Supernova Science and what's next for ESO

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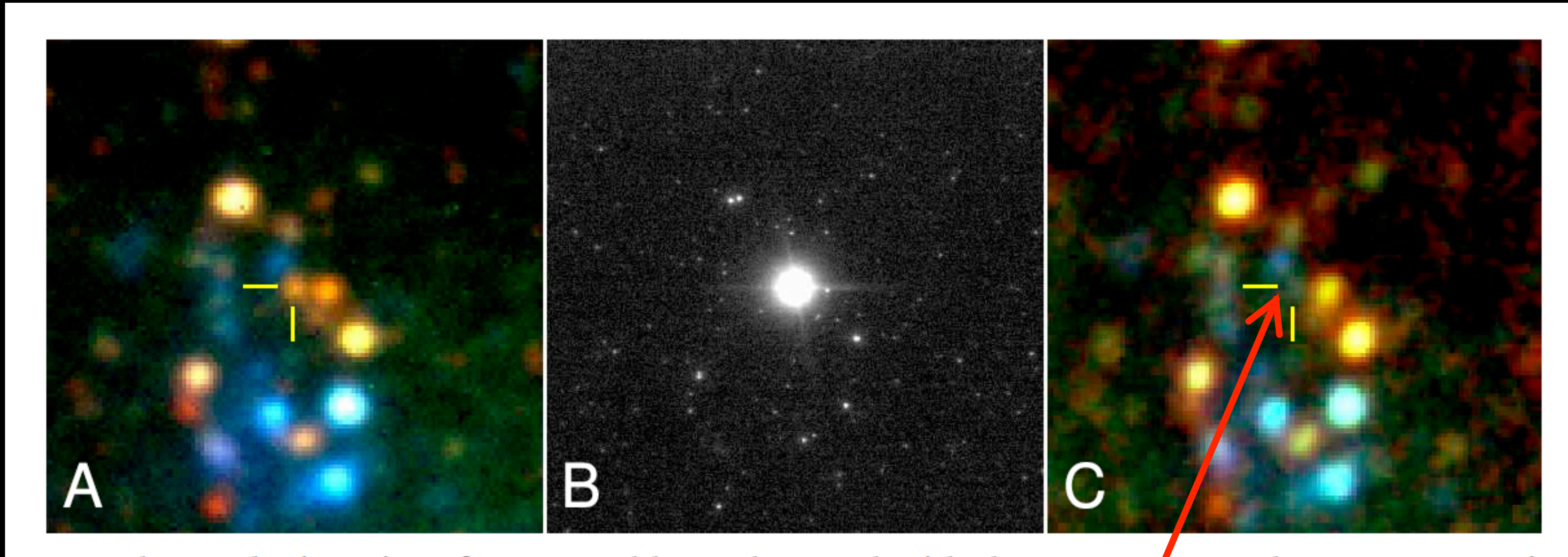
ESO large Program "Supernovae and Nucleosynthesis" (PI : S. Benetti, Padova)

NGC7793 with VLT FORS

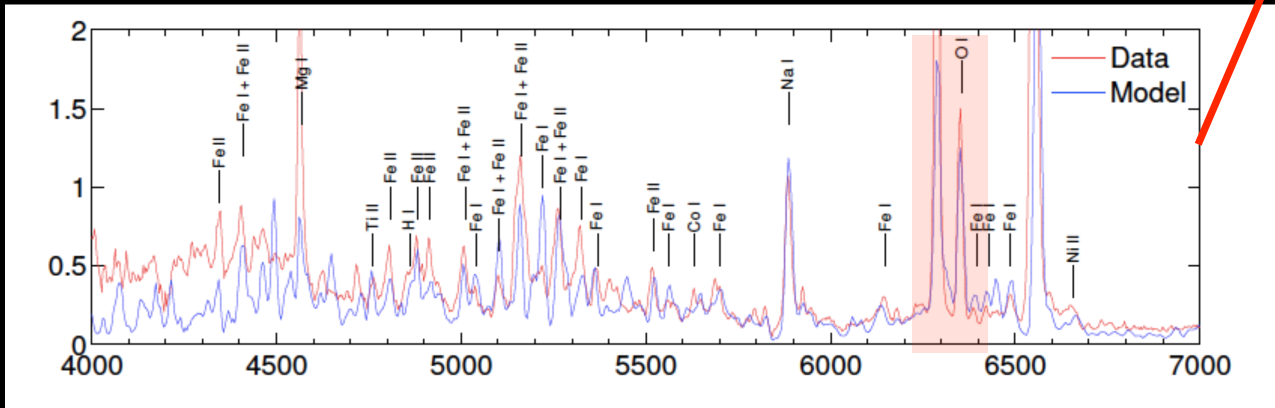
European
Southern
Observatory

50 YEARS 1962–2012

Core-collapse SN : progenitor to enrichment



VLT FORS+HAWKI VLT NACO NTT EFOSC2



VLT FORS

Mattila et al. 08, Maguire et al. 2012

Past, Present and Future

- Core-collapse SNe drive the chemical evolution of galaxies, and formation through feedback
- Test stellar evolution theory and NS/BH formation scenarios
- (Biased!) Summary of ESO related work

- New transient surveys – southern sky with La Silla QUEST (ESO Schmidt), Skymapper and PESSTO
- Future VLT and E-ELT spectroscopic applications to transients

Image Credit: NASA/Filippenko/Challis


Image Credit: R.Jay Gabany

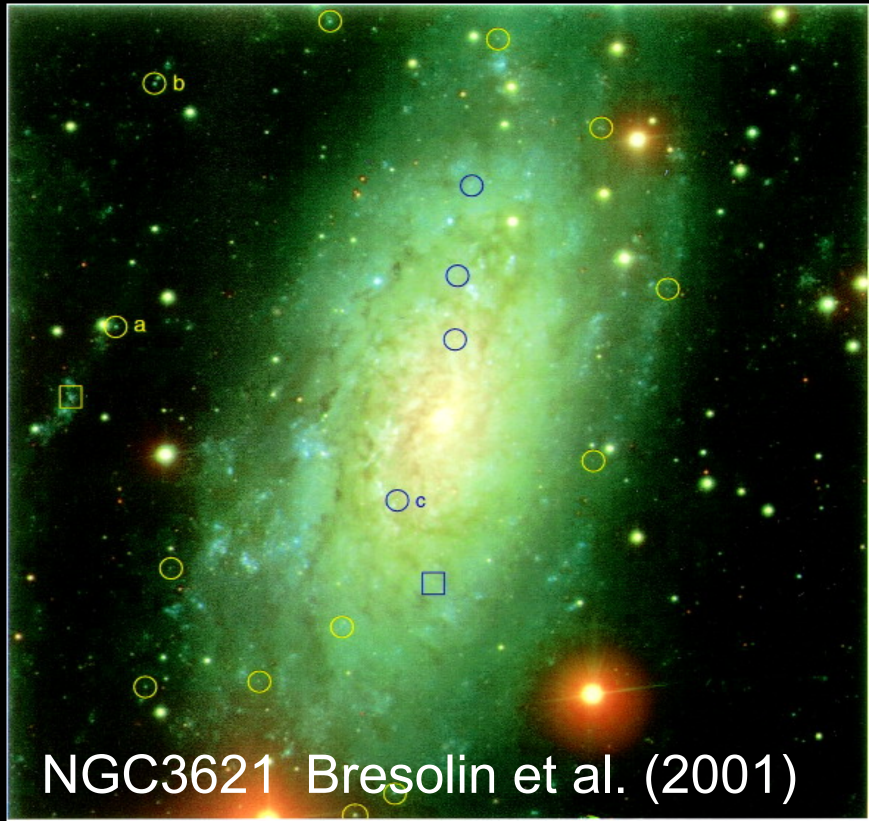
Until 2010 :

Nearby SNe discovered by amateur astronomers , and two professional search teams:

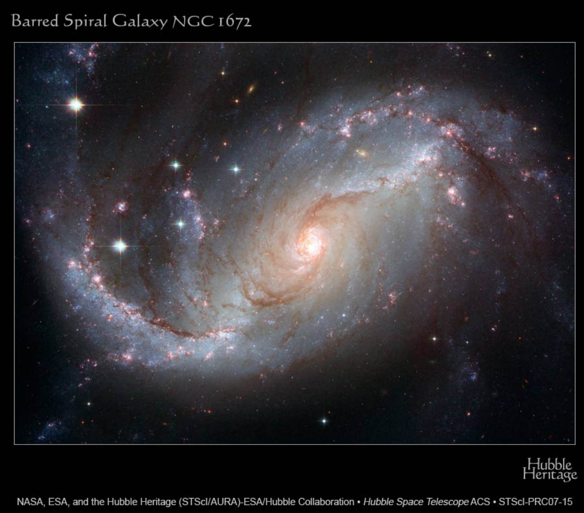
North : LOSS (Filippenko & Li)

South : CHASE (Pignata et al.)


M101


b
a
c
NGC3621 Bresolin et al. (2001)

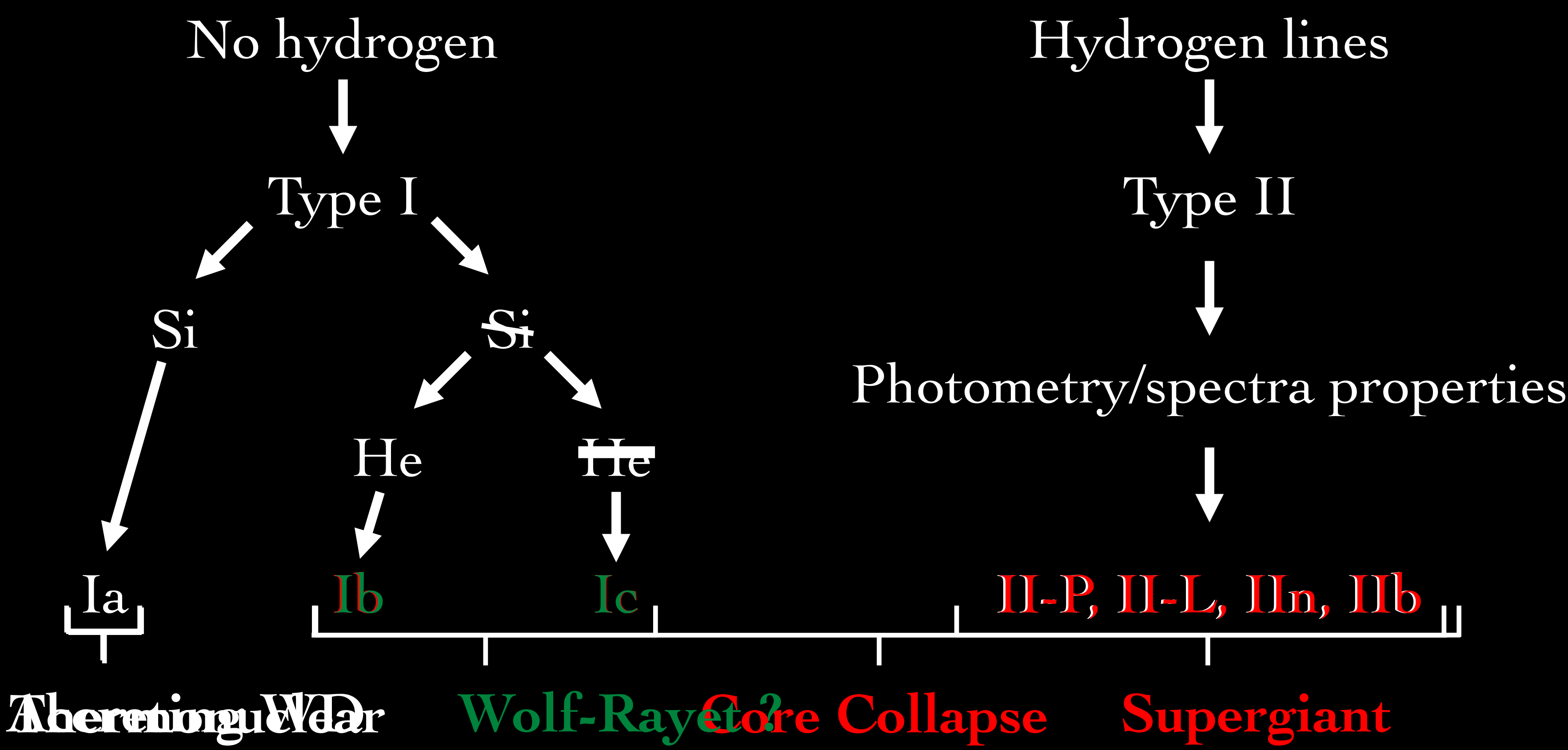

NGC3949


Barred Spiral Galaxy NGC 1672
Hubble Heritage
NASA, ESA, and the Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration • Hubble Space Telescope ACS • STScI-PRC07-15

NGC1672

Supernova types

Supernovae are classified by their optical spectra



Sequence of events in a SN

0.1

0.5

2h

St

~m

elope

Neutrinos & Explosion Mechanism

Paradigm: Explosions by the convectively supported neutrino-heating mechanism

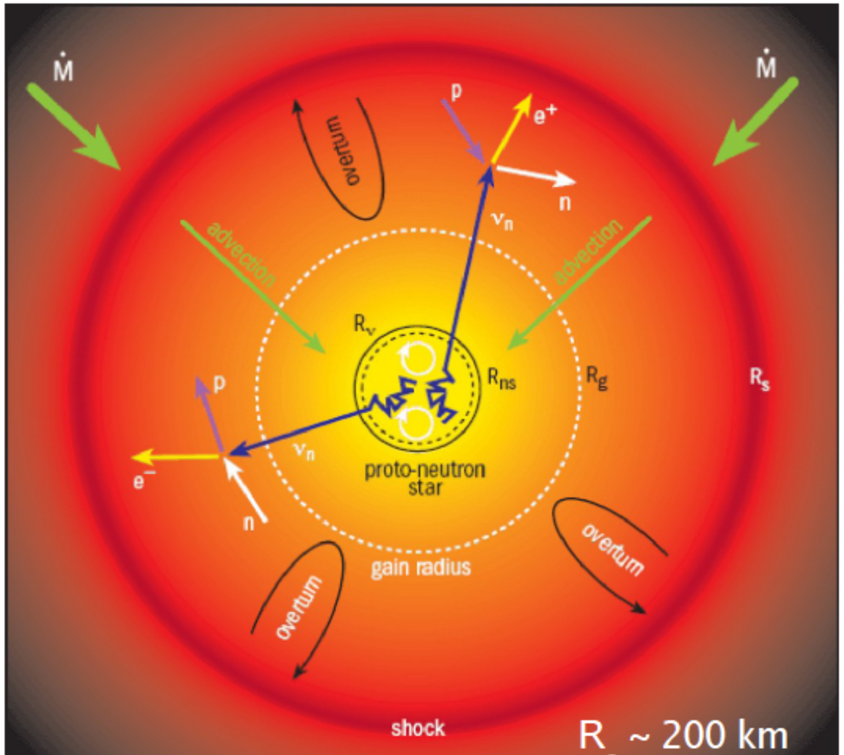
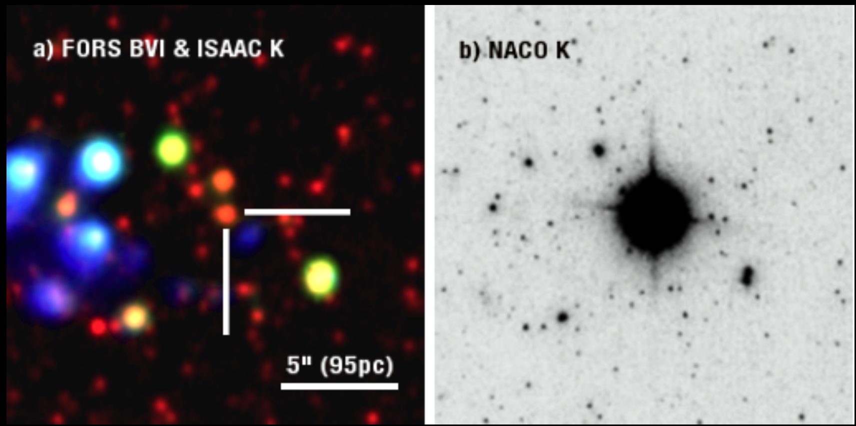
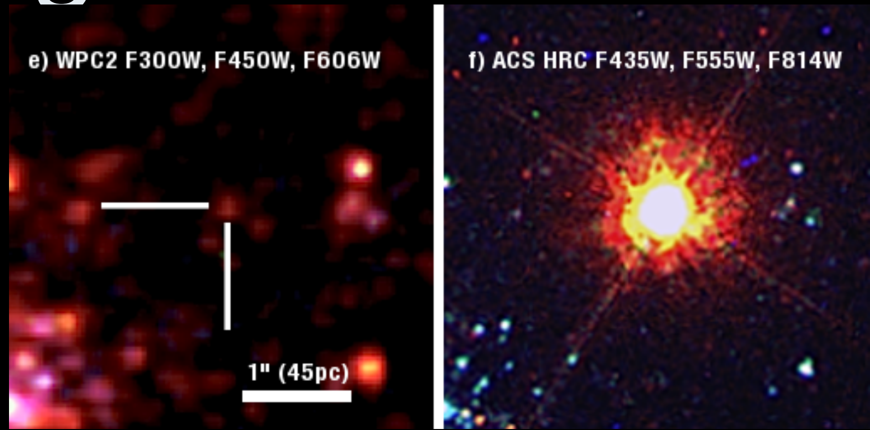


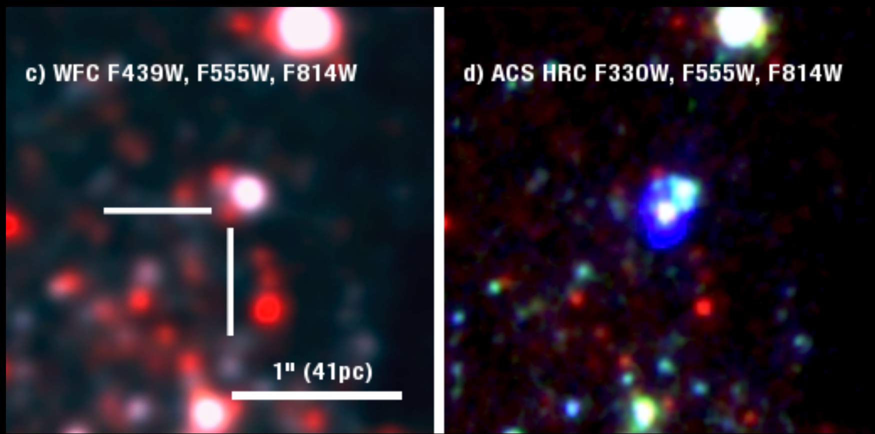
Fig. 6

- "Neutrino-heating mechanism": Neutrinos `revive' stalled shock by energy deposition (Colgate & White 1966, Wilson 1982, Bethe & Wilson 1985);
- Convective processes & hydrodynamic instabilities enhance the heating mechanism (Herant et al. 1992, 1994; Burrows et al. 1995, Janka & Müller 1994, 1996; Fryer & Warren 2002, 2004; Blondin et al. 2003; Scheck et al. 2004,06,08).

Detection of progenitors

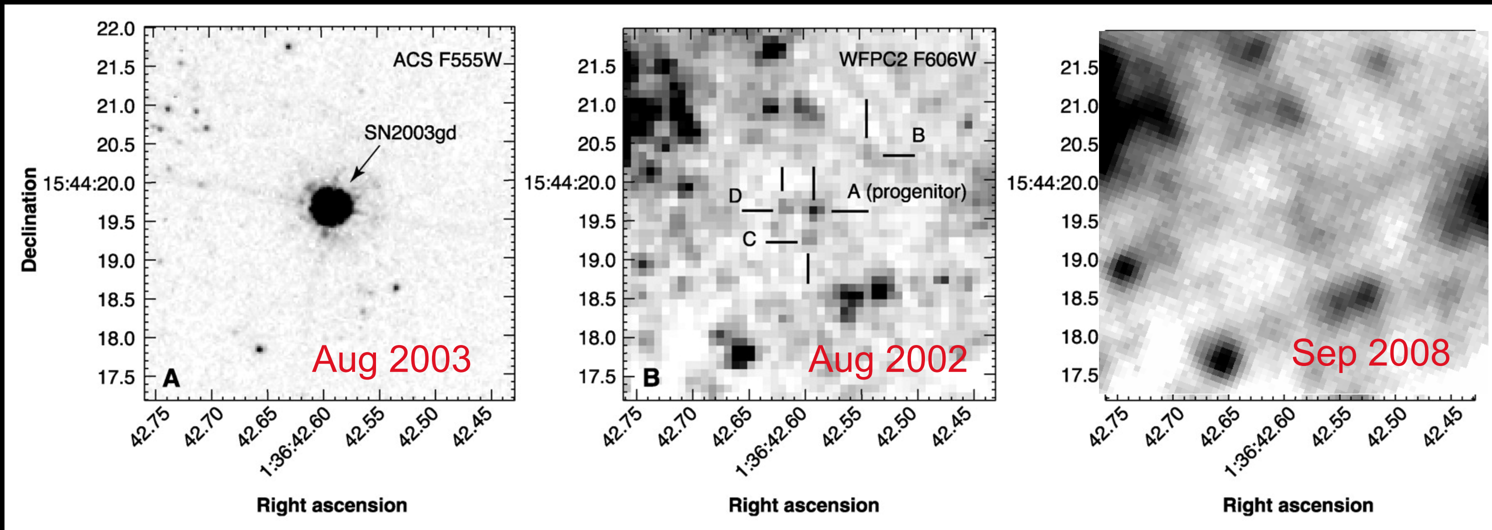






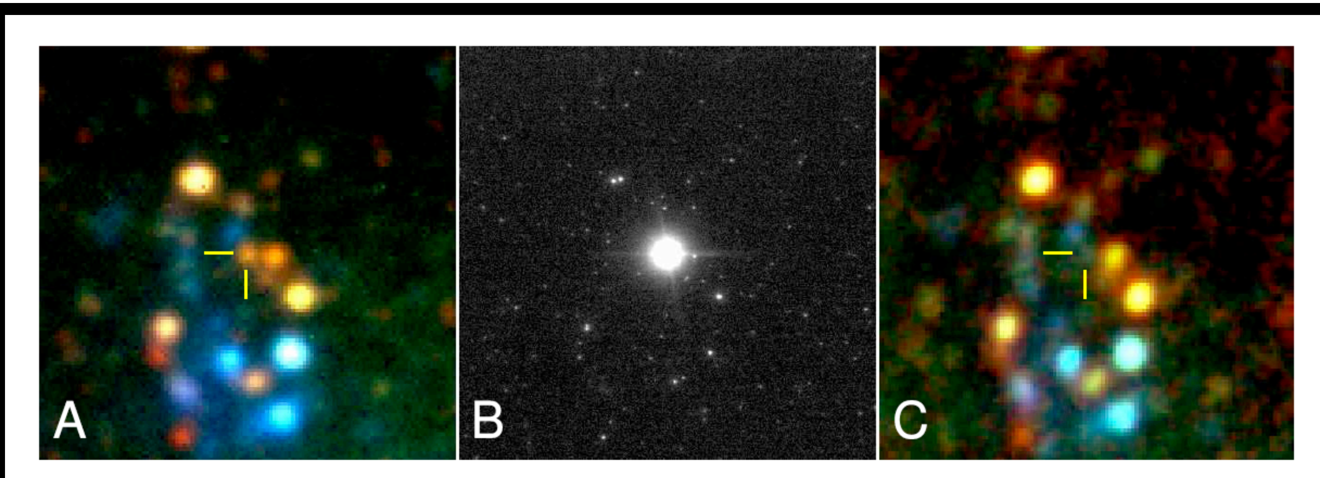
- SN2008bk, SN2005cs, SN2003gd
- Red star identified coincident with all three.
- Typical magnitudes : $M_V \sim -4.5$; $M_I \sim -6.5$
- Review in Smartt 2009
  - Van Dyk et al. 2003, 2010, Li et al. 2006
  - Smartt et al. 2004, 2009, Maund et al. 2005, Mattila et al. 2008

Progenitor disappearance



SN2003gd:
V=25.8 ± 0.15
V–I=2.5 ± 0.2
Smartt et al. 04,
Van Dyk et al. 03

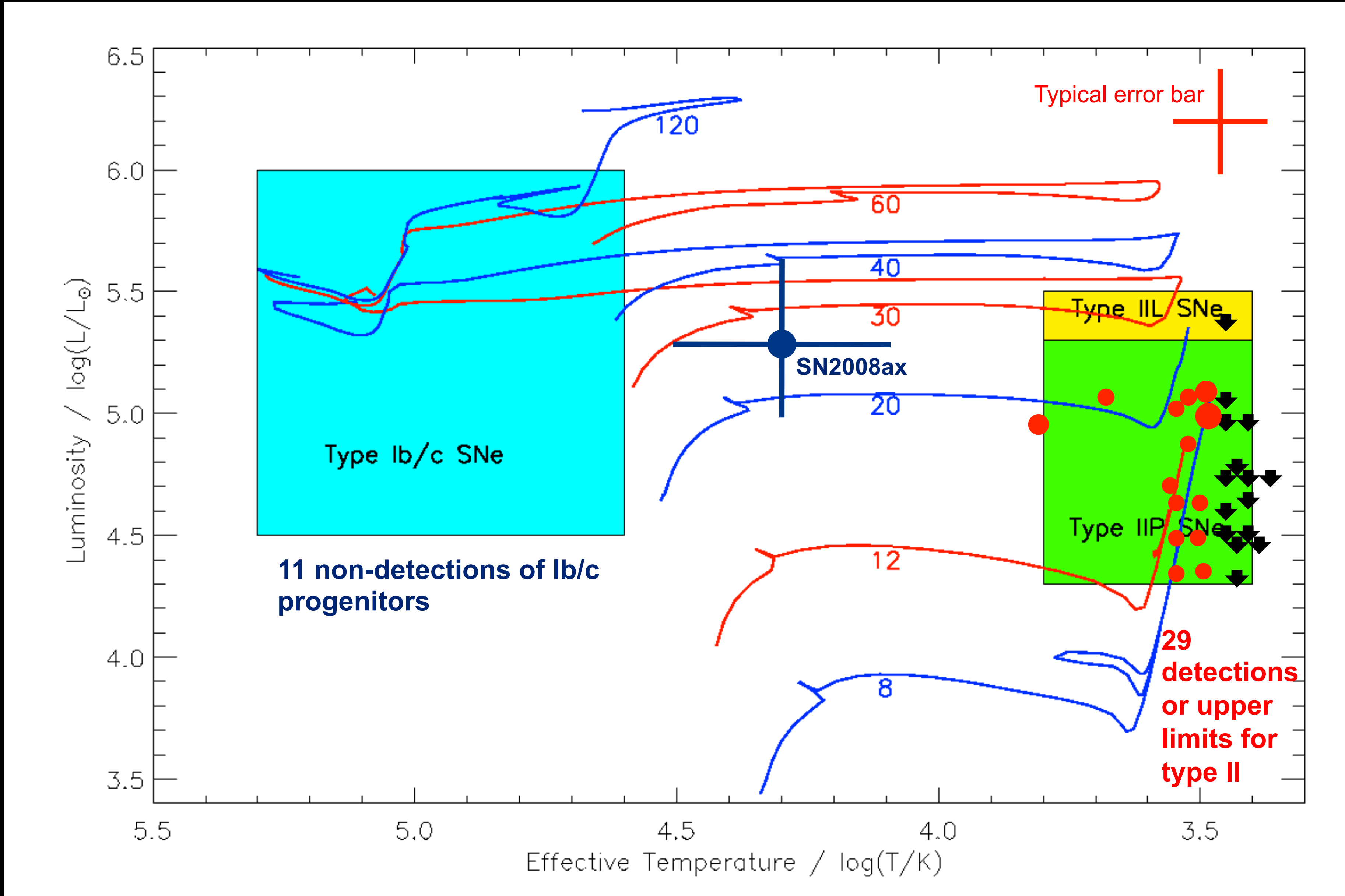
Disappearance
Maund &
Smartt 09



SN2008bk
Mattila et al. 08
Mattila, Maund,
Smartt et al. in prep

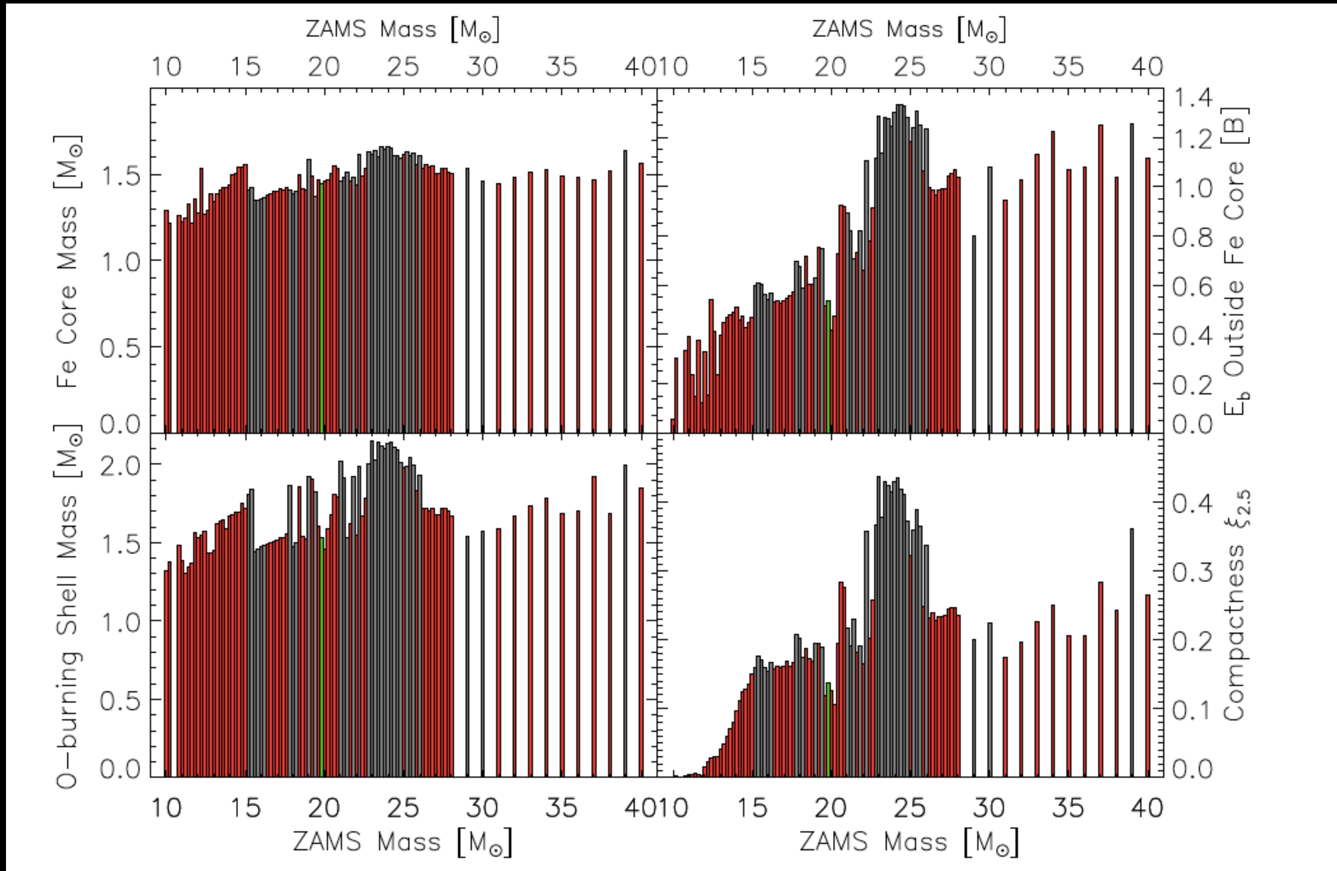
Five confirmed cases of disappearance : SN1987A , SN1993J, SN2003gd, 2008bk, SN2005gl (Gal-Yam & Leonard 2009)

Updated progenitors : 1998 – 2012.5 ; within 28 Mpc (41 total)



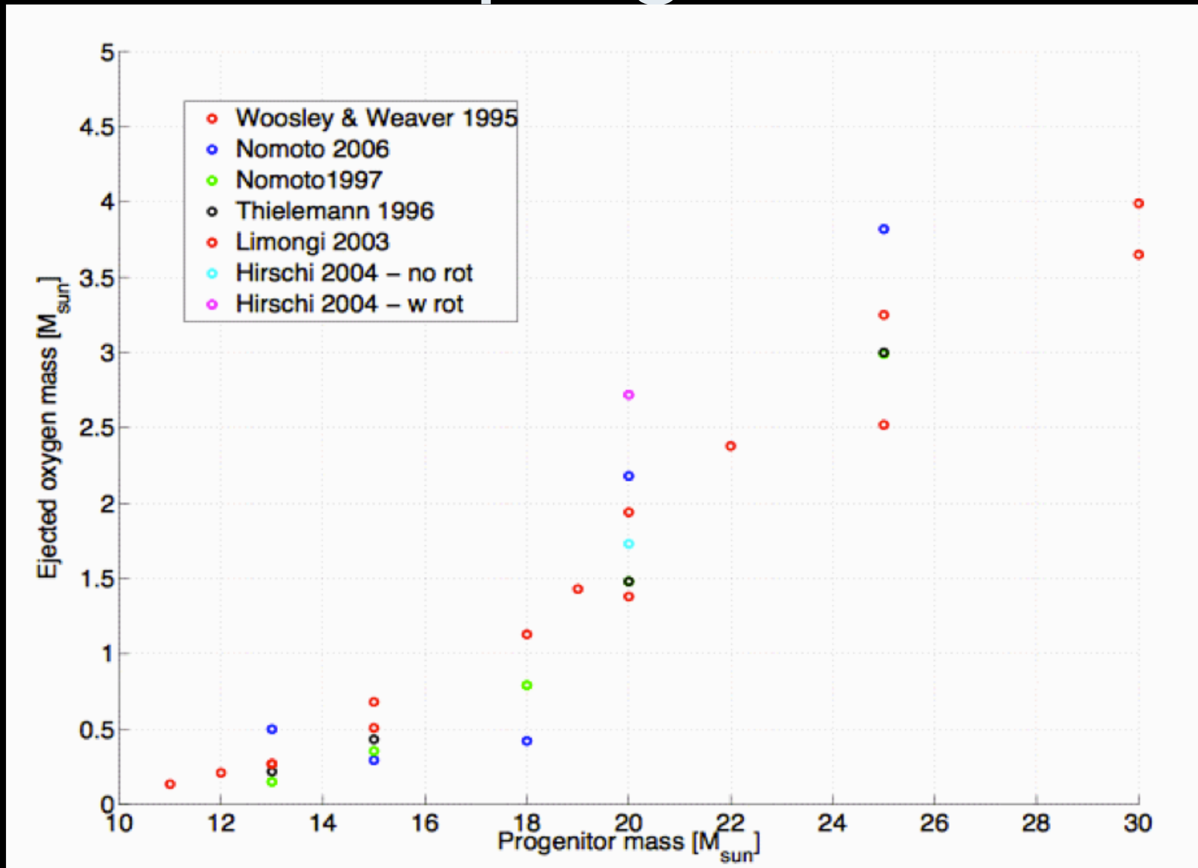
For Salpeter IMF : 75% of 8-100$M_\odot$ stars are 8-20$M_\odot$ (13 “missing”)

Black hole formation



- Ugliano, Janka et al. 2012, arXiv**1205.3657**
- Neutrino driven explosions – no simple mass dependency

Nucleosynthesis : oxygen mass as function of progenitor mass

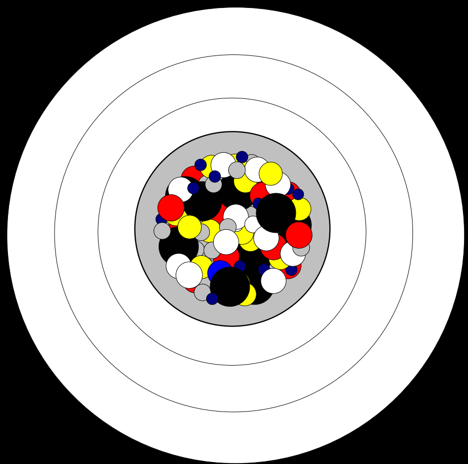


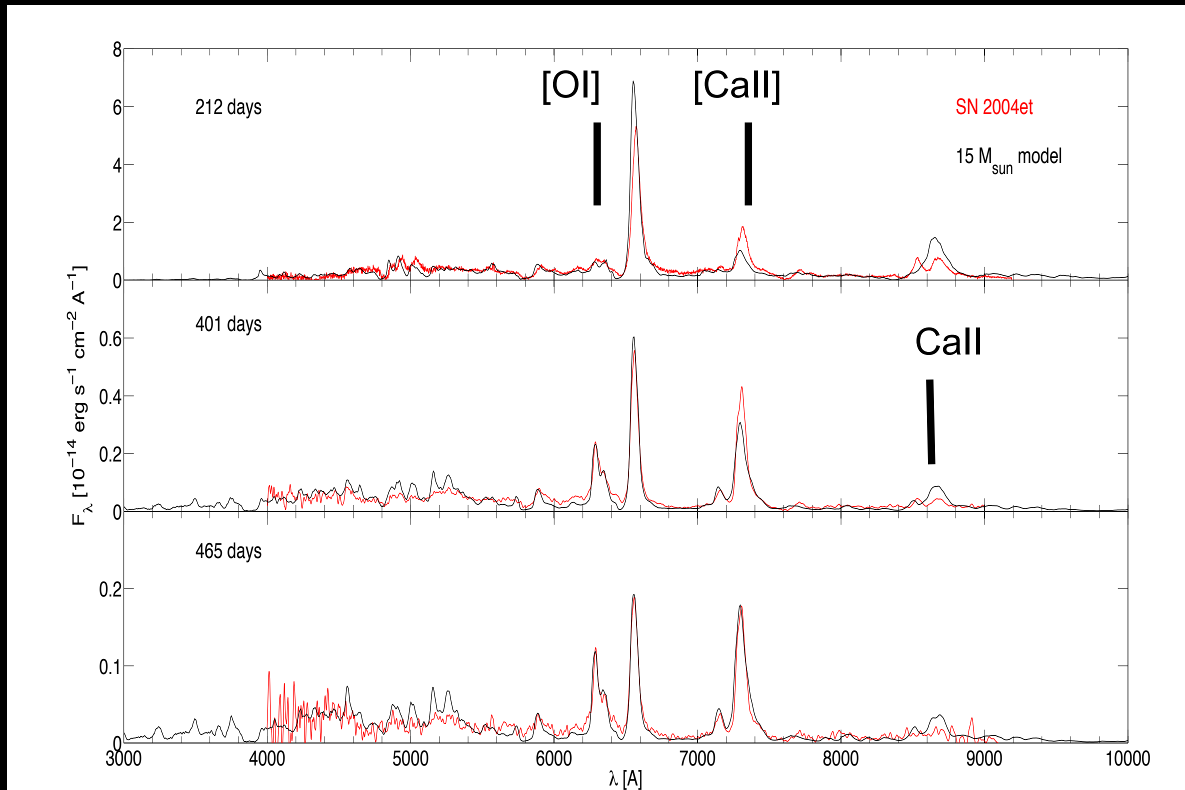
Data : stellar evolutionary calculations

Image credit : Anders Jerkstrand

Stockholm : Radiative transfer model

- Radioactivity
- Temperature, ionization and excitation solutions
- Radiative transfer
- Macroscopic mixing



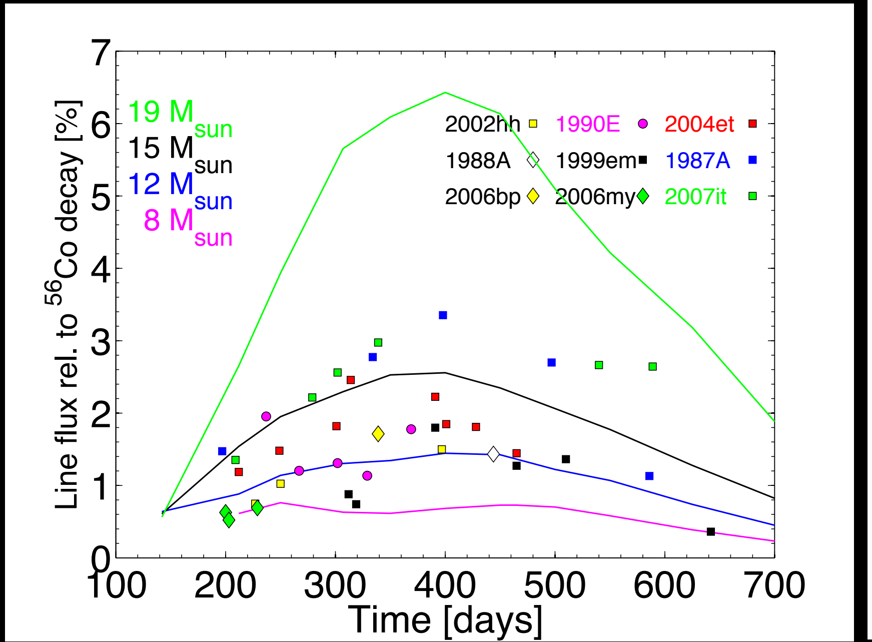


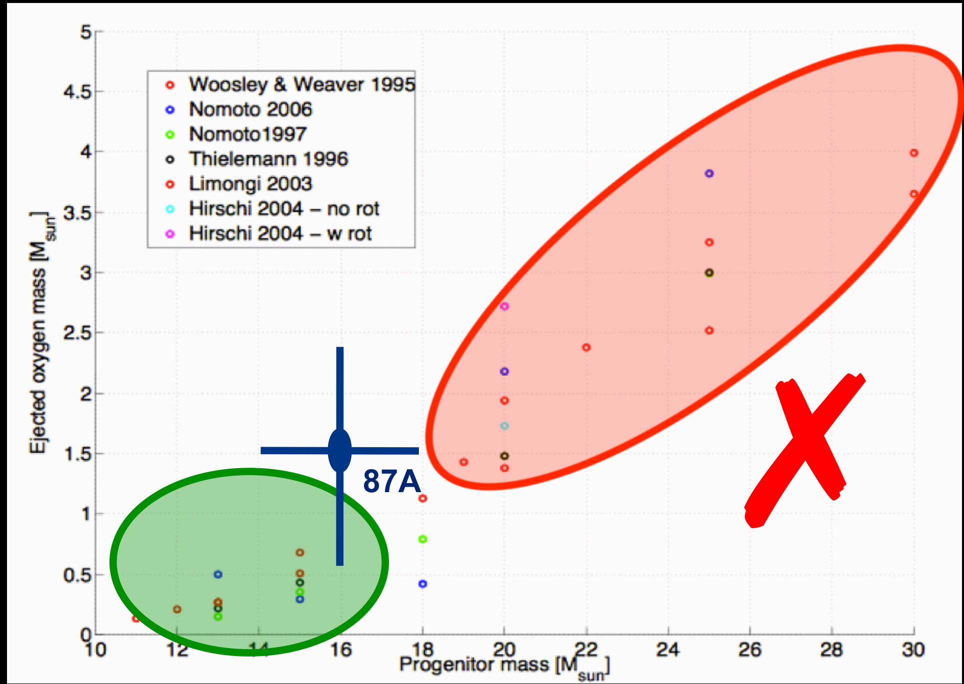
SN 2004et compared to a 15 M_{sun} model (~0.5M_{sun} oxygen)

Kozma & Fransson 1998
Jerkstrand et al. 2012 ; 2010

Type IIP line luminosities in nebular phase

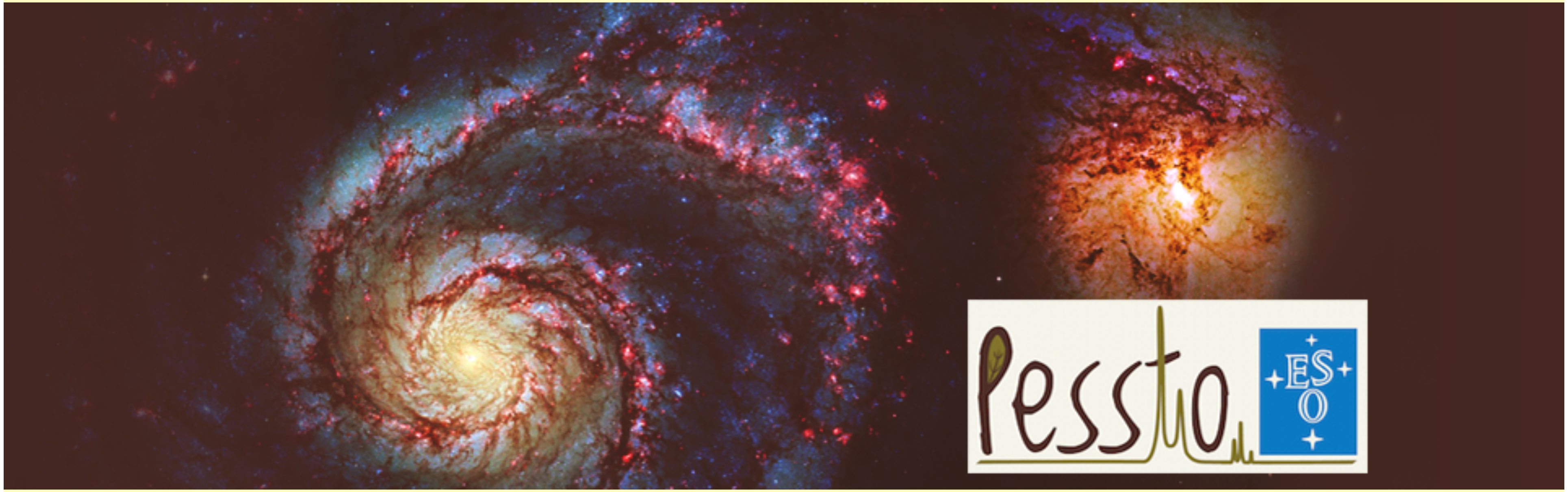
[O I] 6300, 6364 Å





Jerkstrand et al. in prep
Maguire et al. 2012

We haven't detected the cosmic oxygen producers



Public ESO Spectroscopic Survey of Transient Objects

www.pessto.org

Wide-field synoptic surveys : game changer

10 square degree cameras + 1-2m telescopes

PTF – low-z SNe (“factory” follow-up built in)

PS1 – high-z SNe (dedicated 4-8m follow-up)

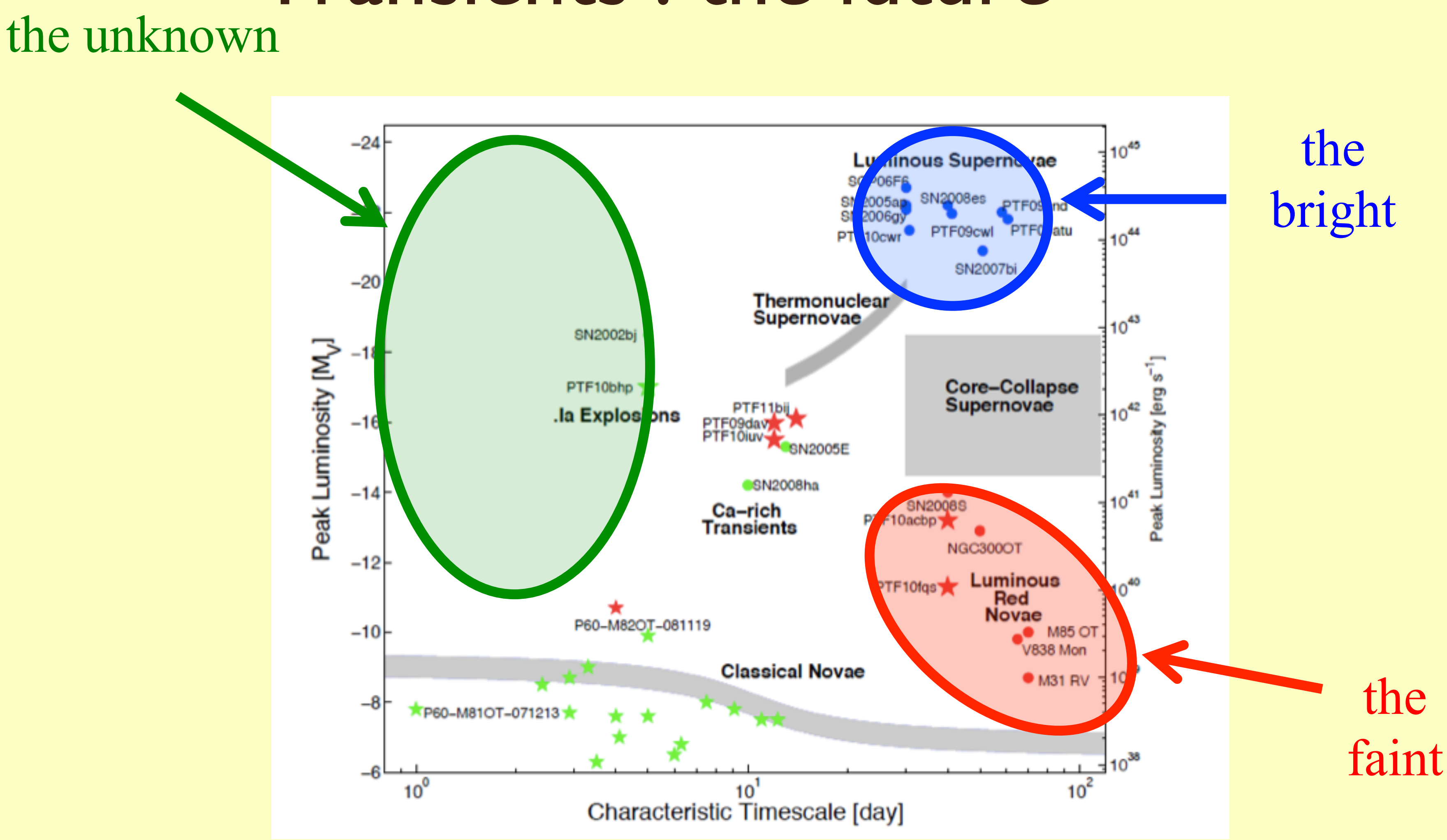
+ Pessto ESO

La Silla QUEST+ SkyMapper

PESSTO in a Nutshell

- 90n per year : 9 months, 10n per month
- 4 yrs (2012-2015), with 1yr more pending formal NTT review
- EFOSC2 + SOFI : breakdown flexible
- Will classify 2000 SNe – all spectra reduced, classified and released within 24hrs
- Will follow approx 150 with full spectroscopic and photometric time series coverage

Transients : the future

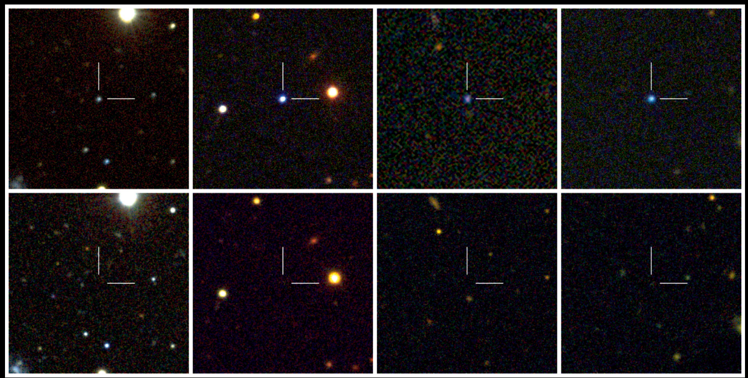


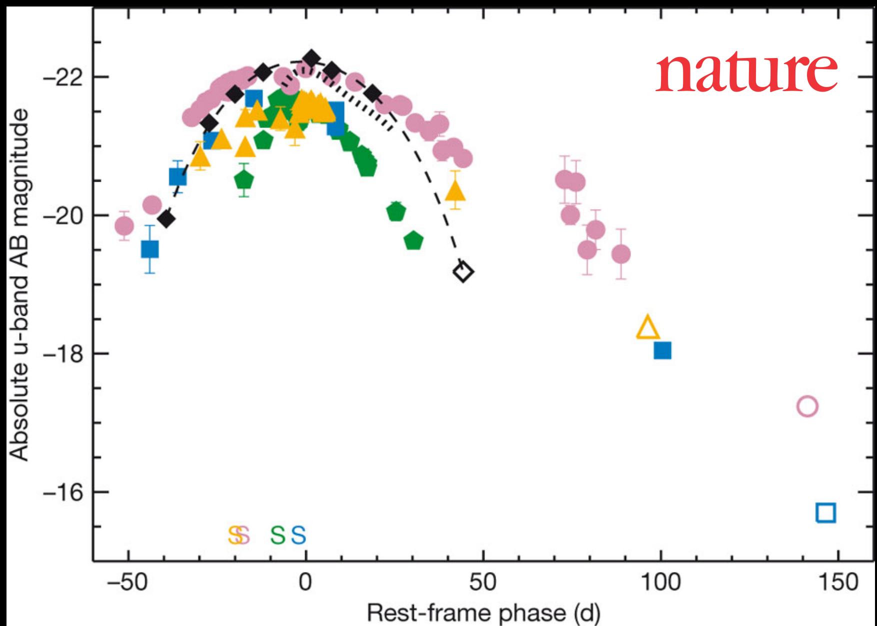
What are the limits of physical explosions and transients ?

Image credit : Shri Kulkarni, CalTech

Superluminous stellar explosions

Palomar Transient Factory

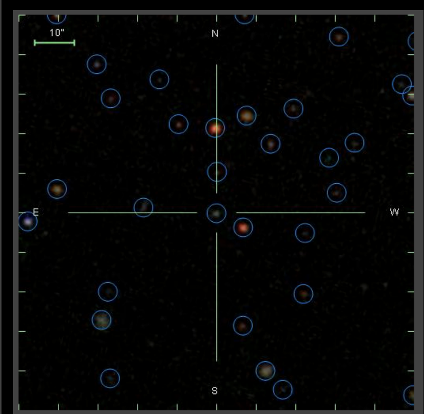




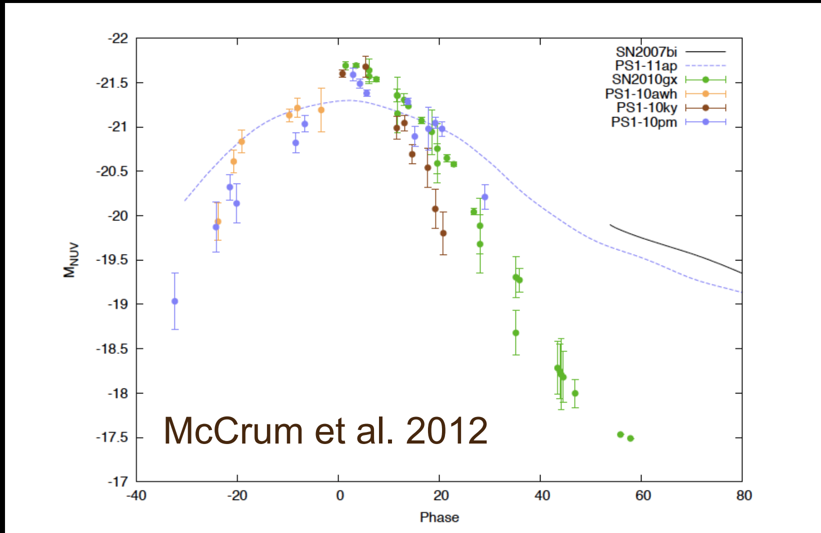
RM Quimby *et al. Nature* 2011 doi: 10.1038/nature10095

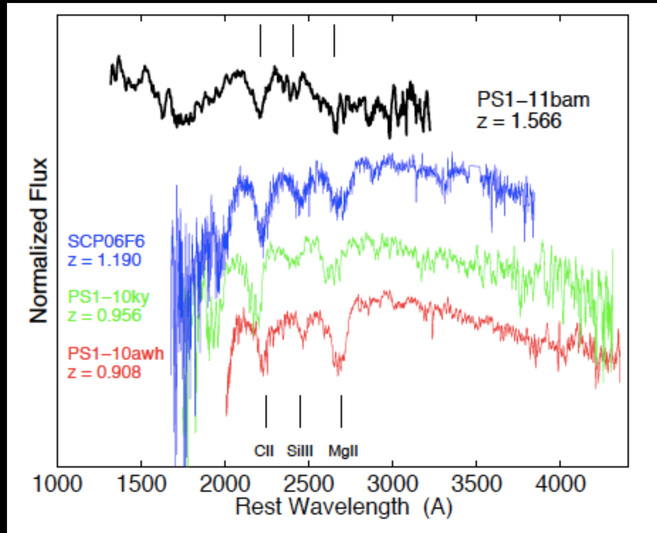
Pan-STARRS1 probing redshift ranges 0.1 – 1.5

- Z = 0.1 – 0.3 in the 3Pi survey
  - SN2010gx, PS1-11xk, PS1-12fo, + two other candidates
- Z= 0.5 – 1.5 in the MD fields

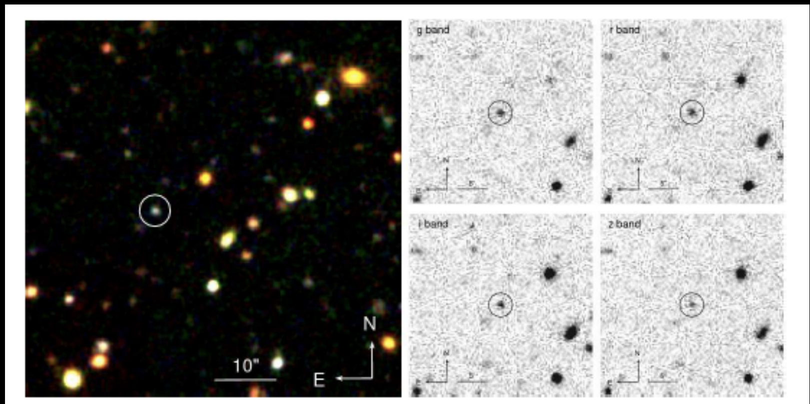


Ultraluminous SNe at high-z





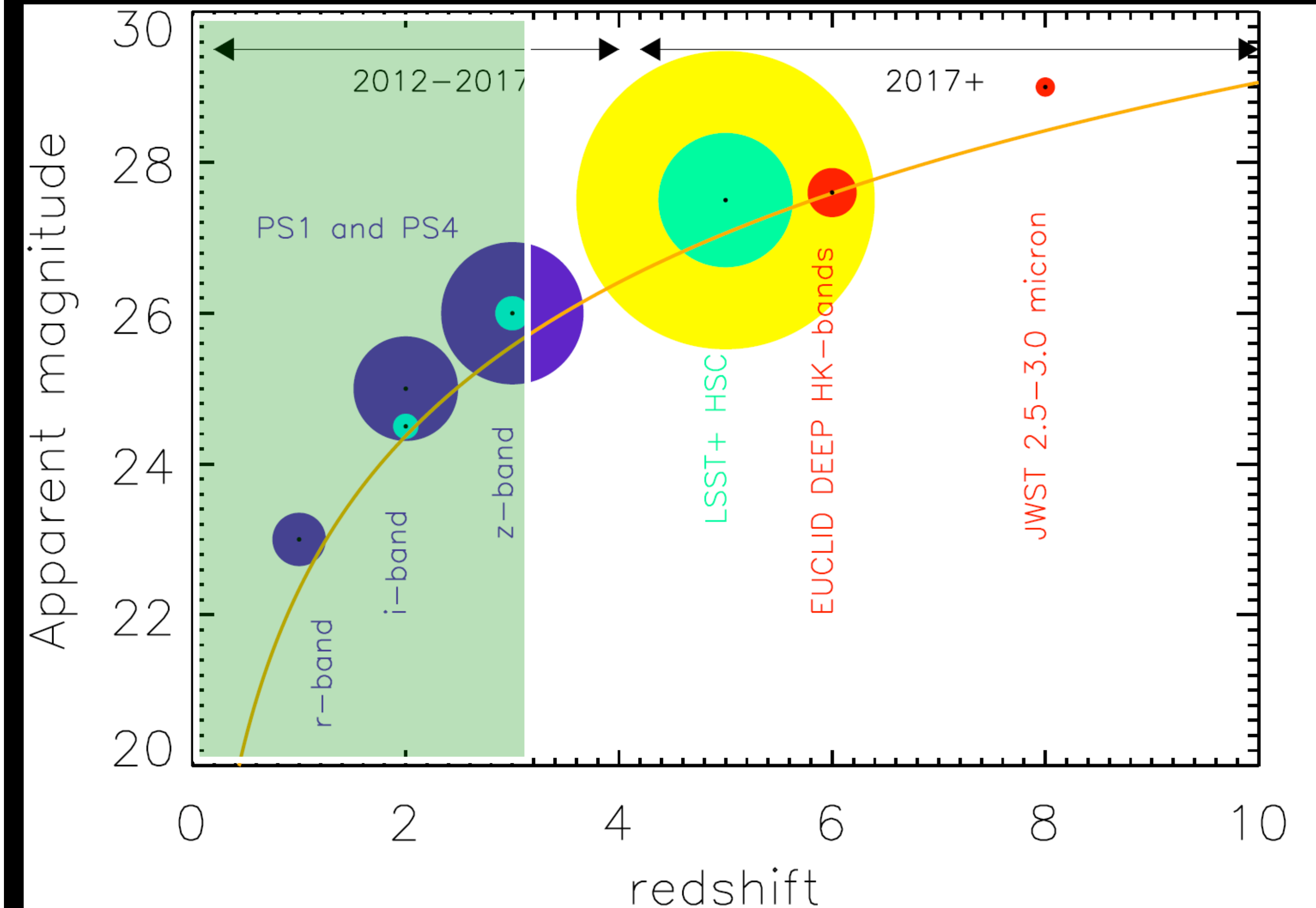
Beger et al. 2012



Beger et al. 2012

- PS1 detecting Ultra-luminous SNe $0.5 < z < 1.6$
- Chomiuk et al. 2011, Berger et al. 2012, McCrum et al, in prep
- Physical origin of extreme luminosity ?
- Magnetar
- Dense circumstallar shells (pulsational instabilities ?)
- Pair instability SNe ?

Surveys to detect ultra-bright high-z SNe



E-ELT spectra

VLT spectra

(Personal!) Outlook for ESO

- Fundamental measurements of progenitor masses – what stellar mass produces black holes (PESSTO + VLT high resolution imaging)
- Can we determine abundances and ejecta masses in SNe with measured progenitors ? (PESSTO + VLT xshooter spectroscopy)
- The extremes of the SN population (NTT can be worlds leading facility : PESSTO)

- Ultra-luminous supernovae – probing out to z~2 (VLT + PS1+PS2)
- Superluminous supernovae in the high-z Universe – probing out to z > 6 (ELT + LSST, EUCLID, JWST)