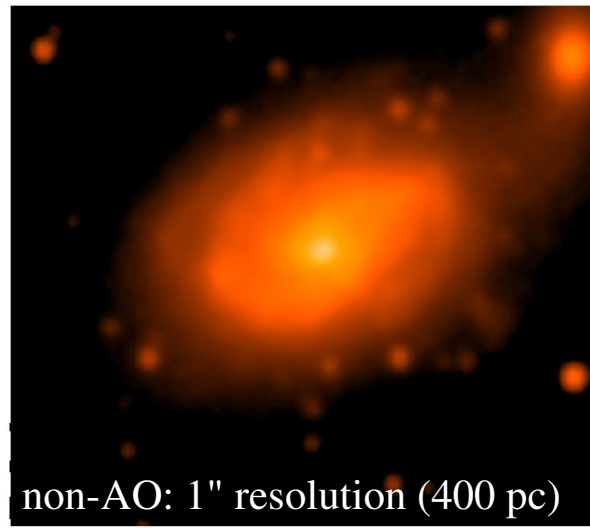
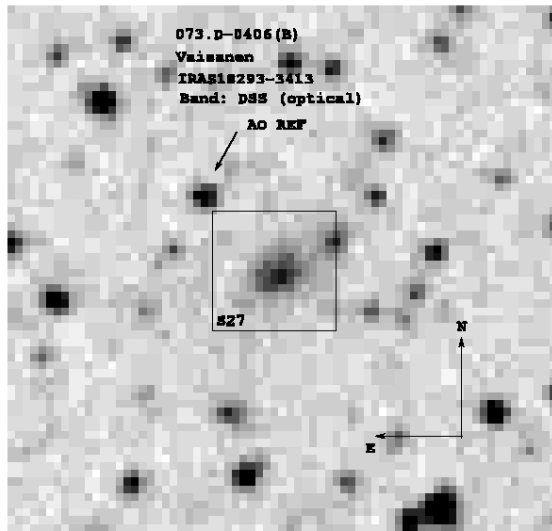
# Infrared observations and Adaptive Optics techniques reveal hidden “Supernova Factories”

- Monitor samples of nearby (<100 Mpc) starburst dominated LIRGs
- Use AO to provide  $\sim 0.1''$  spatial resolution required for the SN detection and study
- Combined use of near-IR AO and high-res. radio for follow-up studies
- Determine the nature of the SNe and estimate extinctions
- How many SNe are we missing in dusty nuclear regions of LIRGs?



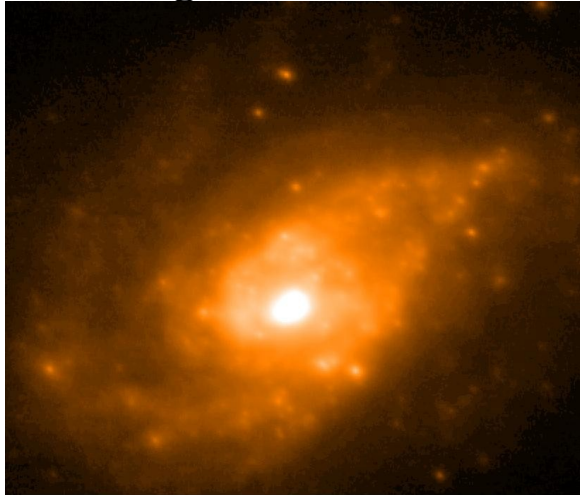
# VLT/NACO observations of IRAS 18293-3413

- Pilot study with NAOS CONICA AO system on ESO VLT in near-IR Ks-band
- Used VIS-WFS, V=15 star 26'' away as a **natural guide star (NGS)**
- Uncorrected seeing FWHM  $\sim 0.5'' - 0.9''$ , am  $\sim 1.1 - 1.3$
- SR  $\sim 10 - 30\%$   $\rightarrow$  FWHM  $\sim 0.1'' \sim 40$  pc @ 80 Mpc



# Image subtraction for the AO images

Image 1 (FWHM~0.1")



$\otimes$  KERNEL =

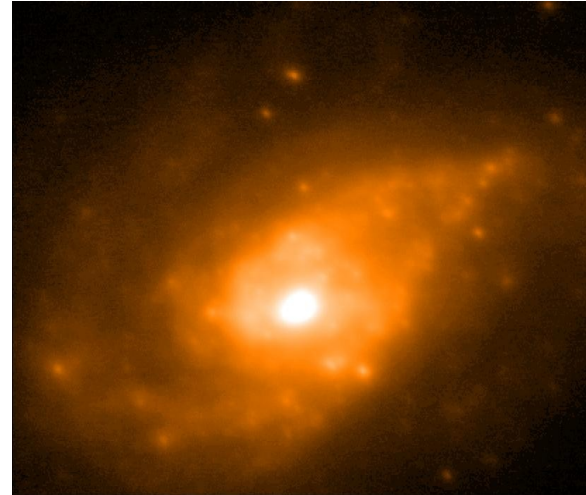
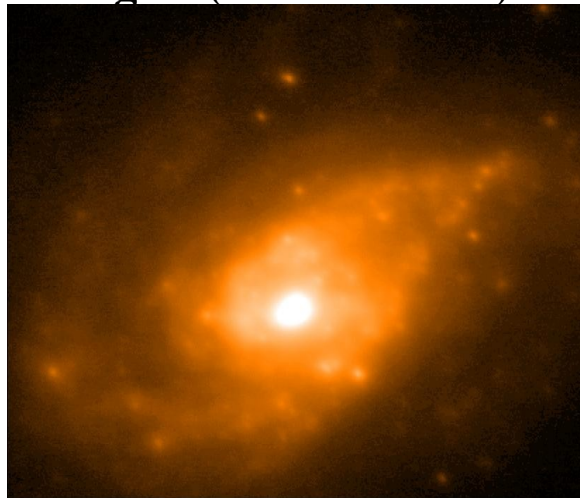
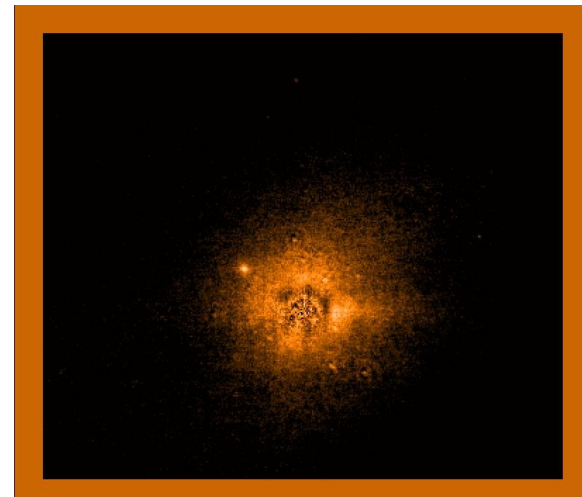


Image 2 (FWHM~0.1")

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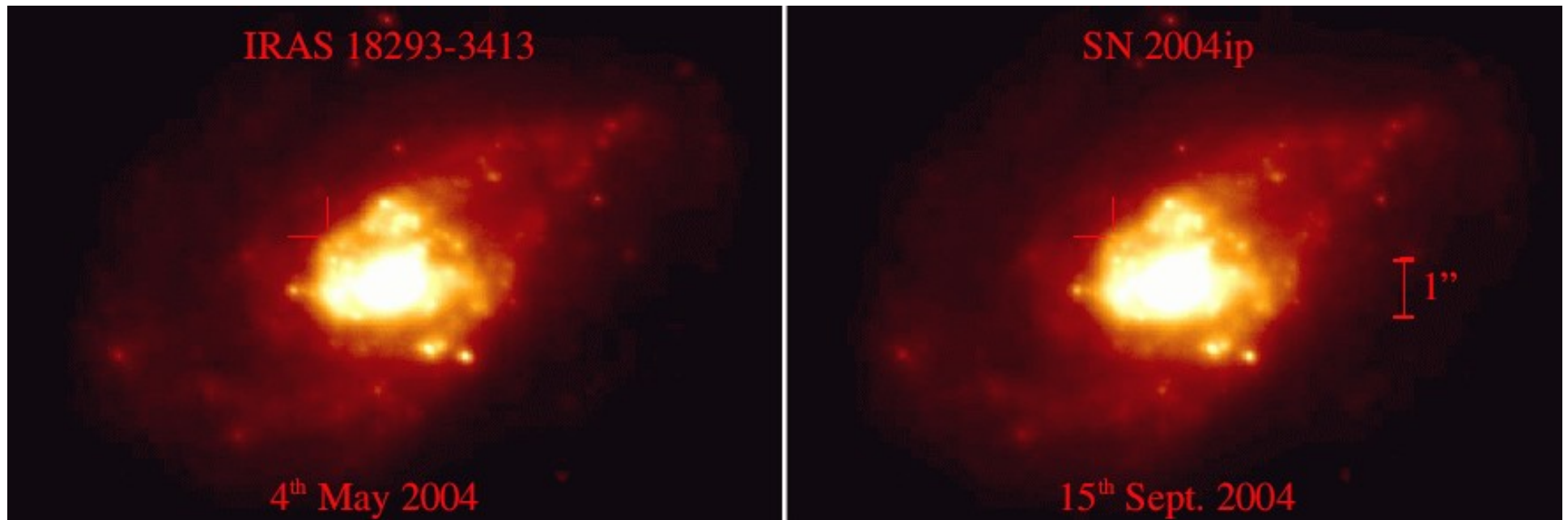


*ISIS 2.2: Alard & Lupton (1998)*

# VLT/NACO reveals SN 2004ip in IRAS 18293-3413

*Mattila et al. (2007); Perez-Torres et al. (2007)*

- SN 2004ip at 1.4'' (500 pc) from the K-band nucleus
- K-band magnitudes consistent with CCSN with  $A_V < 4.0$
- 8.4 GHz VLA detection confirmed the CCSN nature
- First SN to be discovered using AO assisted observations
- Demonstrates the potential of 8-m class telescope + AO in the near-IR

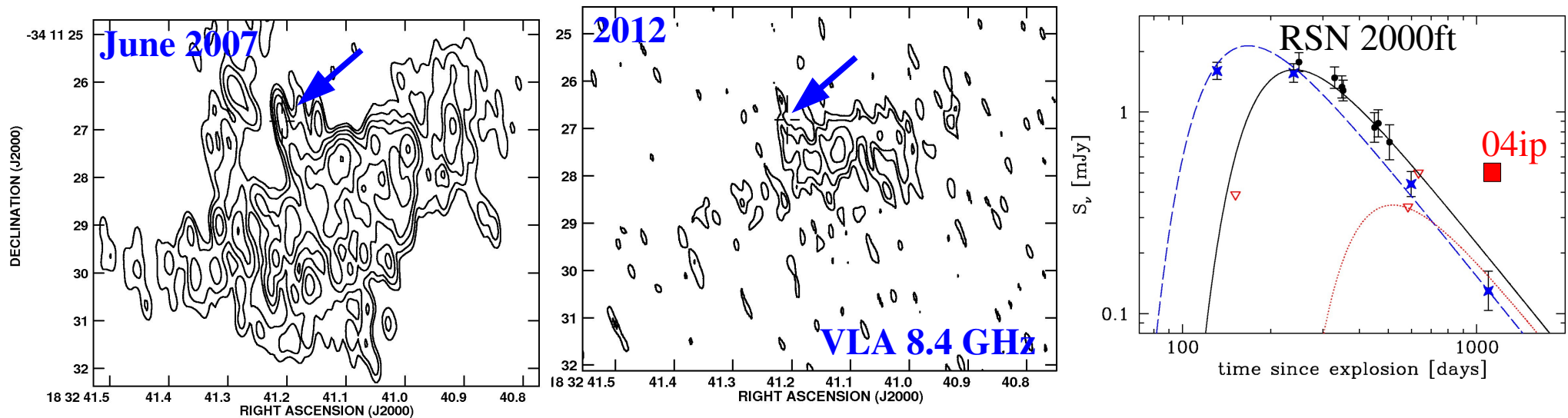




# VL/NACO reveals SN 2004ip in IRAS 18293-3413

*Mattila et al. (2007); Perez-Torres et al. (2007)*

- SN 2004ip at 1.4'' (500 pc) from the K-band nucleus
- K-band magnitudes consistent with CCSN with  $A_V < 40$
- 8.4 GHz VLA detection confirmed the CCSN nature
- First SN to be discovered using AO assisted observations
- Demonstrates the potential of 8-m class telescope + AO in the near-IR

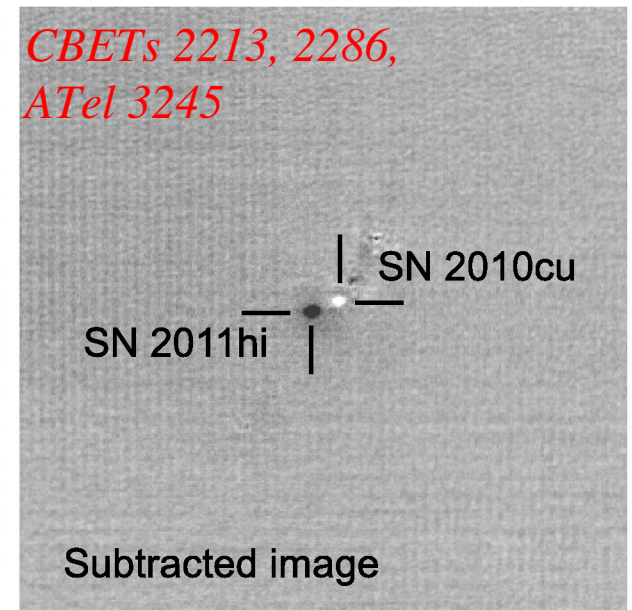
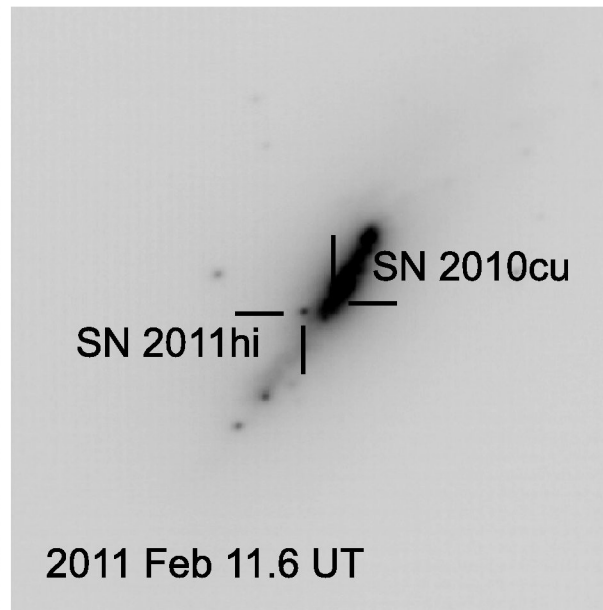
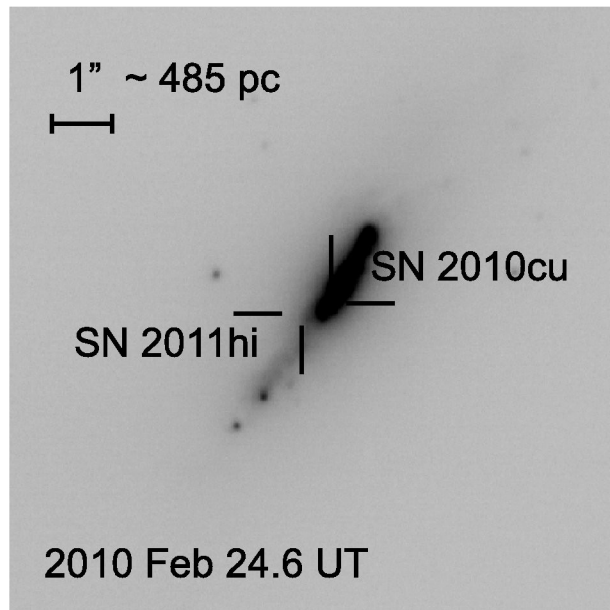


*Perez-Torres et al. (2007); Herrero-Illana et al. in pre.*

# Gemini-N/ALTAIR reveals SNe 2010cu and 2011hi

*Kankare et al. (2012); Romero-Canizales et al. (2012)*

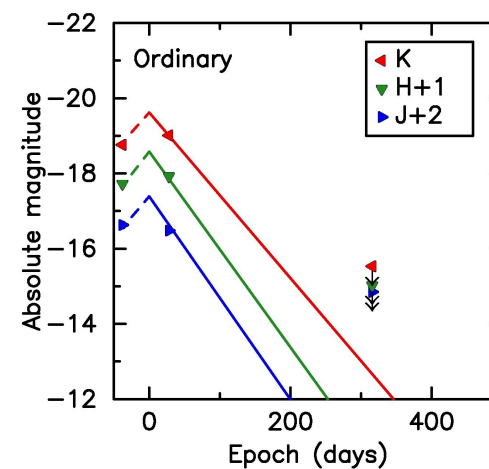
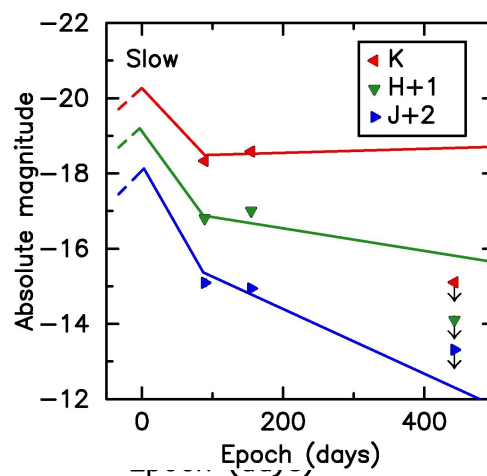
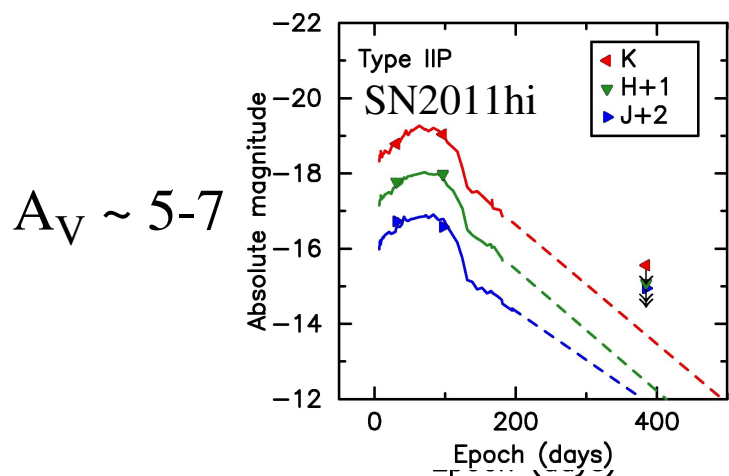
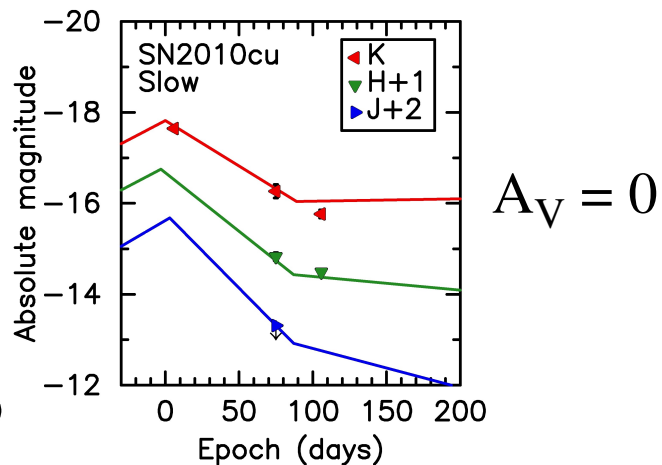
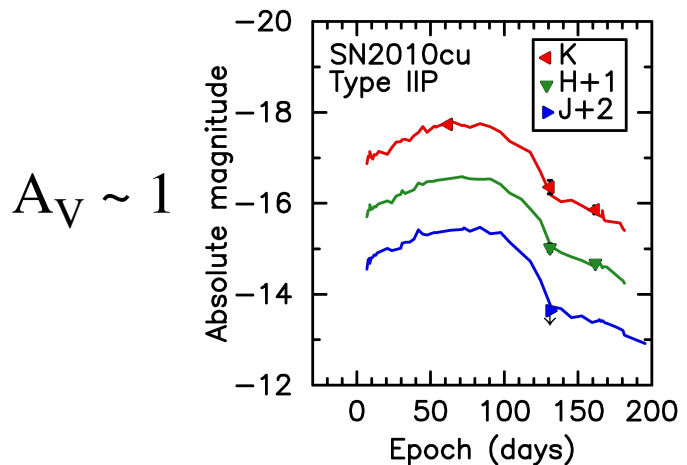
- Observations with Gemini-N+ALTAIR/NIRI with **laser guide star (LGS)**
- Two SNe with projected galactocentric distances 0.37" (180 pc) and 0.79" (380 pc)
- The closest SNe yet discovered to a LIRG nucleus in the near-IR
- Accurate SN photometry from follow-up AO imaging using image subtraction



# Gemini-N/ALTAIR reveals SNe 2010cu and 2011hi

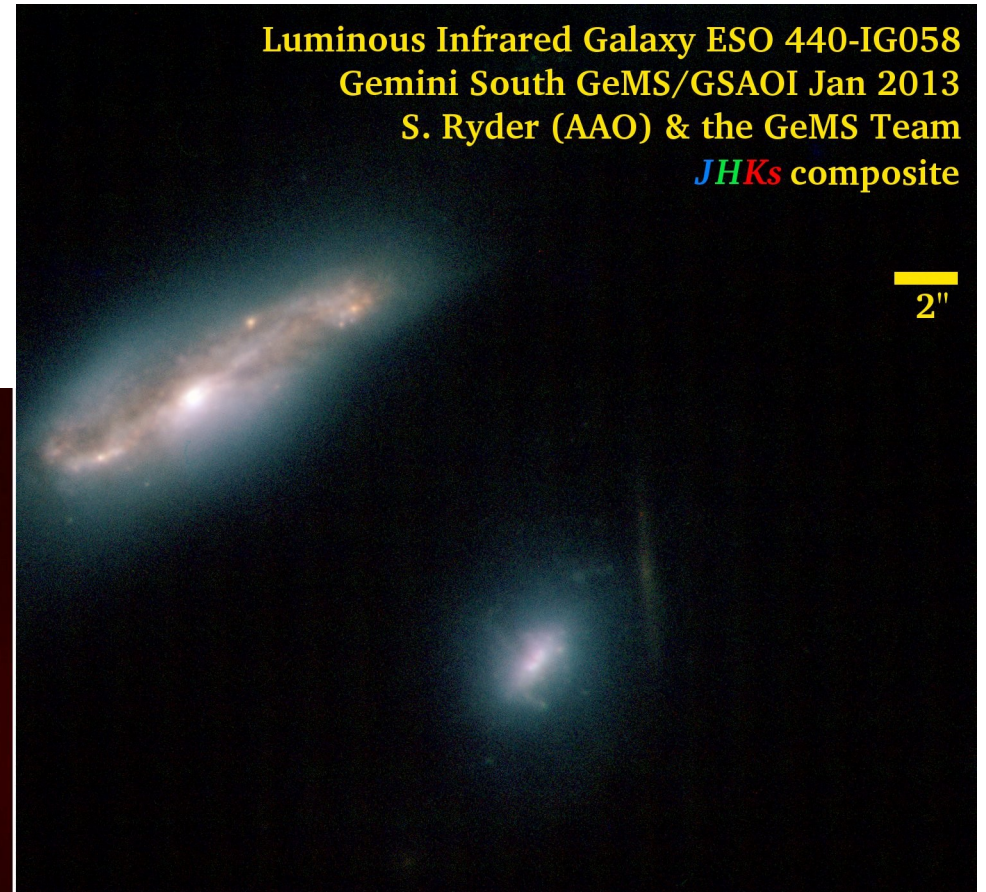
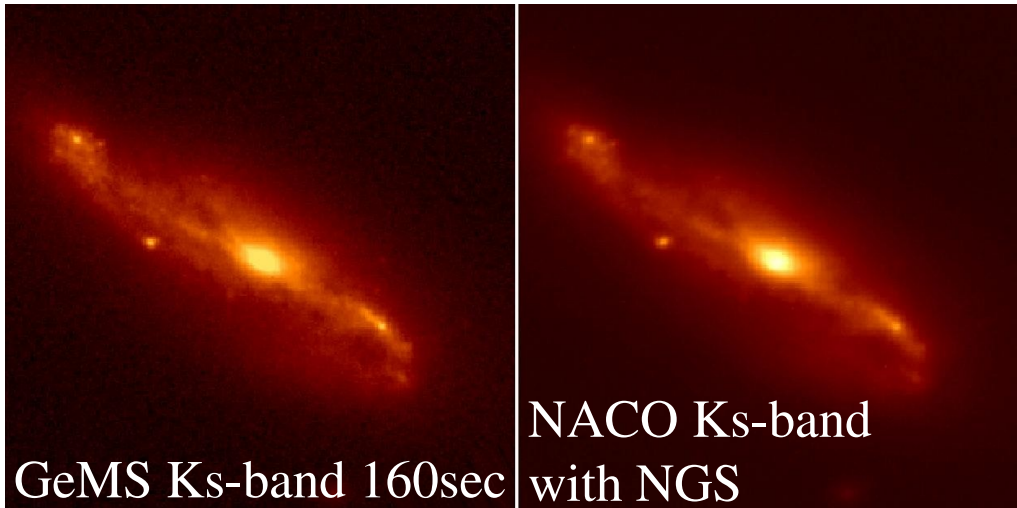
*Kankare et al. (2012); Romero-Canizales et al. (2012)*

- Likely CCSN types and extinctions from 'template' light curve fitting



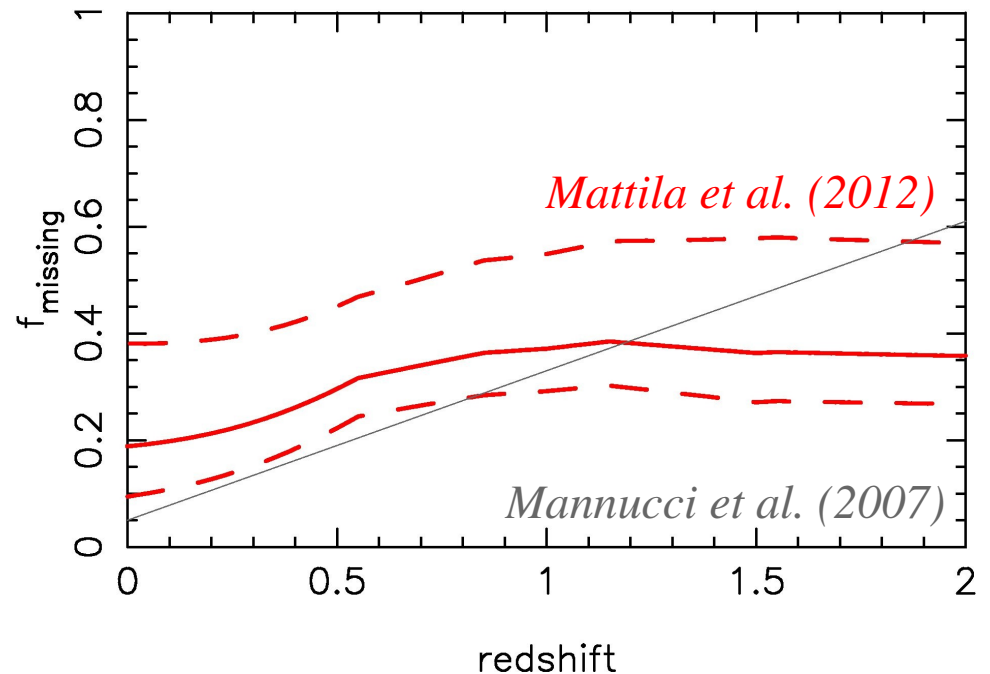
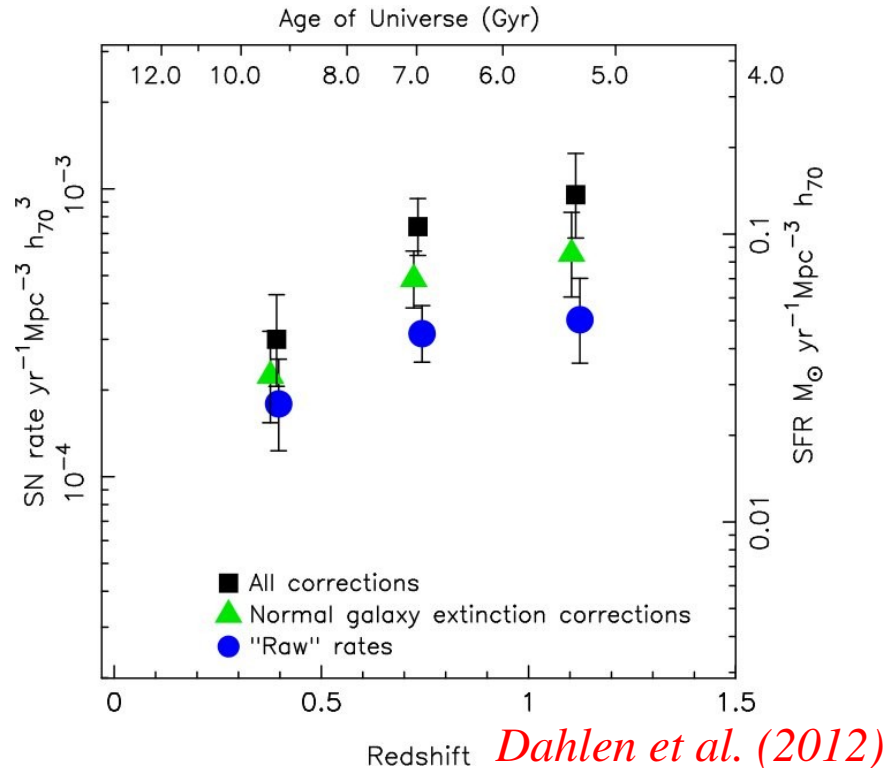
# Early results from Gemini-S + GeMS/GSAOI

- ESO 440-IG058 observed as a part of the GeMS System Verifications
- Used 3 natural guide stars for tip-tilt + 1 on-detector guide star
- Provides 85''x85'' FOV with 0.02''/pixel
- Observe 4 LIRGs in Semester 2013A
- Test PSF uniformity, SN detection by image subtraction, photometry etc.
- Feasibility for SNe at high-z ?



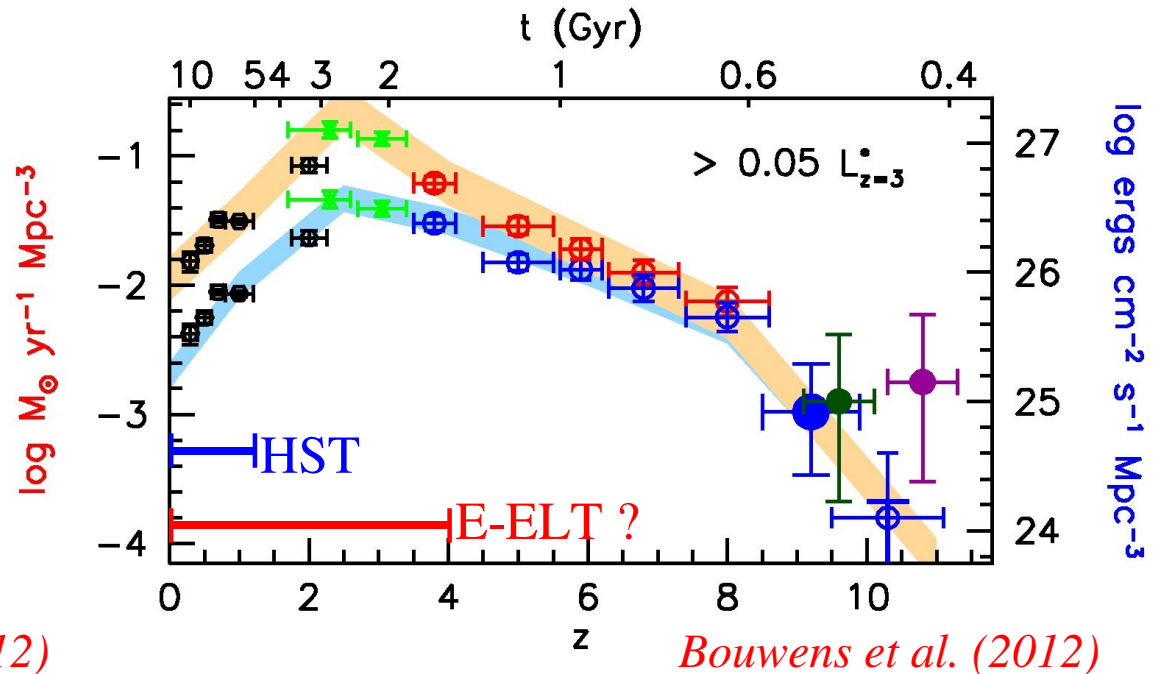
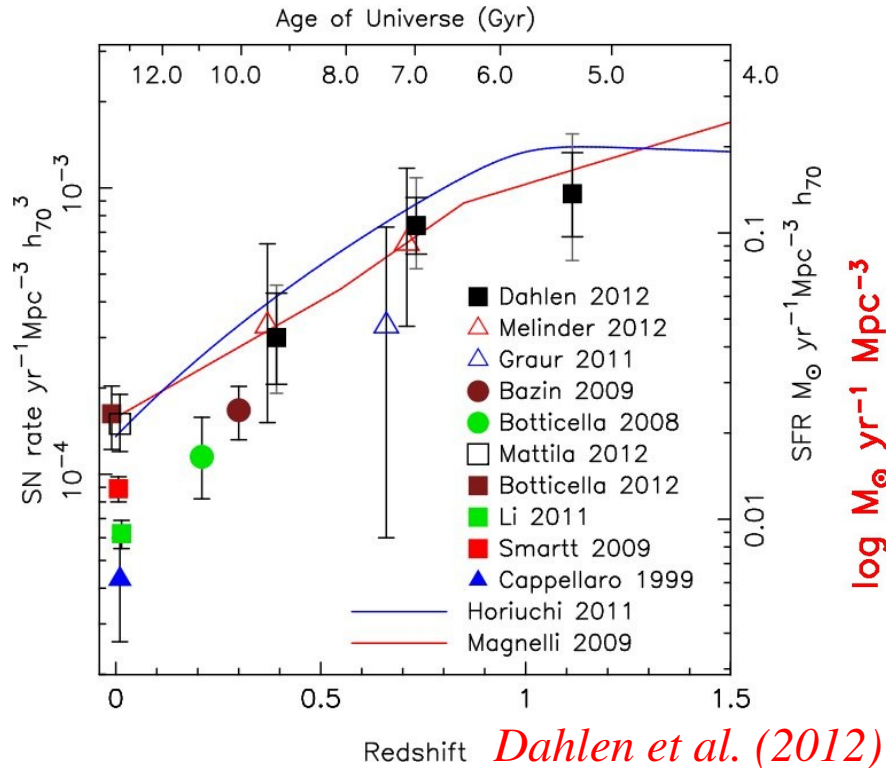
# Supernovae as probes of the cosmic star formation

- Correct CCSN rates for the SNe missed due to *obscuration* by dust
- After correction CCSN rates consistent with expectations from the SFRs
- CCSNe provide an *independent* measurement of cosmic star formation history
- Recent HST measurements up to  $z \sim 1.3$ , E-ELT will provide to  $z \sim 4$  (and beyond?)



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## Summary

- Substantial fraction of CCSNe in U/LIRGs hidden in nuclear regions
- High-res. near-IR AO imaging well suited to detect and study
- Important for estimating *complete* CCSN rates as a function of redshift
- Valuable for testing methods for AO observations of SNe at high- $z$