Core-collapse supernovae in dusty environments

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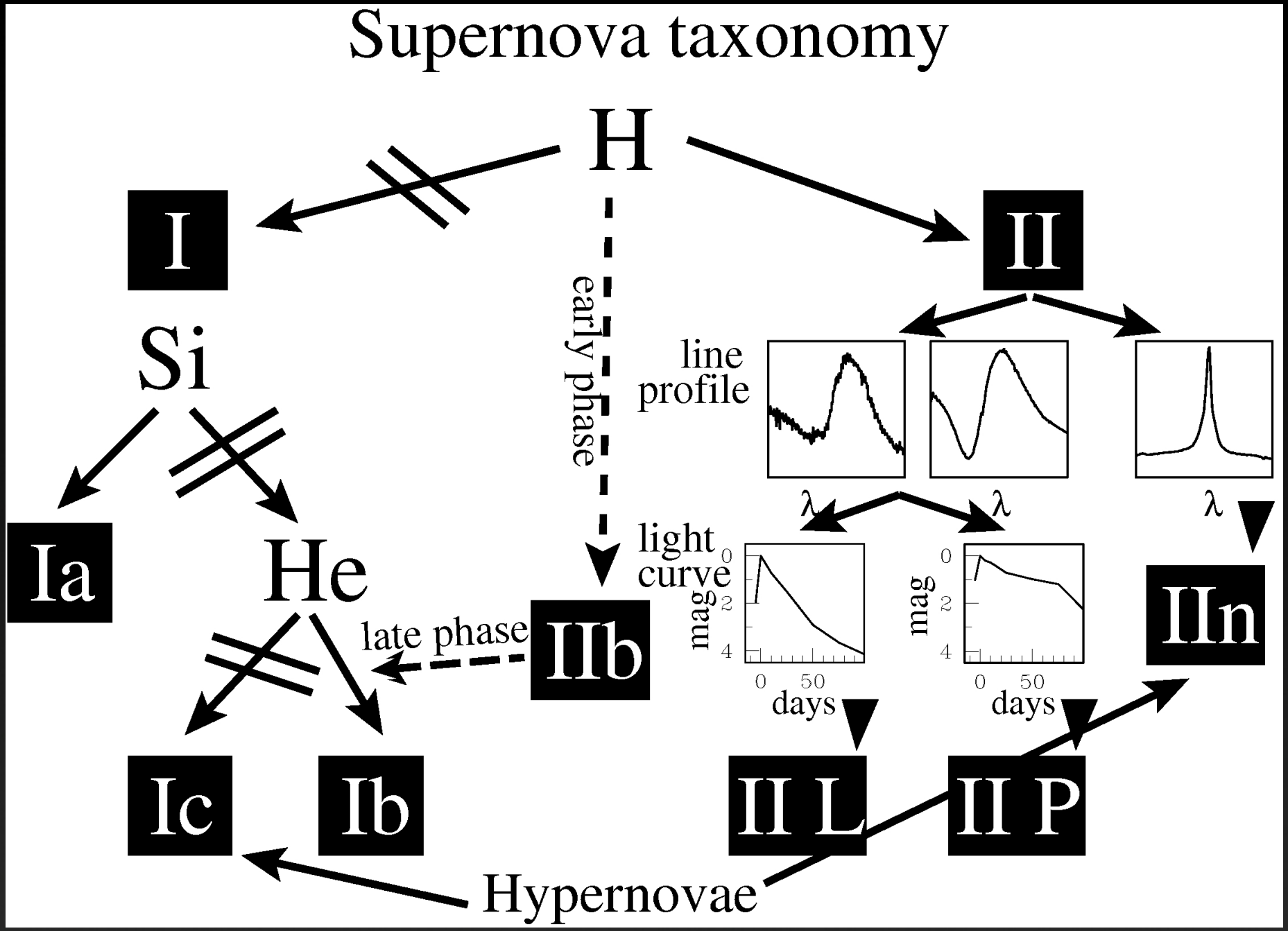
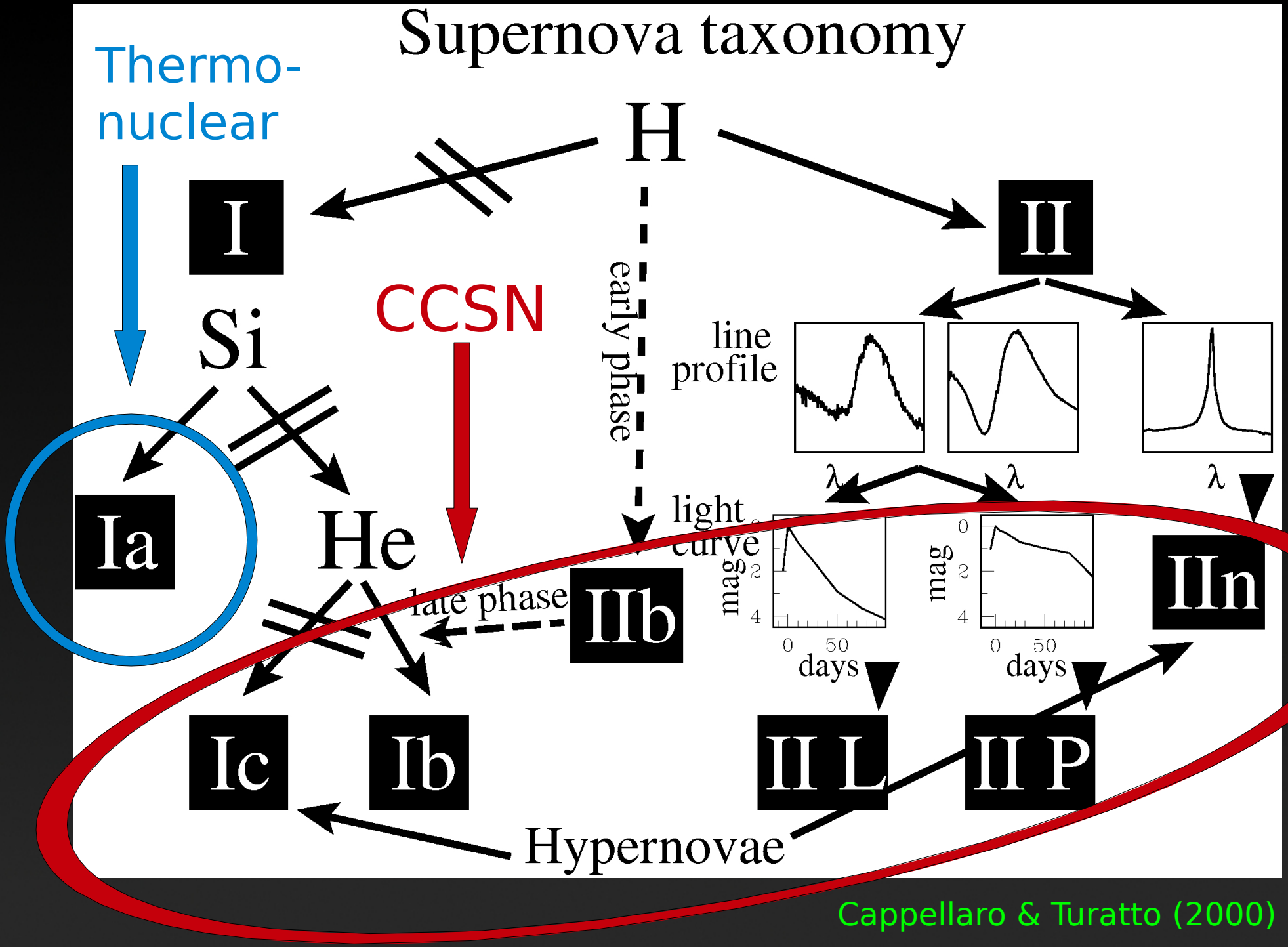
Seppo Mattila, Cristina Romero-Cañizales, Jari Kotilainen,
Ari Takalo (Turku); Stuart Ryder (AAO); Petri Väisänen (SAAO);
Miguel Ángel Pérez-Torres, Antxon Alberdi (IAA-CSIC);
Jens Melinder (Stockholm) et al.

June 4th - Astronomers' Days 2012 - Haikko, Porvoo

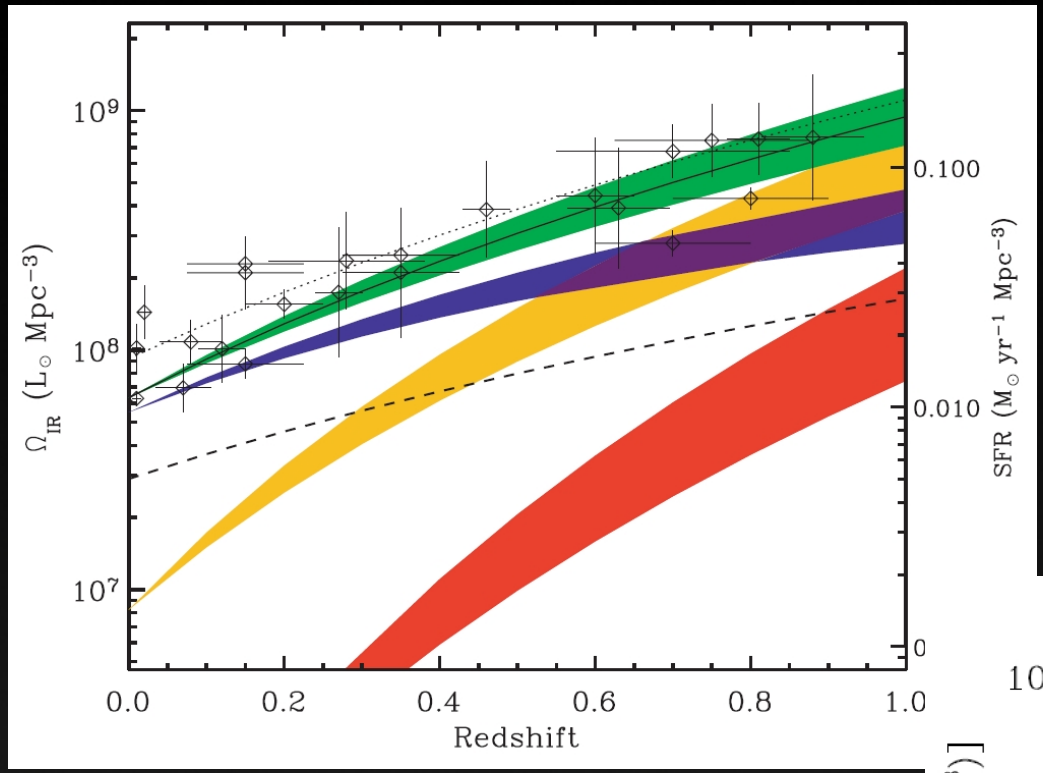


Cappellaro & Turatto (2000)



Cappellaro & Turatto (2000)

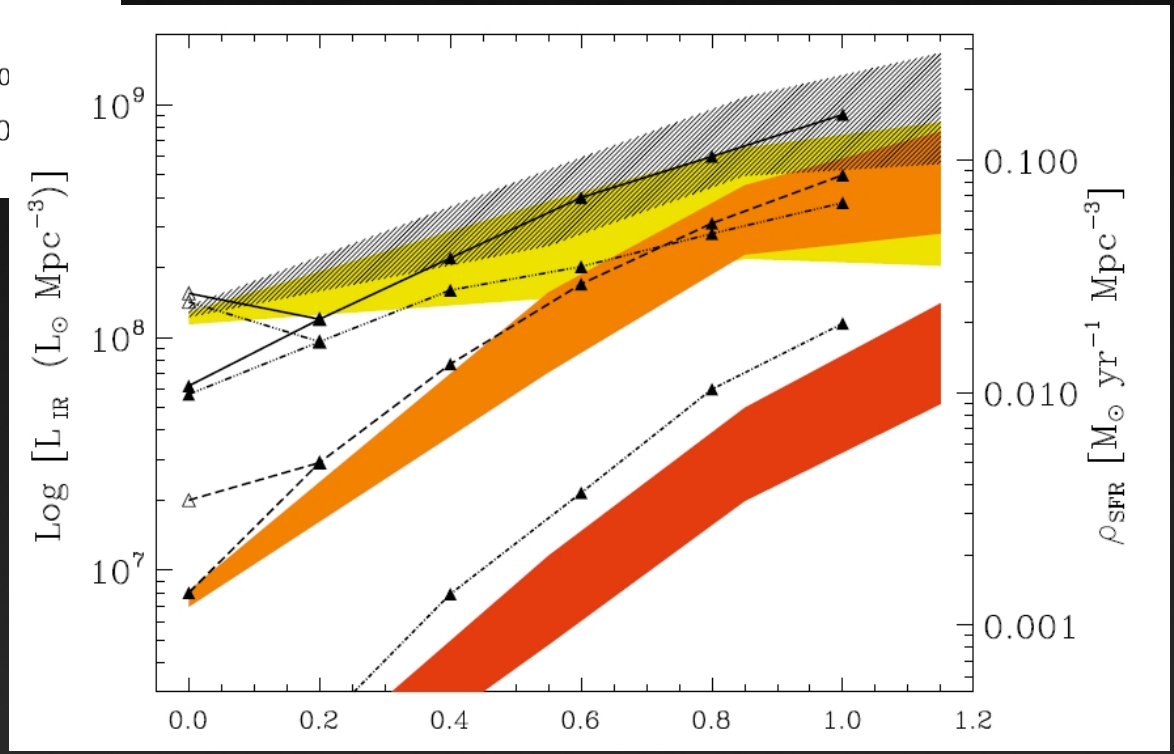
Supernovae in U/LIRGs



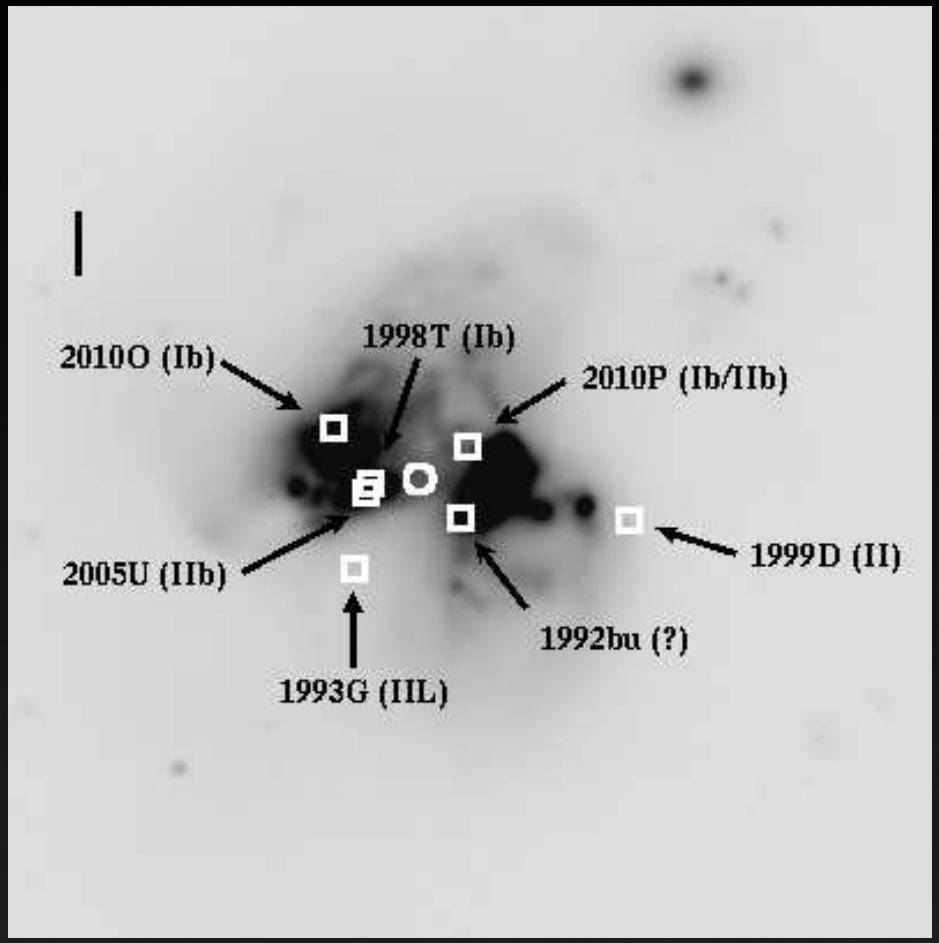
Le Floc'h et al. (2005)

- Luminous ($L_{IR} > 10^{11} L_\odot$) and ultraluminous ($L_{IR} > 10^{12} L_\odot$) infrared galaxies (LIRGs and ULIRGs)
- At redshift z~0.7 U/LIRGs become the dominant source of star formation
- SN rate provides an independent tool to measure star formation

- Dusty, highly obscured galaxies
  - SNe can be used to map the extinction distributions in their host galaxies



Magnelli et al. (2009)

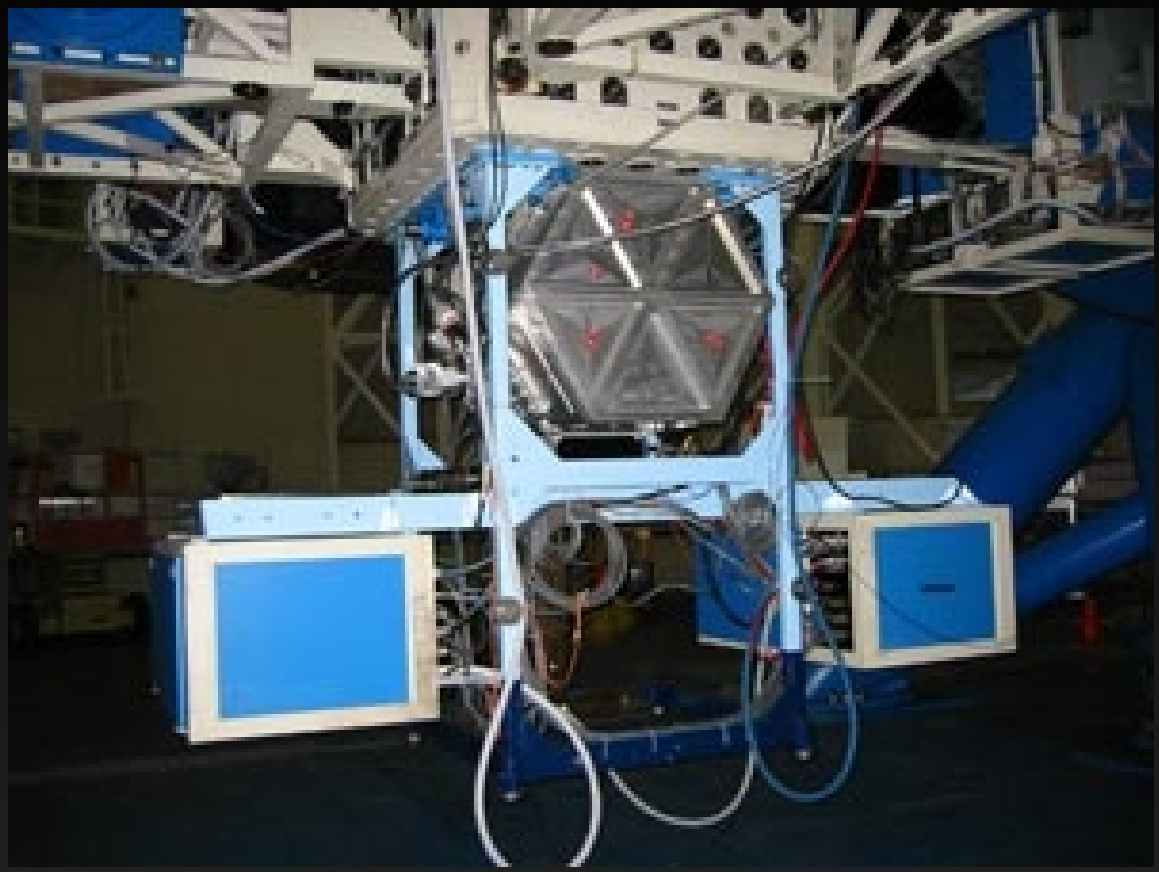


Anderson et al. (2011)

- Potentially different SN population in LIRGs compared to normal spiral galaxies (Anderson et al. 2011)
  - Case study on Arp 299
  - Ratio of stripped envelope (Ib/c, IIb) SNe to normal Type II (IIP/L) SNe higher compared to normal spiral galaxies in the local Universe
- Small number statistics: so far only a low number of SNe have been discovered in U/LIRGs in optical/near-IR
- Dusty, highly obscured environments - especially in the nuclear regions
- Near-IR observations and high spatial resolution required
  - Adaptive optics
  - Space telescopes

ALTAIR/NIRI

- **N**ear **I**nfra**R**ed **I**mager and Spectrograph
- Single-conjugate adaptive optics (AO) system ALTAIR
- Gemini-North
- *JHK* broad band filters
- 22 arcsec x 22 arcsec
- 0.0219 arcsec/pixel
- FWHM ~ 0.1 arcsec
- Natural guide star (NGS) or laser guide star (LGS) modes
- Sample of 8 LIRGs
  - < 100 Mpc
  - SN rate ~ 1 yr^{-1}



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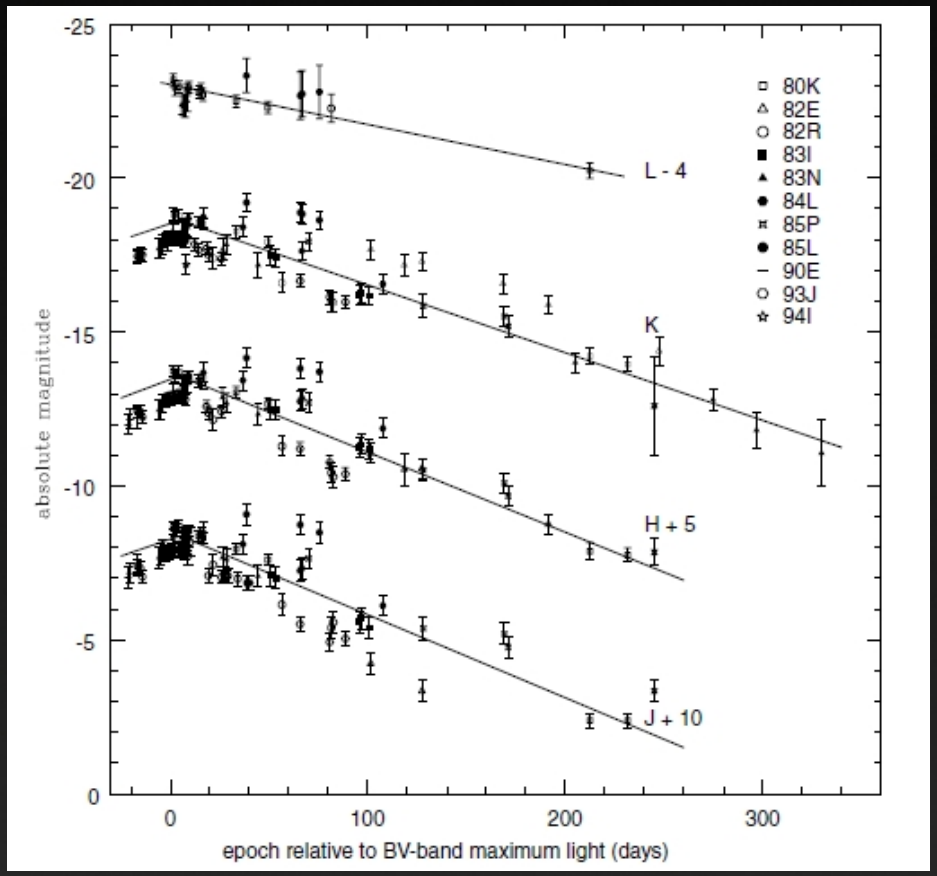
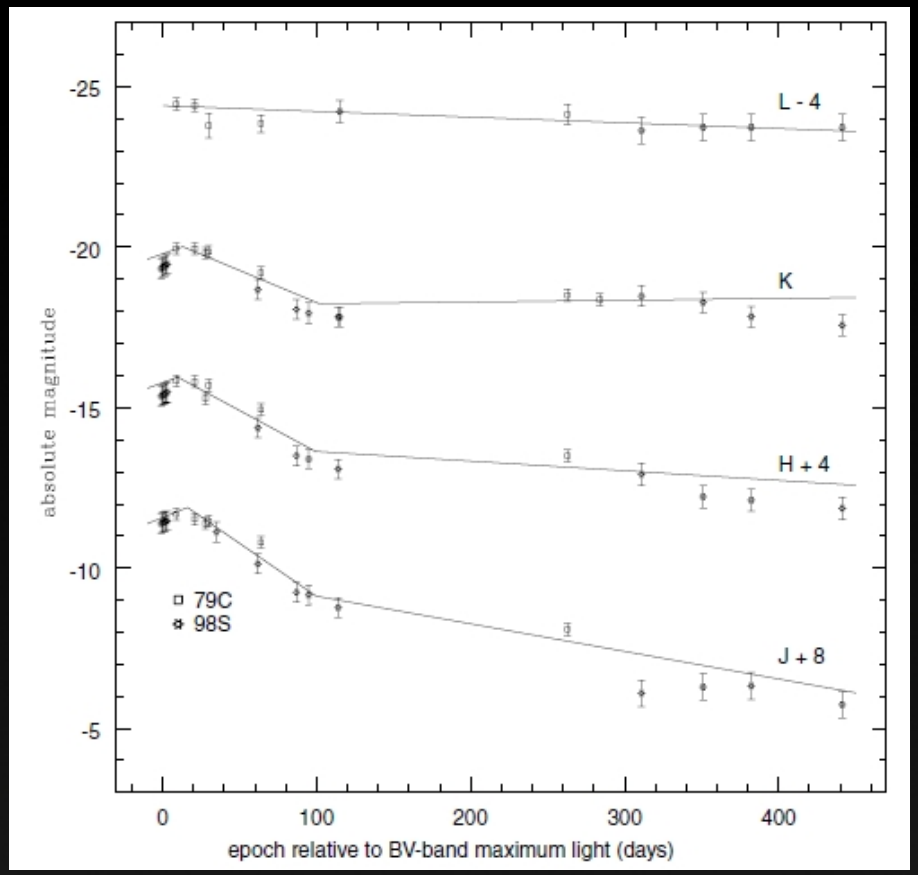
Near-IR light curve templates

- Mattila & Meikle (2001):
  - 'normal' & 'slowly declining SNe'
- 'normal' template based on several Type Ib/c SNe (also some Type II-P and Type II-L data)

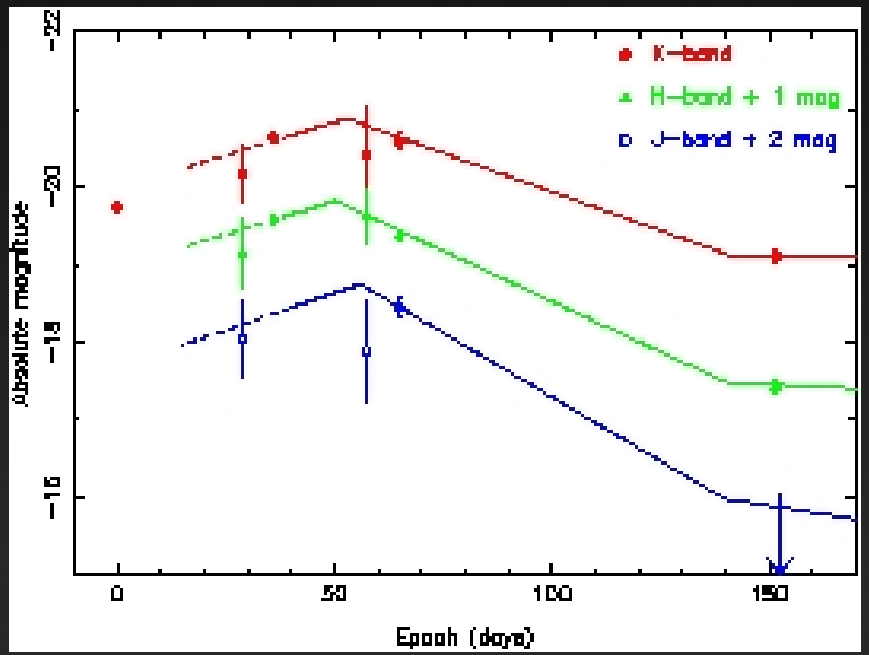


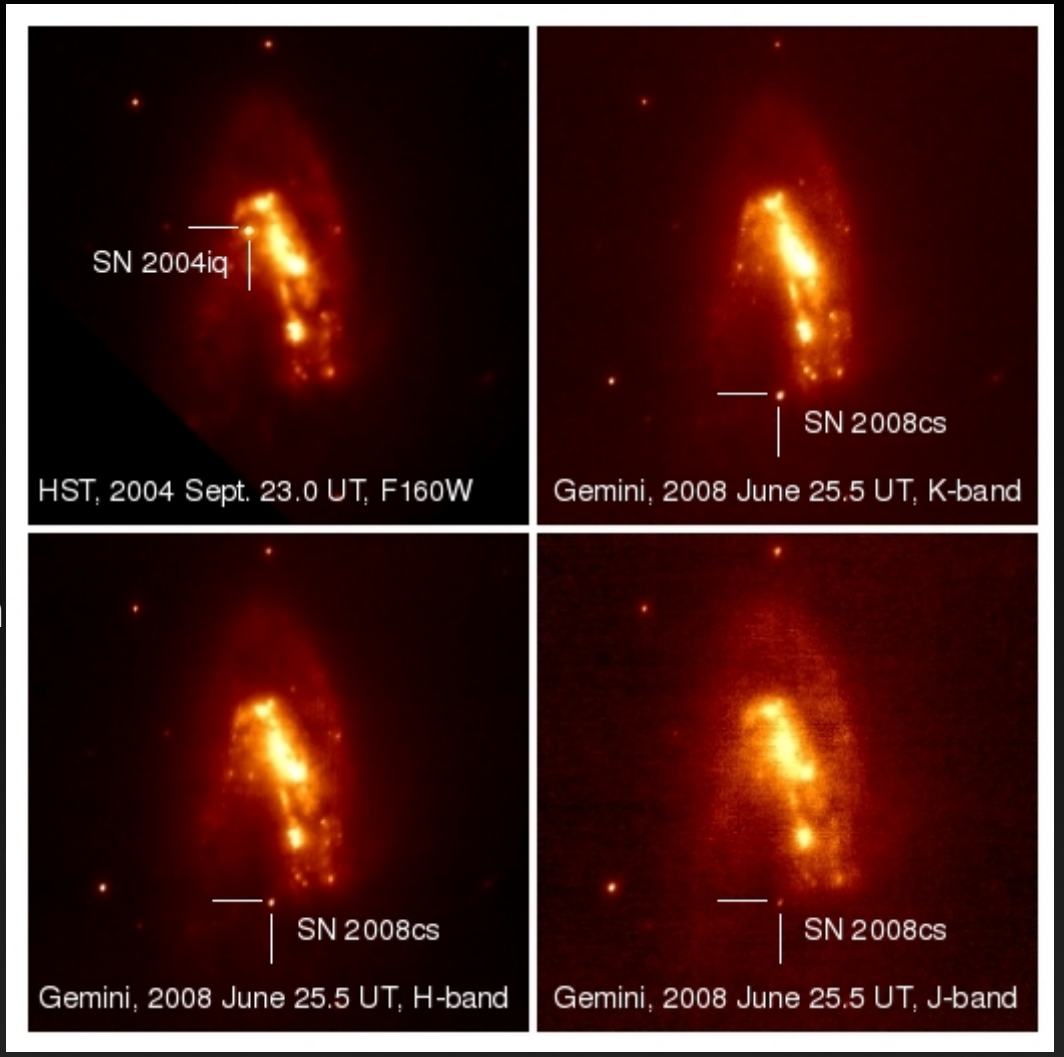


- 'slowly declining' template based on two SNe: Type IIn SN 1998S and II-L SN 1979C
- However, volume limited LOSS sample:
  - 53% CCSNe Type II-P SNe
- Well sampled Type II-P *JHK* light curve of SN 1999em (Krisciunas et al. 2009) as a temporary template

SN 2004iq & SN 2008cs in IRAS 17138-1017

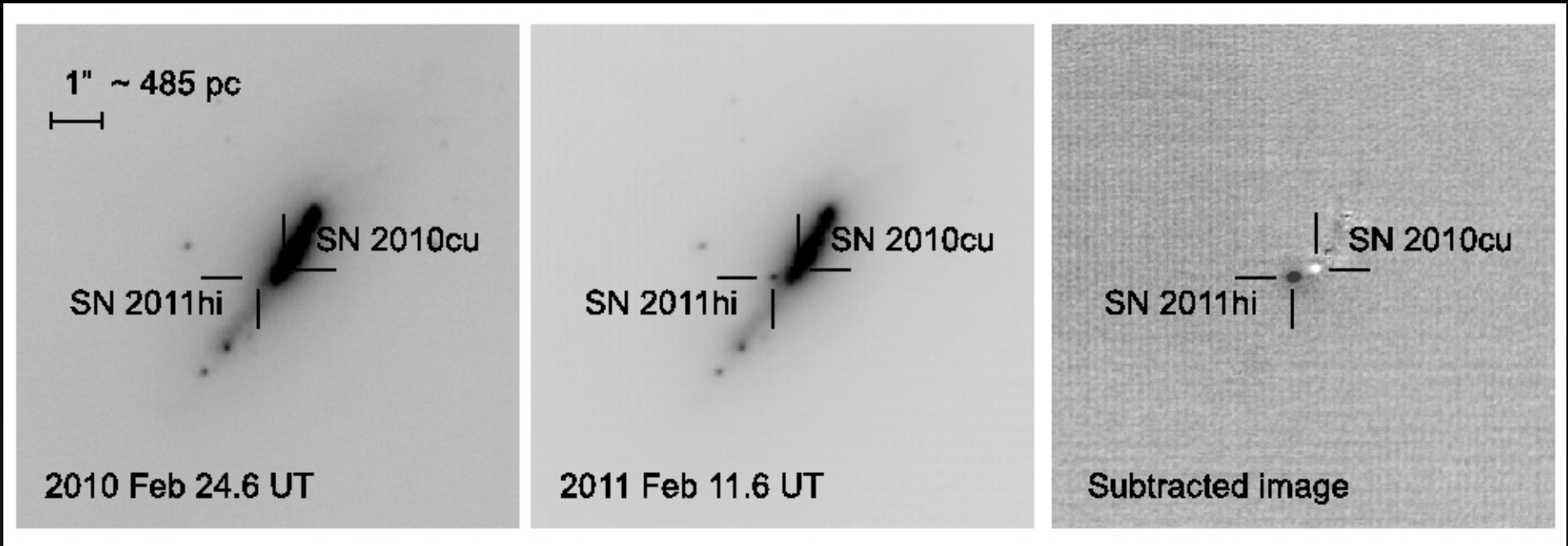
- Kankare et al. (2008), ApJ, 689, L97
- SN 2004iq: SN in HST archive images
  - Host galaxy extinction of $A_V \sim$ 0-4 mag?
- SN 2008cs: First LGS SN discovery
  - Total line-of-sight extinction of $A_V \sim$ 18 mag
  - Rieke & Lebofsky (1985) extinction law





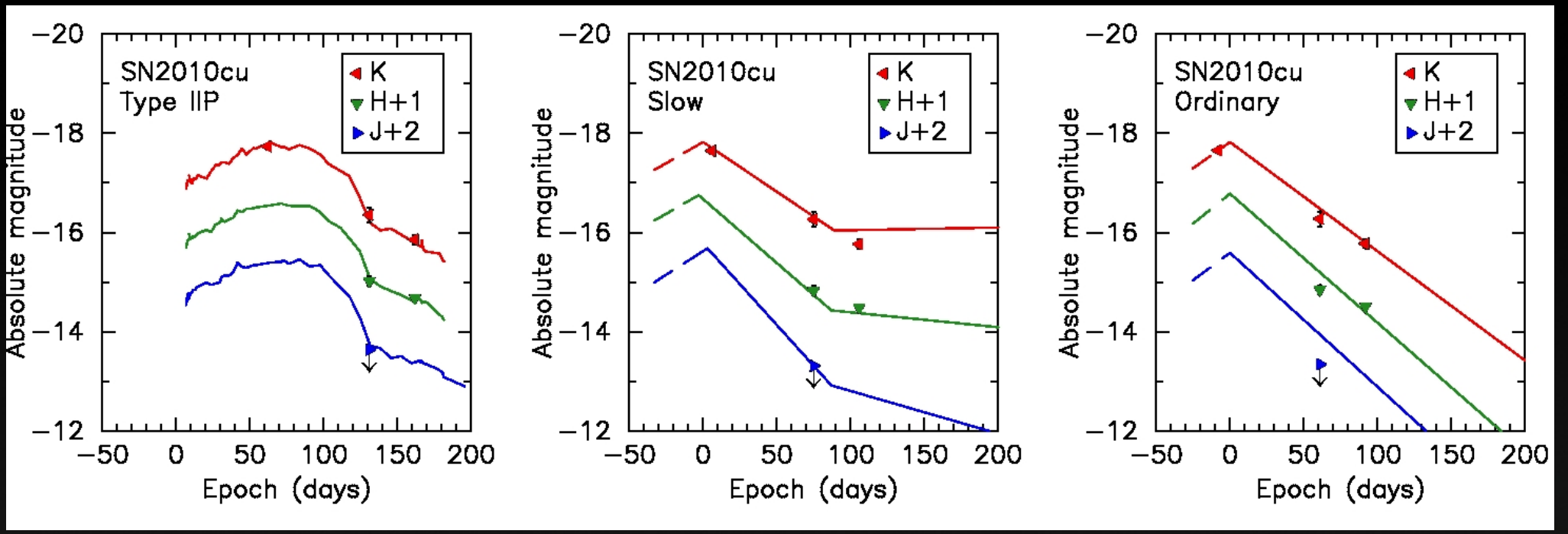
- Expected SN rate of IRAS 17138-1017 ~0.7 SNe yr^{-1}

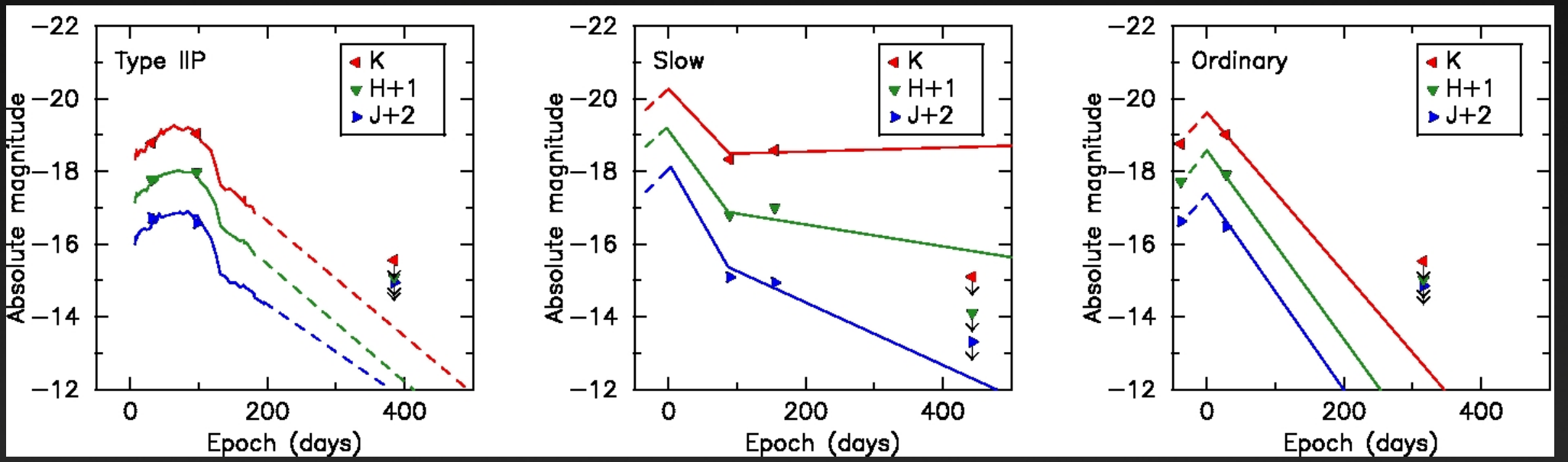
SN 2010cu & SN 2011hi in IC 883



- Kankare, Mattila, Ryder et al. (2012), ApJ, 744, L19
- Radio paper on IC 883 with additional ALTAIR/NIRI data, Romero-Cañizales et al. (2012), A&A in press
- Expected SN rate of IC 883 ~1.3 SNe yr^{-1}
- SN 2010cu at 0.4” (180 pc) and SN 2011hi at 0.8” (380 pc) from the nucleus (projected distance)

SN 2010cu & SN 2011hi in IC 883

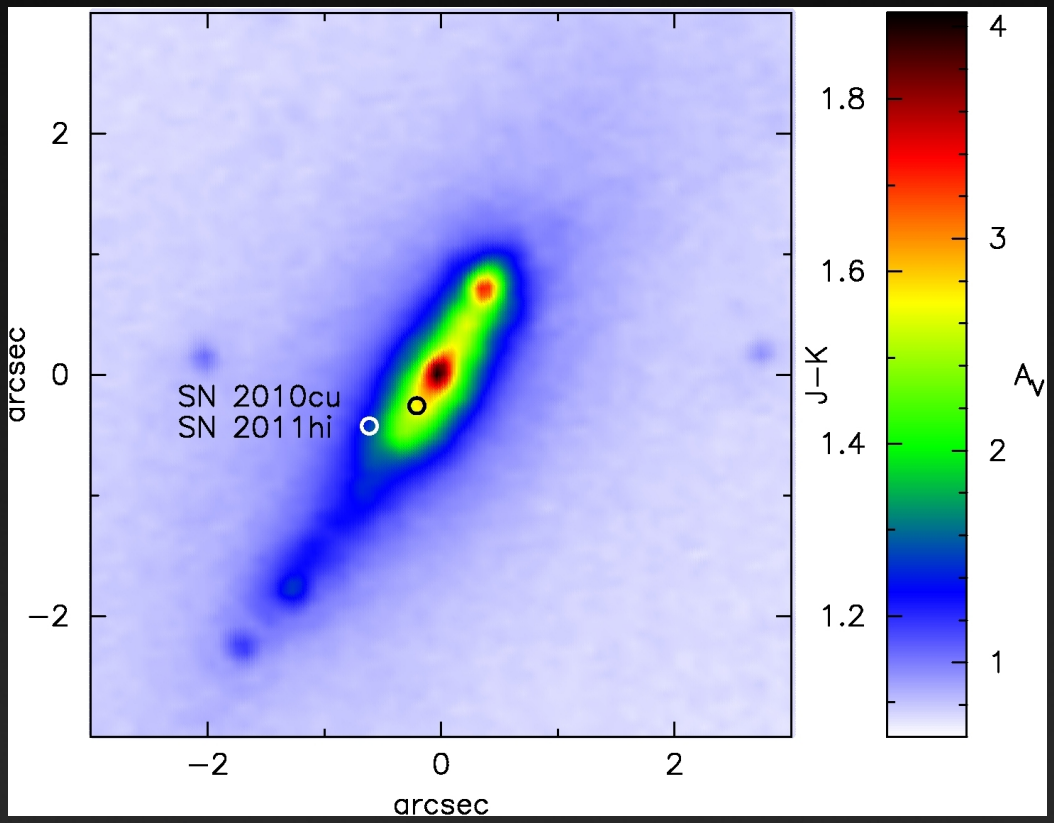




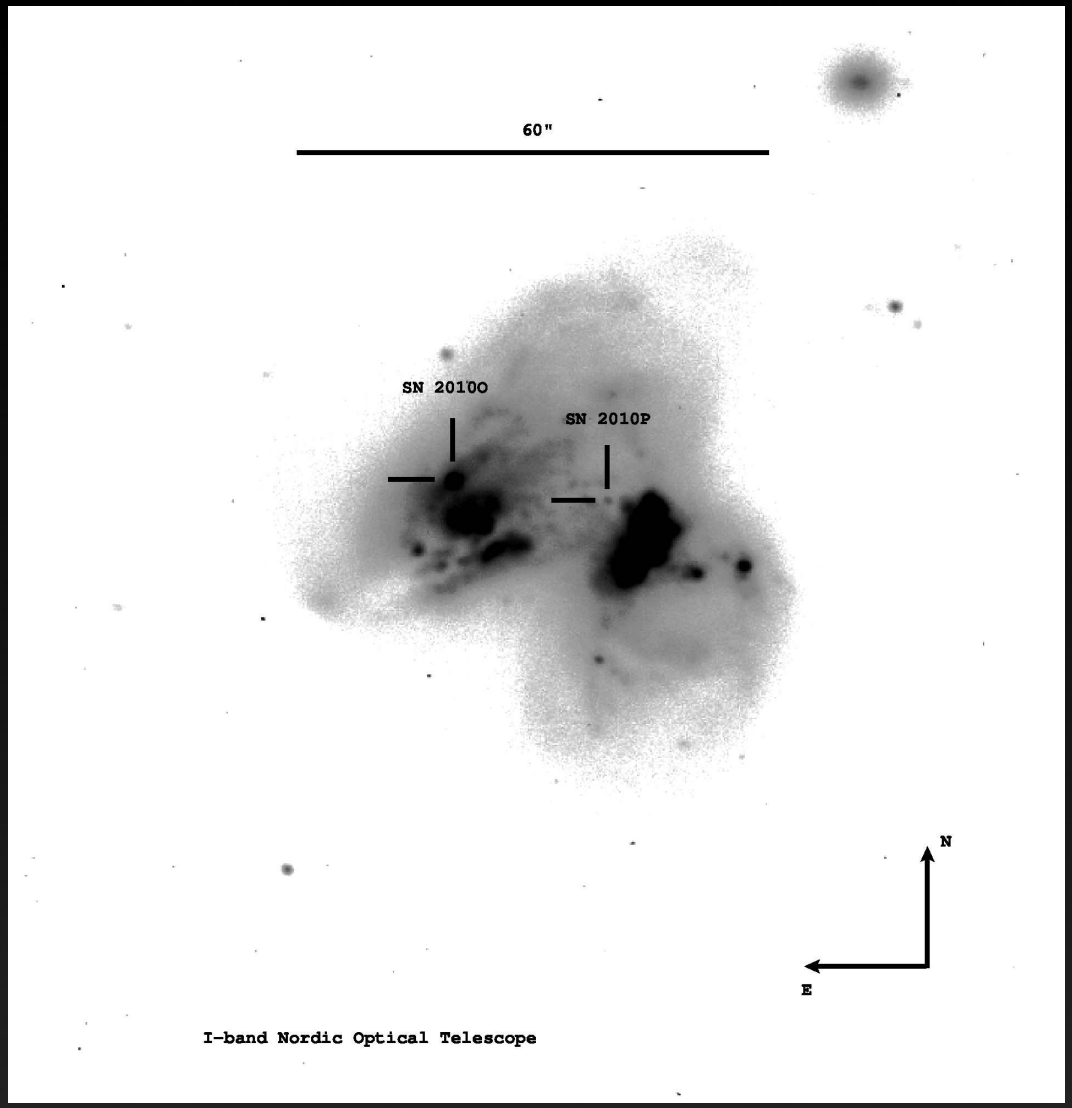
SN 2010cu & SN 2011hi in IC 883

Template	A_V (mag)	t_0 (days)	C (mag)	$\tilde{\chi}^2$	A_V (mag)	t_0 (days)	C (mag)	$\tilde{\chi}^2$
SN 2010cu	Cardelli law				Calzetti law			
ordinary	0.1	-8	+0.80	11	0.1	-8	+0.80	11
slow	0.0	6	+2.20	8.5	0.0	6	+2.20	8.5
IIP	1.3	62	+0.10	1.7	1.0	62	+0.15	1.7
SN 2011hi								
ordinary	6.8	-38	-1.35	5.0	4.7	-38	-1.00	4.4
slow	0.0	89	-0.25	27	0.0	89	-0.25	27
IIP	7.0	31	-1.65	9.4	5.0	31	-1.30	8.8

- *J-K HST*/NICMOS archive data colour map
  - Upper limit for the line-of-sight extinction
  - Localized higher extinction possible
- SN 2010cu most consistent with 'slowly declining' and IIP templates
- New data on 31st of January 2012. No clear detection of SN 2011hi → likely a Type IIP



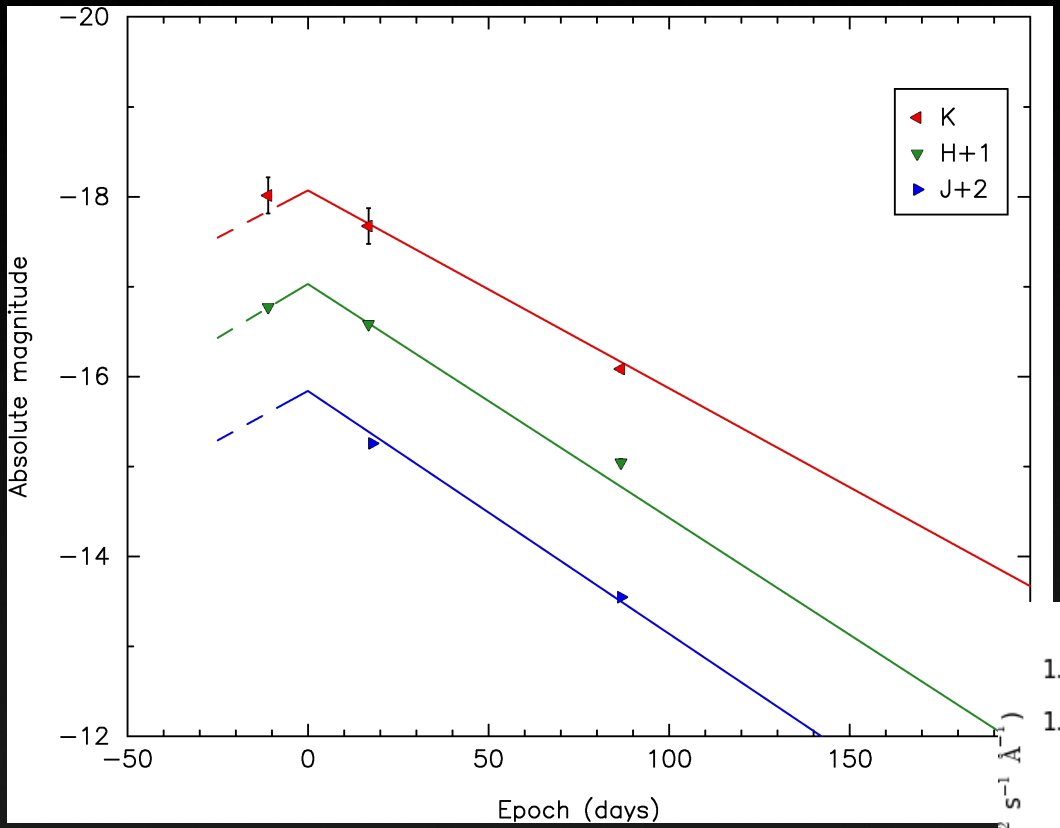
SN 2010O & SN 2010P in Arp 299



- SN 2010O discovered by Newton et al. (2010), CBET 2144
- SN 2010P discovered by Mattila & Kankare (2010), CBET 2145
- SN 2010O typed as Ib by Mattila, Kankare, Datson & Pastorello (2010), CBET 2149
- SN 2010P typed as Ib/IIb by Ryder, Mattila, Kankare & Perez-Torres (2010), CBET 2189

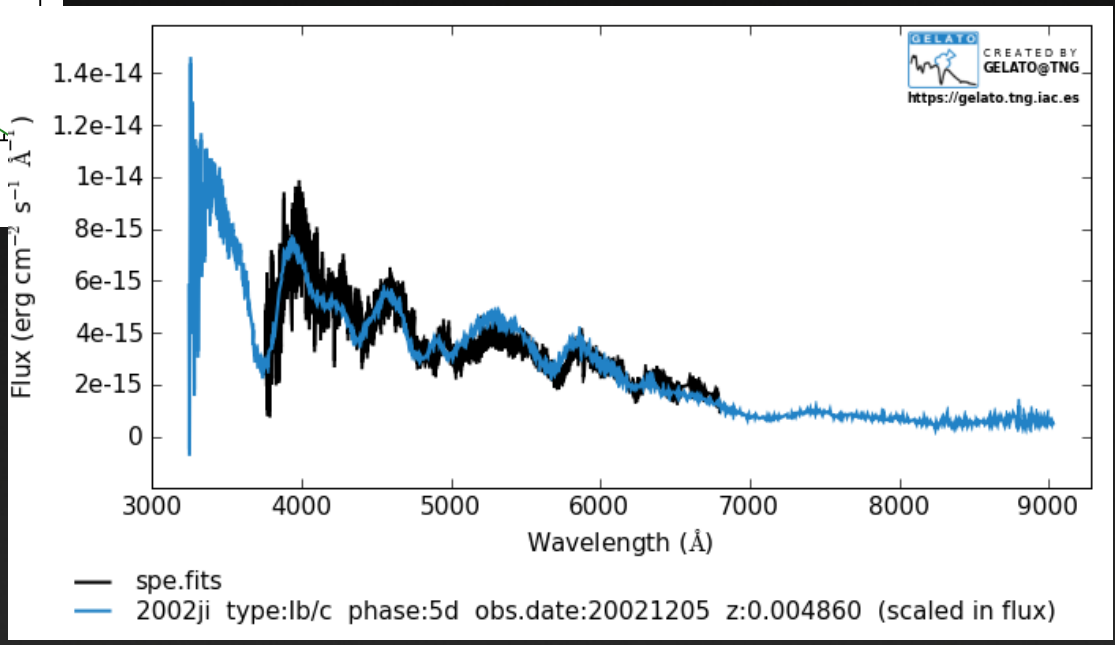
- Expected SN rate of Arp 299 ~2 SNe yr^{-1}

SN 2010O in Arp 299

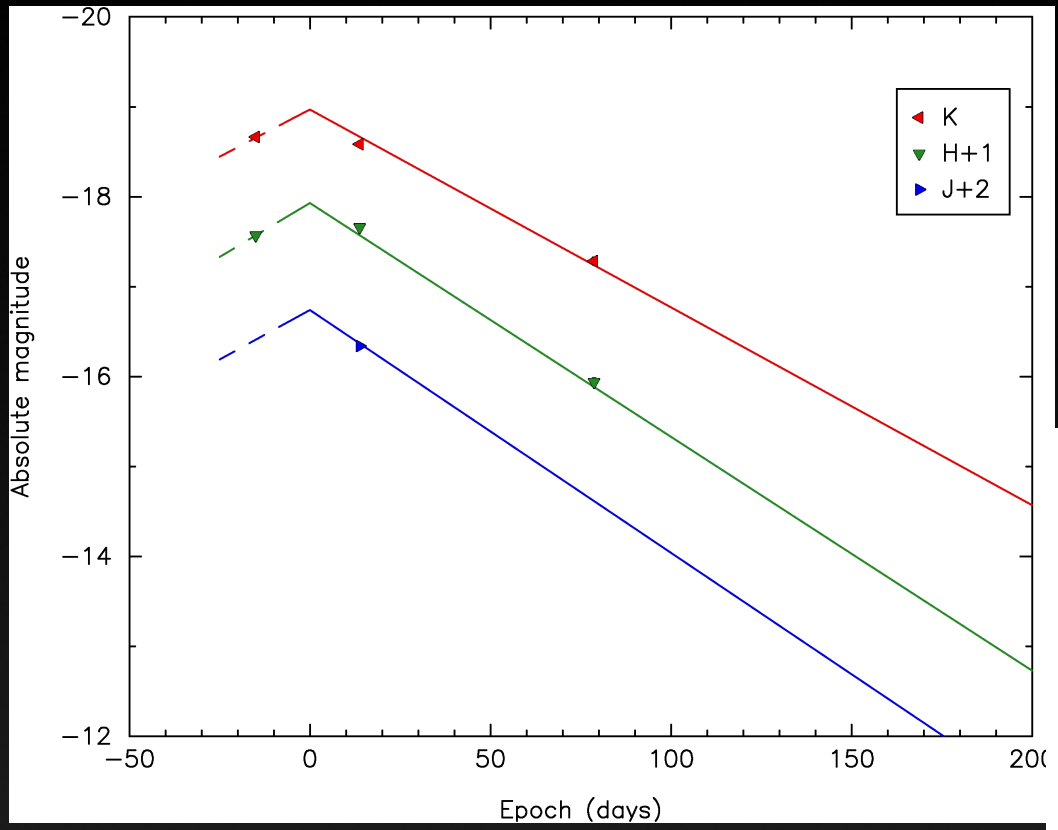


- 'normally' declining template
- $A_V = 2.7$ mag
- Discovered on day -11 respective to the peak
- Scaling constant 0.55 mag

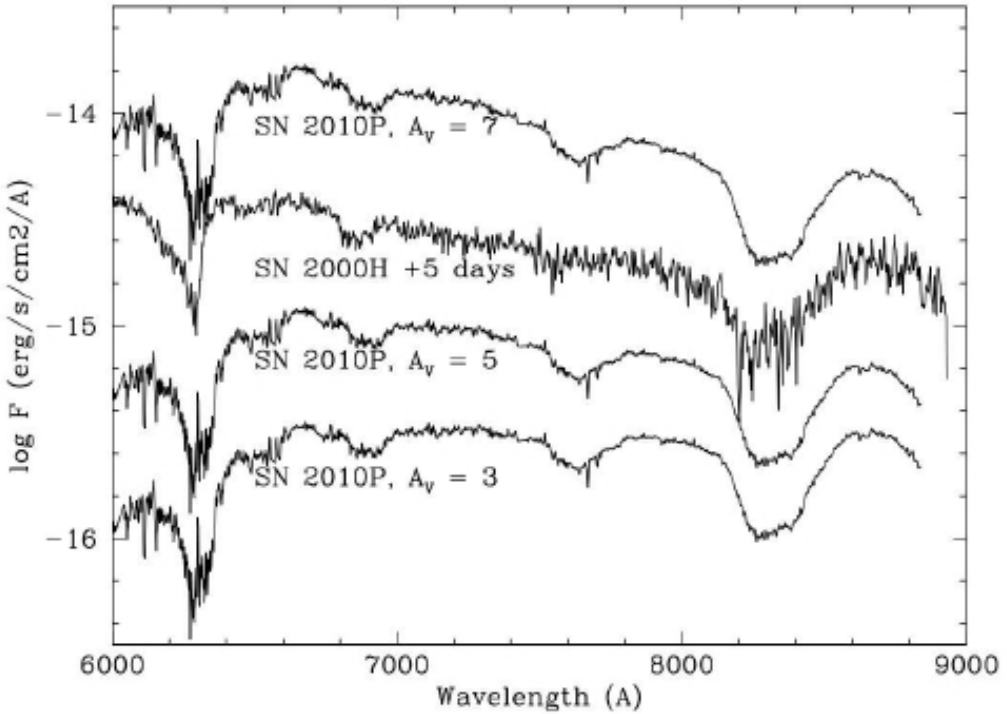
- Spectroscopically typed as a Ib SN
- Consistent with the spectroscopic typing and extinction estimate of 2 mag derived based on the spectrum



SN 2010P in Arp 299



- 'normally' declining template
- $A_V = 7.0$ mag
- Discovered on day -15 respective to the peak
- Scaling constant -0.35 mag



- Spectroscopically typed as a Ib/IIb SN
- Consistent with the spectroscopic typing and extinction estimate of 5-7 mag derived based on the spectrum

Mattila, Dahlen, Efstathiou, Kankare et al. (submitted to ApJ)

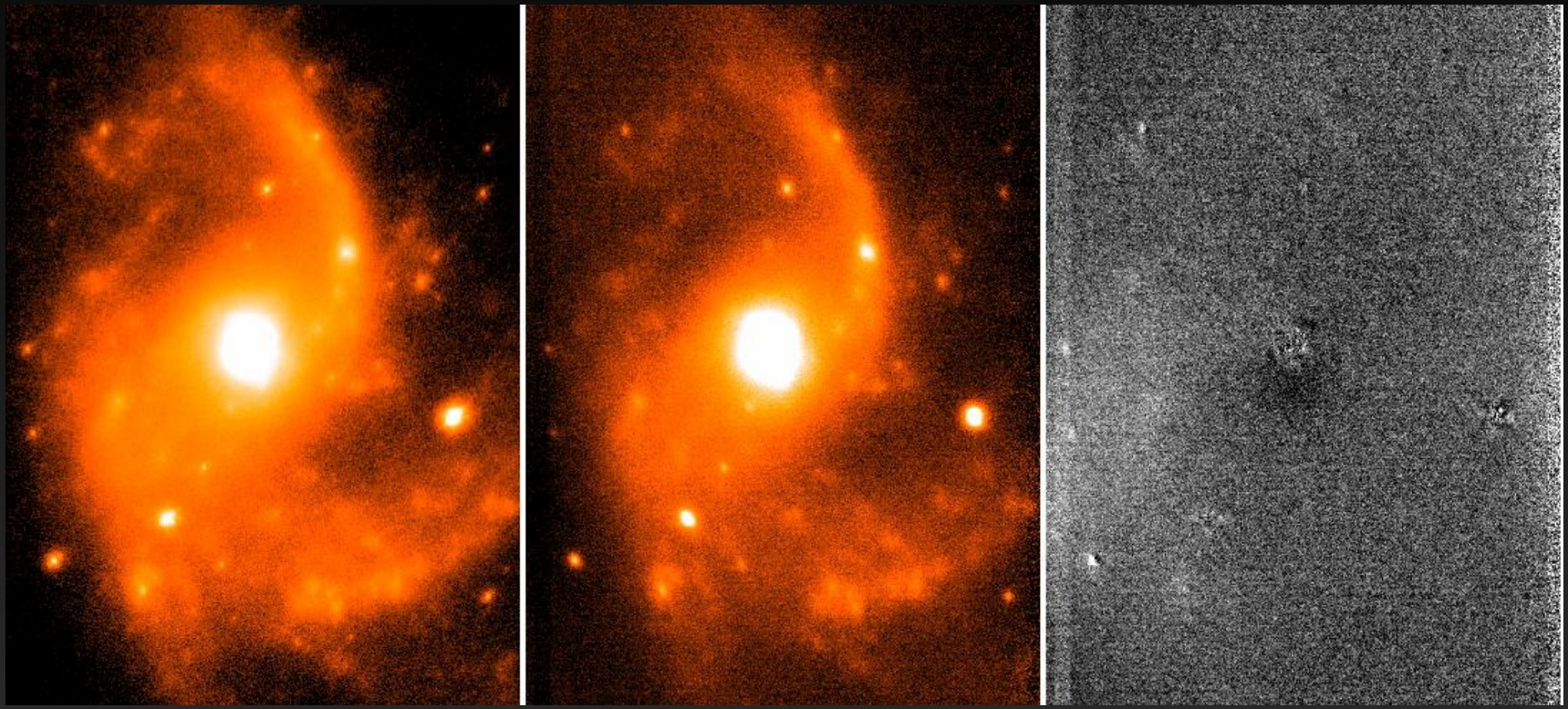
VLT/NaCo

- LIRG SN project continuing with the VLT/NaCo in the period 89
- Nasmyth Adaptive Optics System (NAOS) Near-Infrared Imager and Spectrograph (CONICA) in UT4
- Single-conjugate AO system with a natural guide star

www.eso.org

VLT/NACO

- Example of VLT/NACO data
  - ESO 221-IG 010
  - Expected SN rate of ~0.4 SNe yr^{-1}
  - Smooth subtraction, no SNe



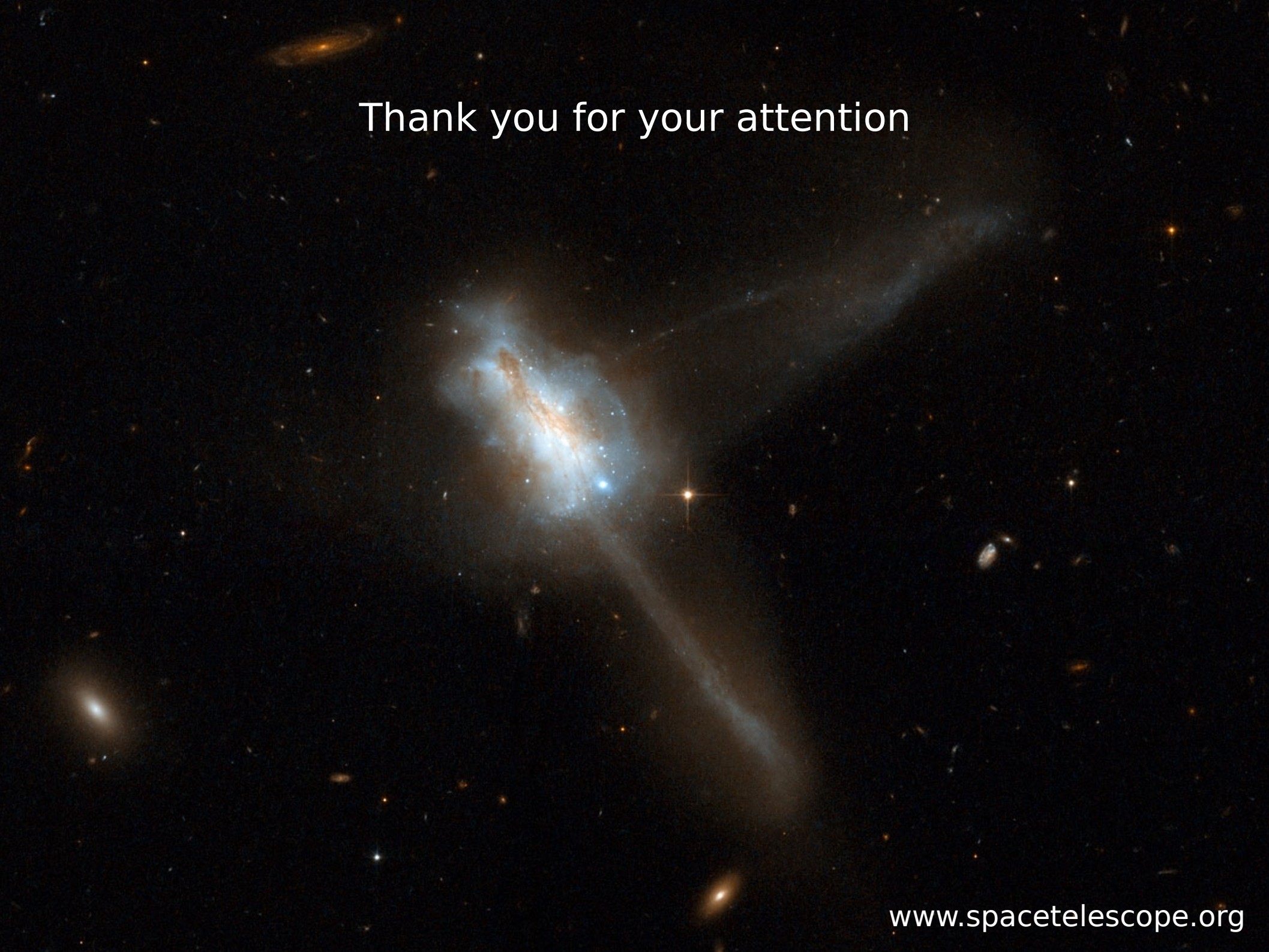
2011 February 14th | 2012 May 21st | subtraction

Summary

- Increased statistics important for mapping SN populations and extinctions distributions of LIRGs
- 6 SNe discovered in 8 LIRGs within 4 years
- Line-of-sight extinctions and types estimated based on near-IR light curves, colours and magnitudes

SN	Type	A_V
2004iq	?	0 - 4 mag
2008cs	IIn/II-L	14 - 16 mag
2010O	Ib	2 - 3 mag
2010P	Ib/IIb	5 - 7 mag
2010cu	II	0 - 1 mag
2011hi	IIP	5 - 7 mag

- Next generation multi-conjugate adaptive optics systems and large sample size will dramatically increase the number of discovered CCSNe in LIRGs


Thank you for your attention
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