Explosive transients in the next decade

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Public ESO Spectroscopic Survey of Transient Objects

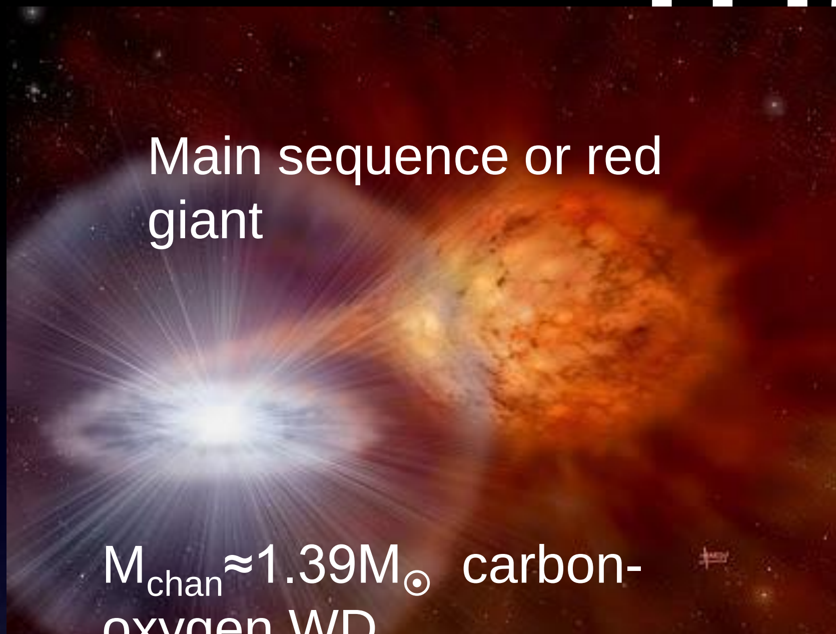
90N per yr on NTT, visitor mode, flexible time domain science

All of ESO community/Chilean SN researchers (~150 Co-Is)

Overview

- Science and context
- Current transient science 2015-2020 (ground-based focus)
- Future 2015-2025+

Type Ia : thermonuclear



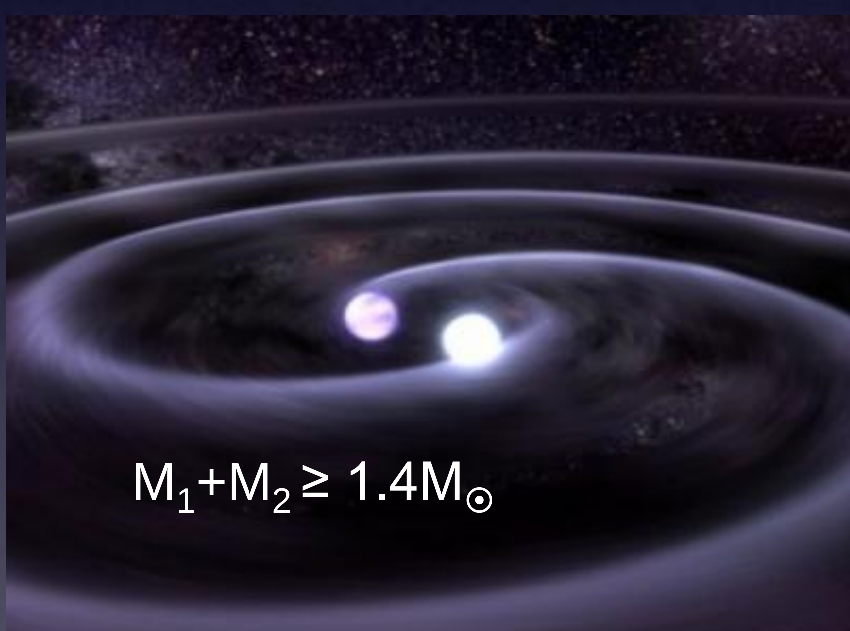
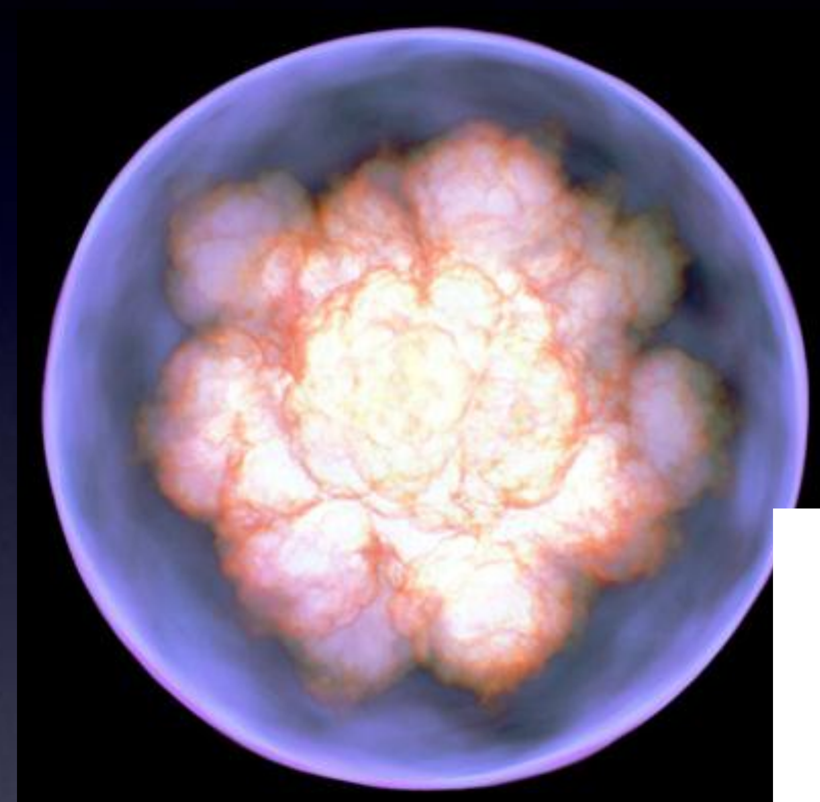
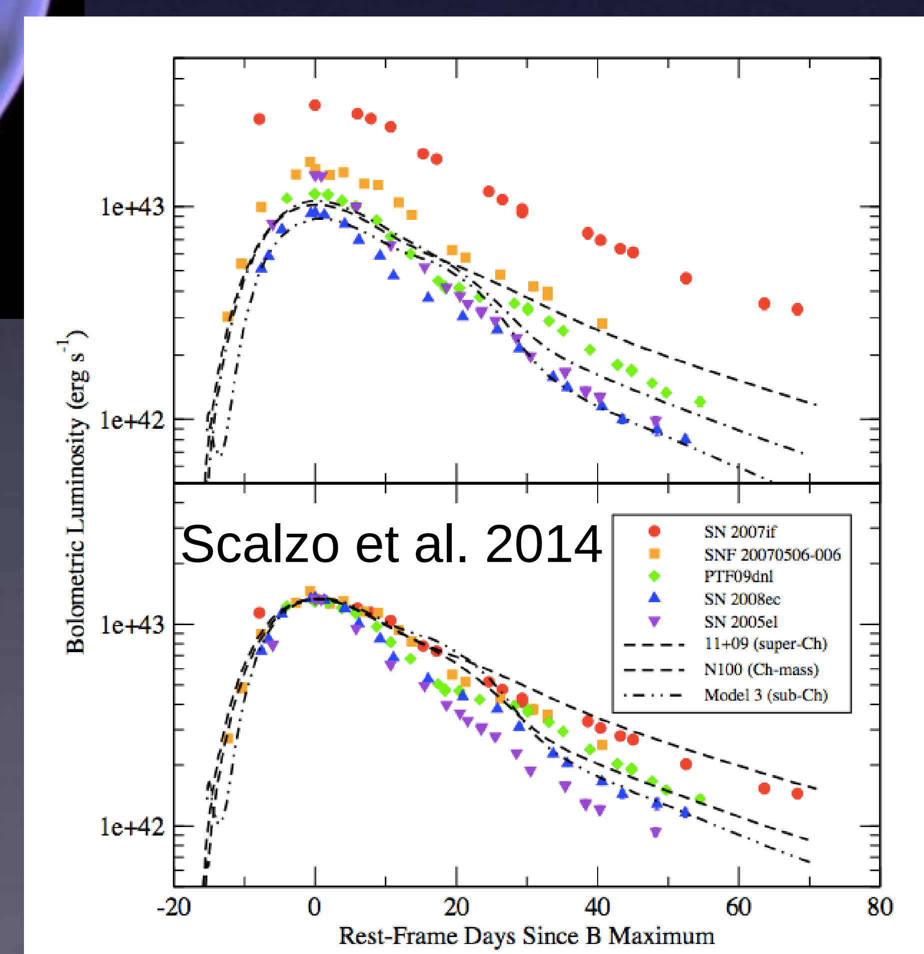


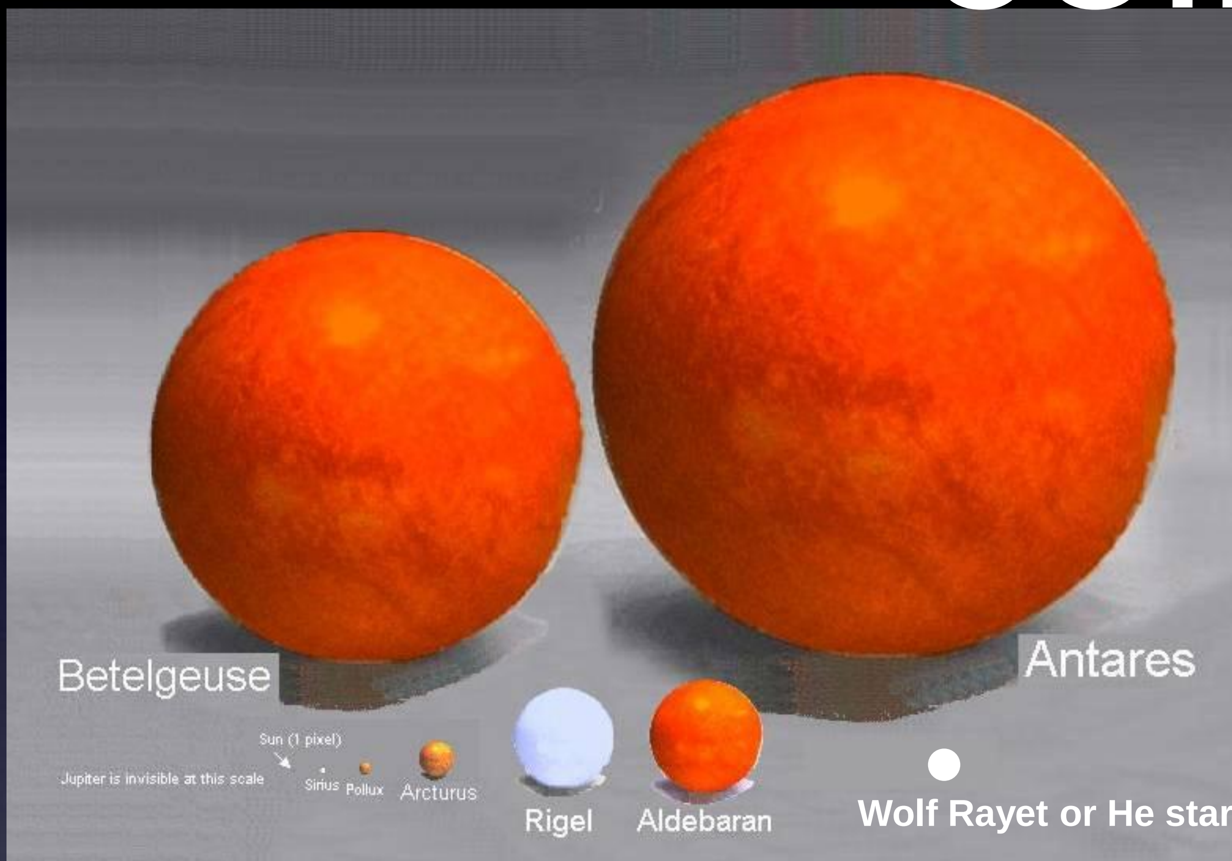
Image Credits : D. Hardy, GSFC/D. Berry/F. Ropke



$$^{12}_{6}C,\ ^{16}_{8}O \rightarrow\ ^{24}_{12}Mg,\ ^{28}_{14}Si,\ ^{32}_{16}S,\ ^{40}_{20}Ca$$
$$+\ ^{56}_{28}Ni\ (0.7\mathrm{M}_{Sol})$$



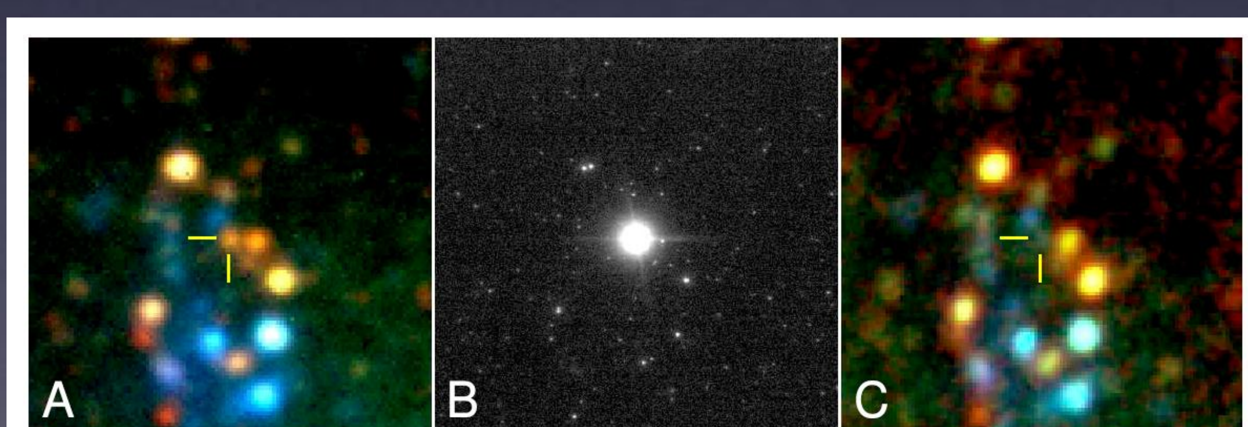
Type II, Ib, Ic : core-collapse



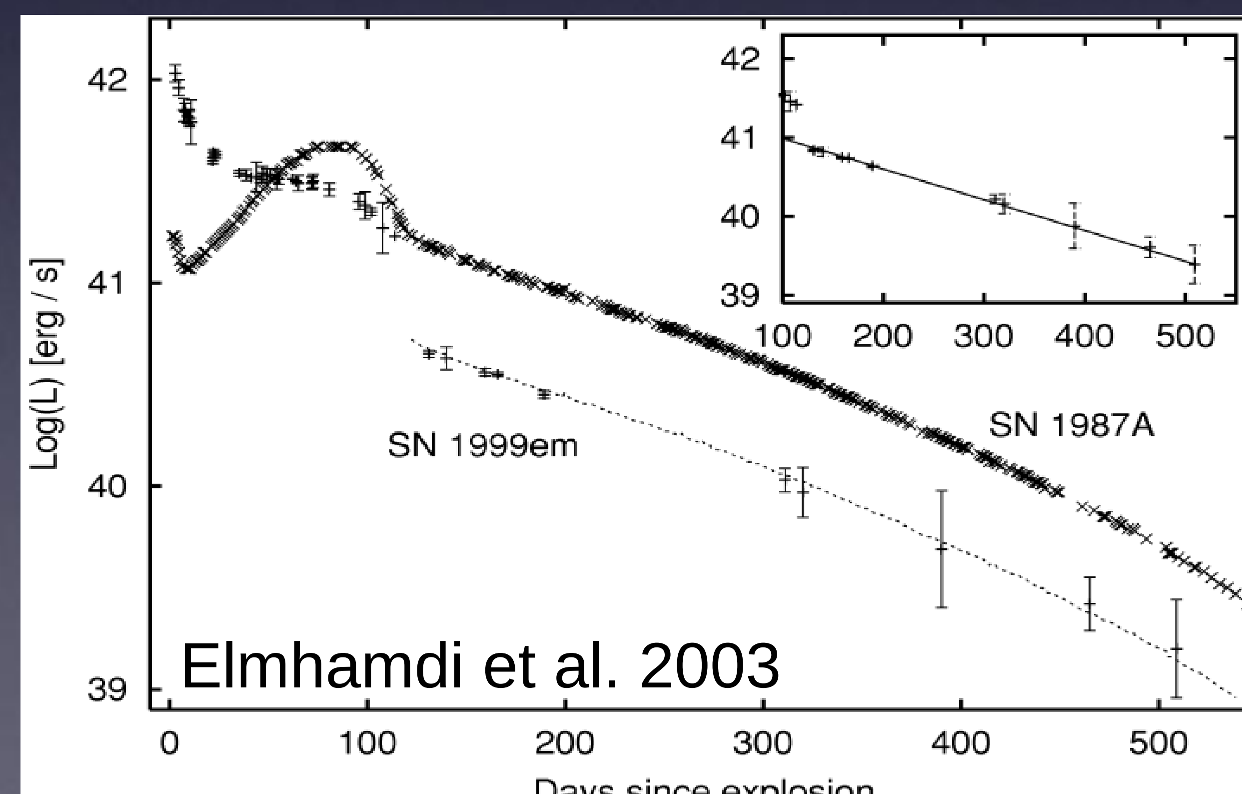
- 1.4 Fe core reaches Chandrasekhar degeneracy limit
- 10^{53} ergs of gravitational potential energy
- 1% of neutrino energy is captured
- Explosions with $E_{tot} \sim 10^{51}$ ergs

$$^{56}Ni \rightarrow {}^{56}Co + e^{+} + n_{e} + g \quad (t_{1/2} = 6 \text{ days})$$

$$^{56}Co \rightarrow {}^{56}Fe + e^{+} + n_{e} + g \quad (t_{1/2} = 77.1 \text{ days})$$

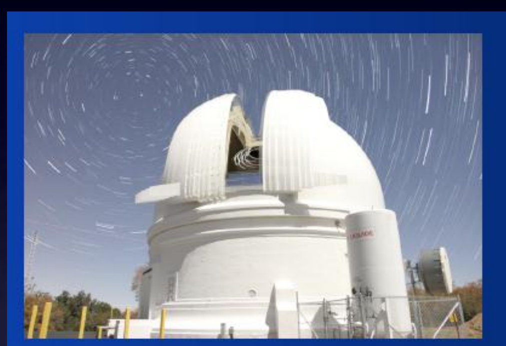


Picture credit : Mattila, Maund, Smartt et al.
Maund & Smartt 2009, Science,
Maund et al. 2013, arXiv 1308.4393
Smartt 2009, ARAA



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

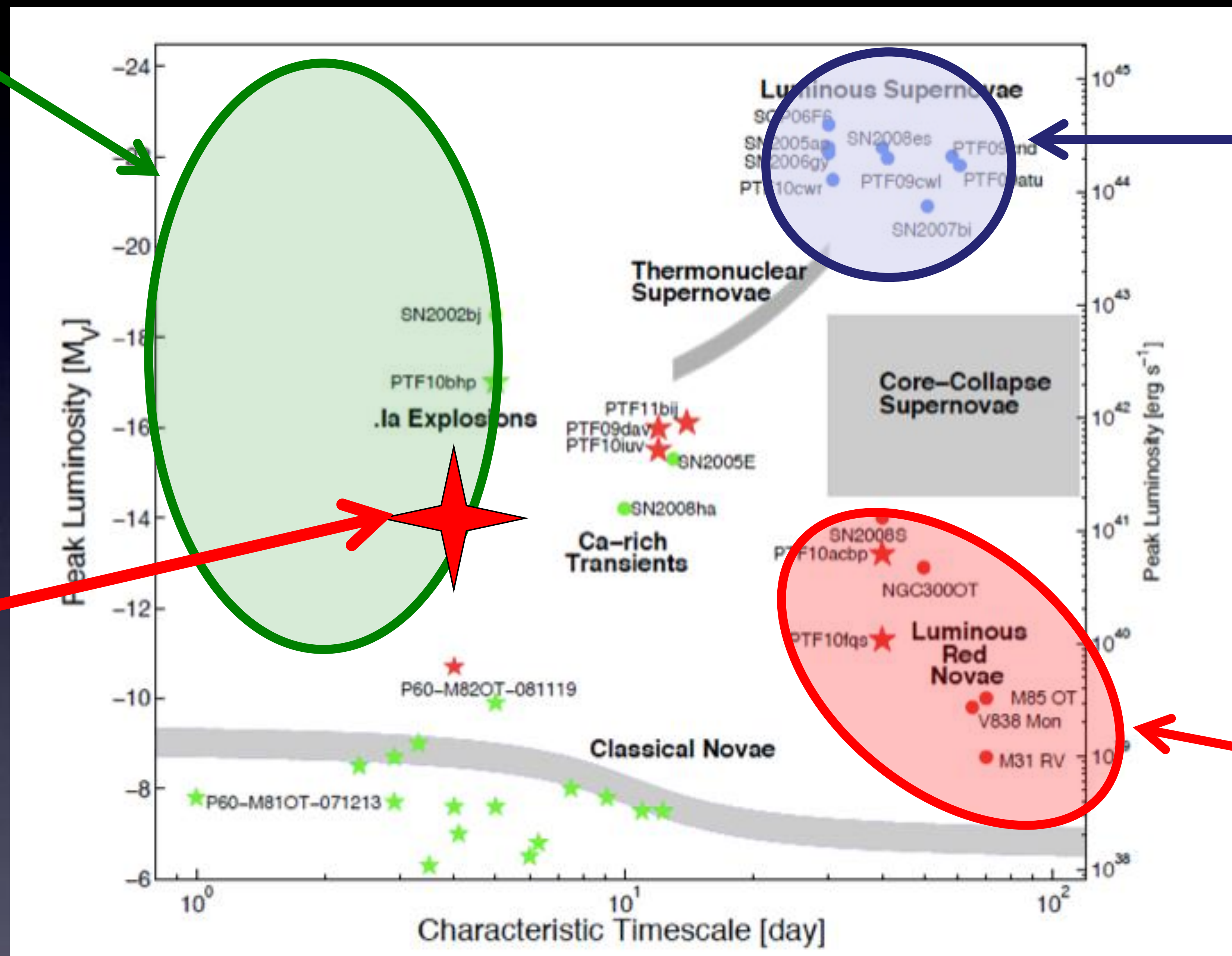
Transients : current science

the unknown

the bright

The first "kilonova" ?

the faint

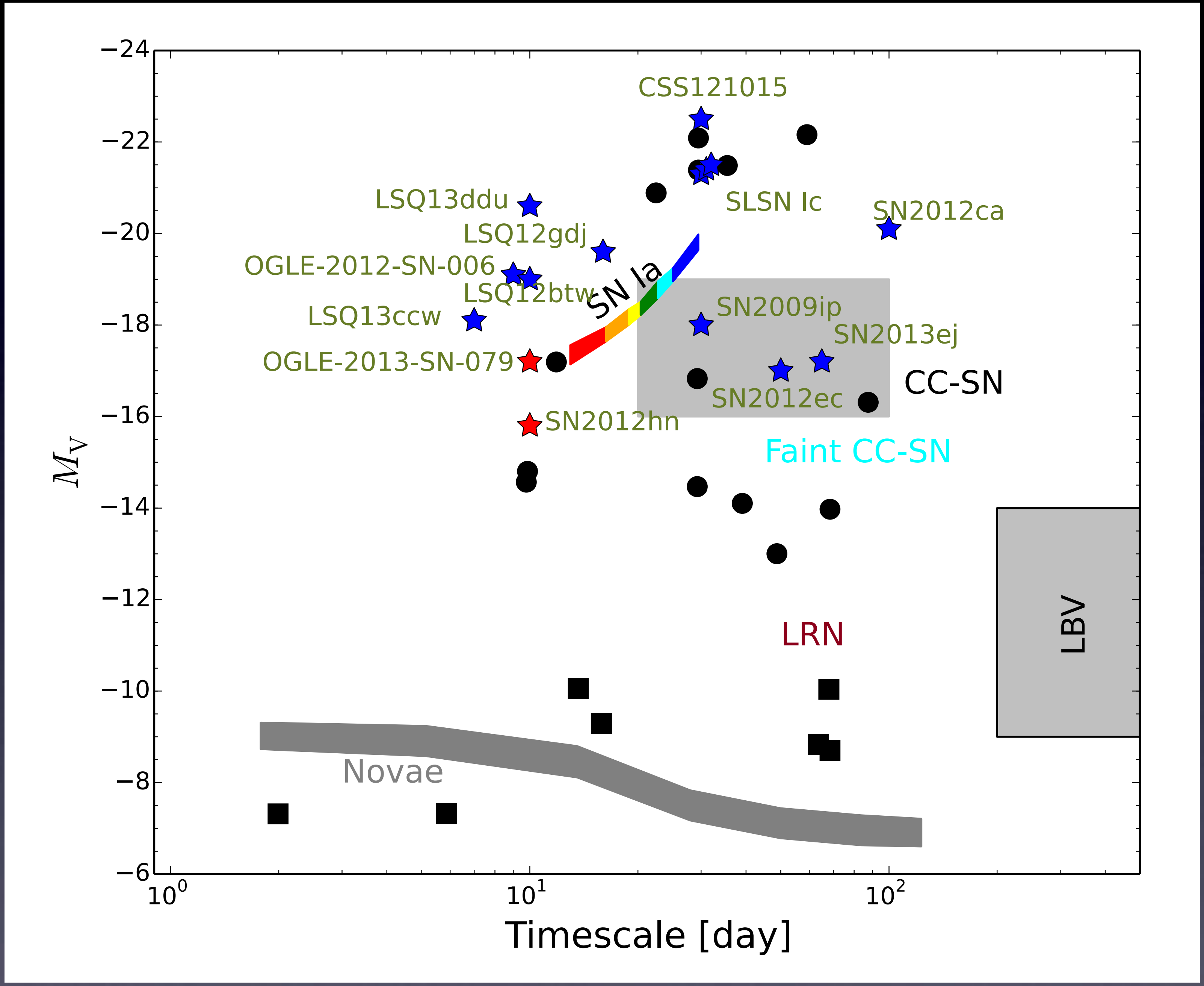


What are the limits of physical explosions and transients ?

Image credit : Shri Kulkarni, Mansi Kasiwal

Transients : current science

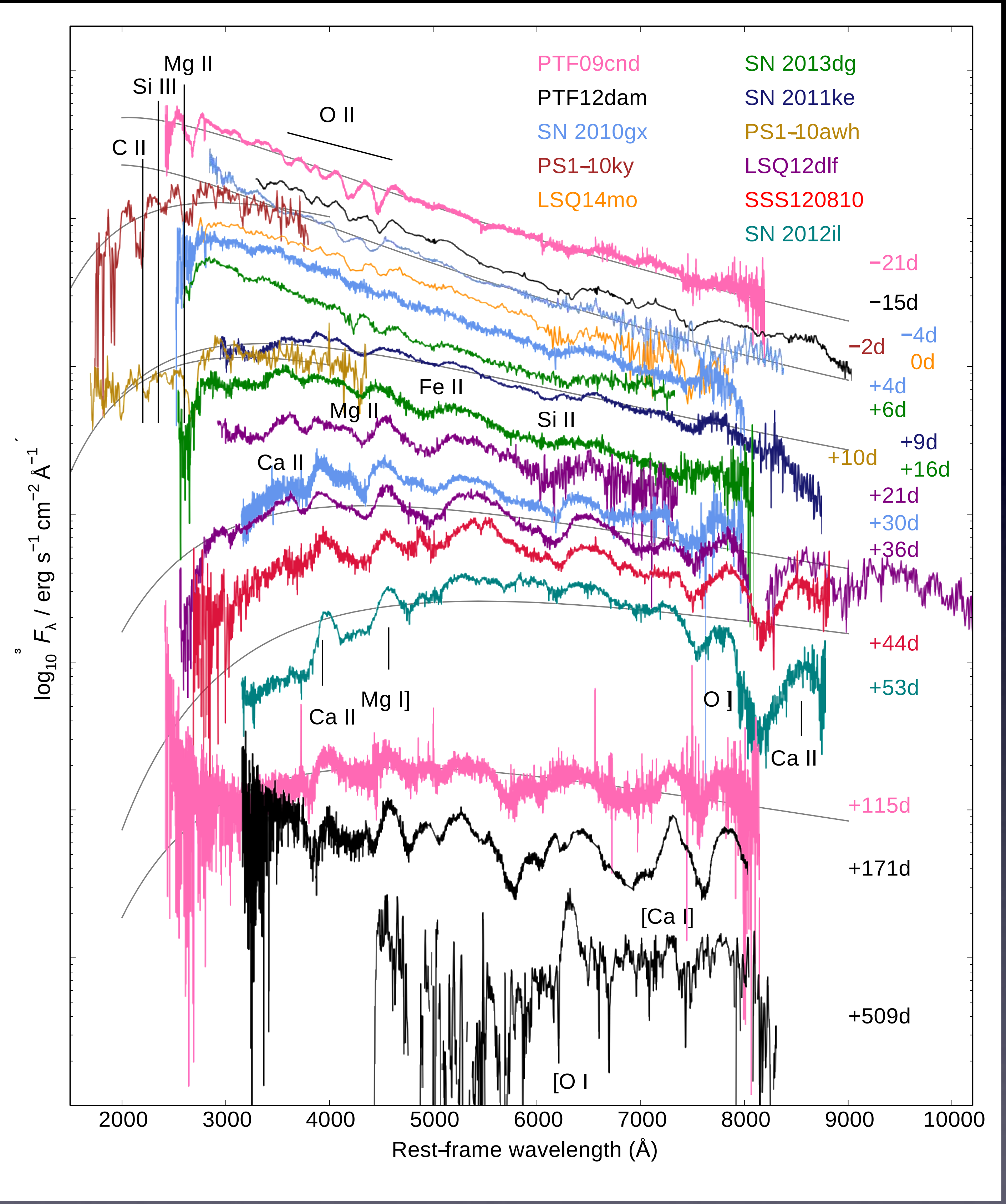
Smartt et al. 2015:
Survey description and products from the first data release by PESSTO,
A&A, submitted



What are the limits of physical explosions and transients ?

Image credit : Shri Kulkarni, Mansi Kasiwal, C. Inserra

Superluminous supernovae

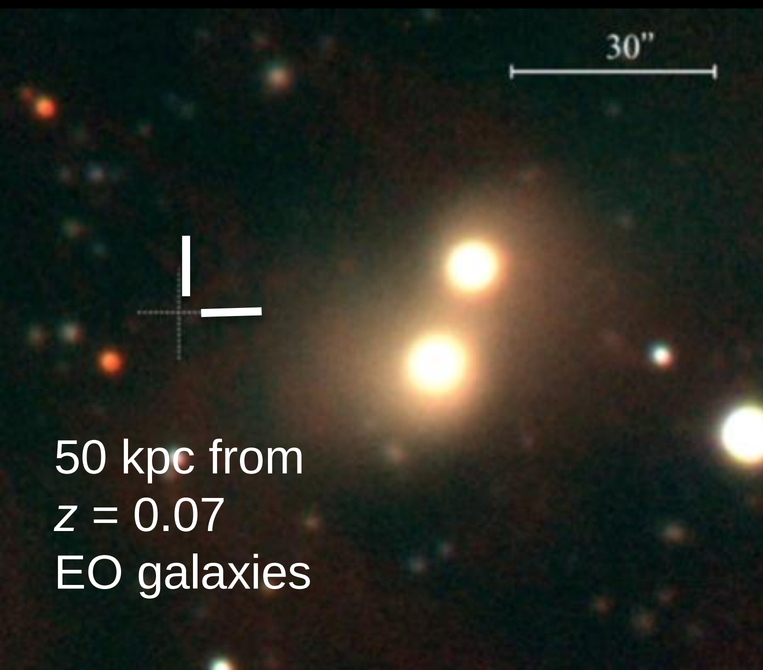


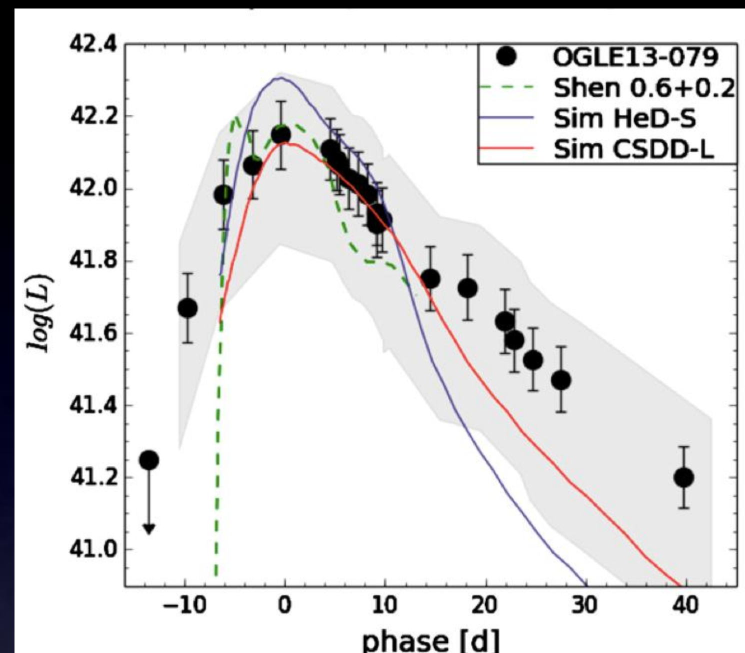
What are they : stellar Explosions in dwarf galaxies – 100 times more luminous than core-collapse SNe. Luminosity source unconfirmed.
No hydrogen and helium seen in spectra
What is the physics powering this extreme luminosity ?
Current leading model – magnetar powering

Nicholl, Smartt et al. 2014 2015
Chomiuk et al. 2011, Berger et al. 2012,
Nicholl, Smartt et al. 2013,
Inserra, Smartt et al. 2013,
Chornock et al. 2013,
Lunnan et al. 2013+2014, Howell et al. 2013

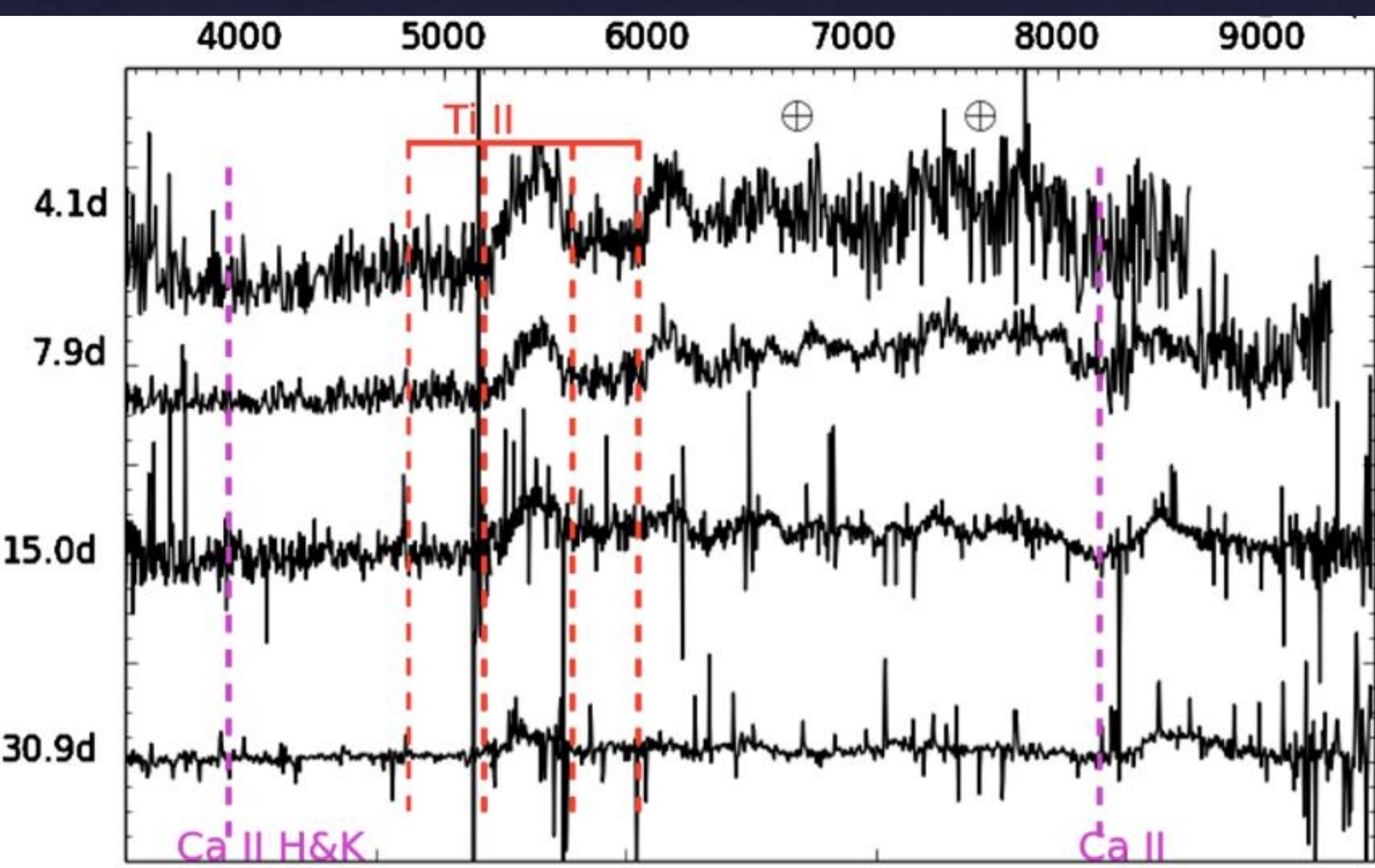
PTF discoveries : Quimby *et al*. *Nature* 2011

OGLE13-79 : faint and fast fading



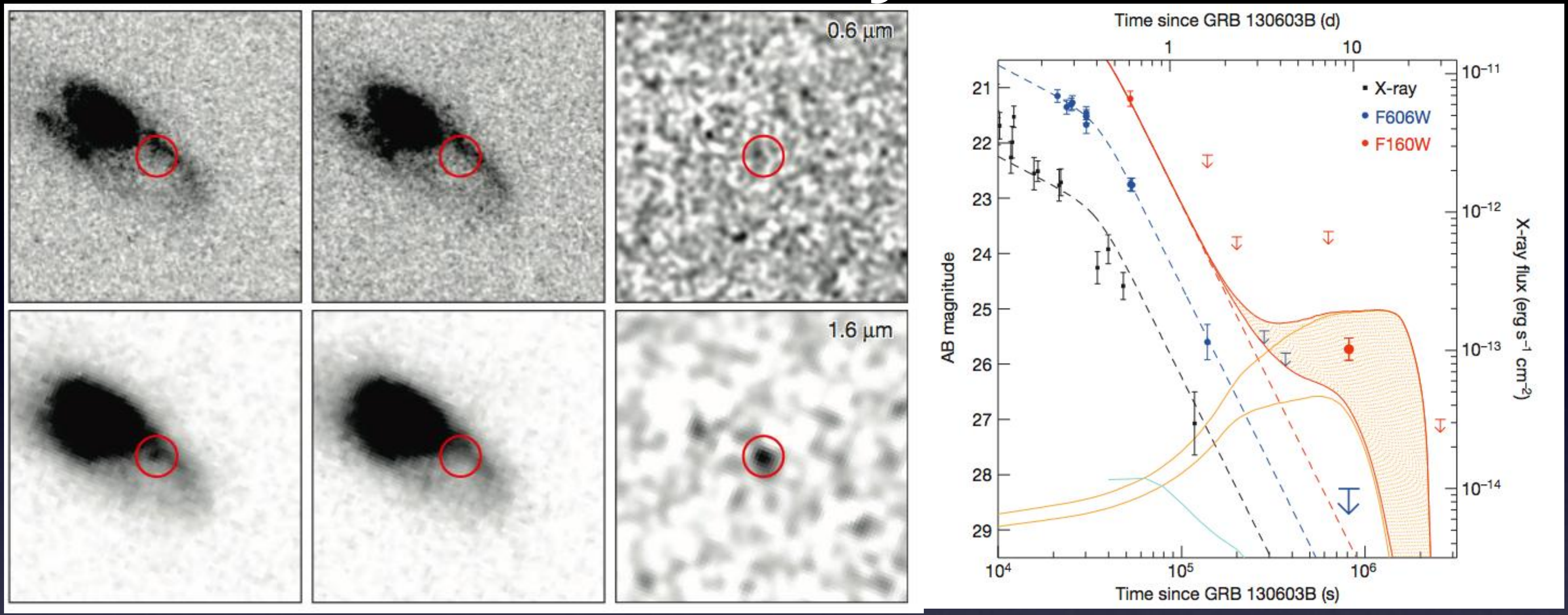


- Fainter than type Ia SNe
- Faster declining (factor 3) than SNe Ia
- ".Ia" = a tenth of a SN Ia



- He shell detonation on a low-mass WD
- Ti and Ca are expected burning products
- Inserra et al. 2015 ApJL

Multi-wavelength : transient gamma-rays



Tanvir et al. 2013, Nature

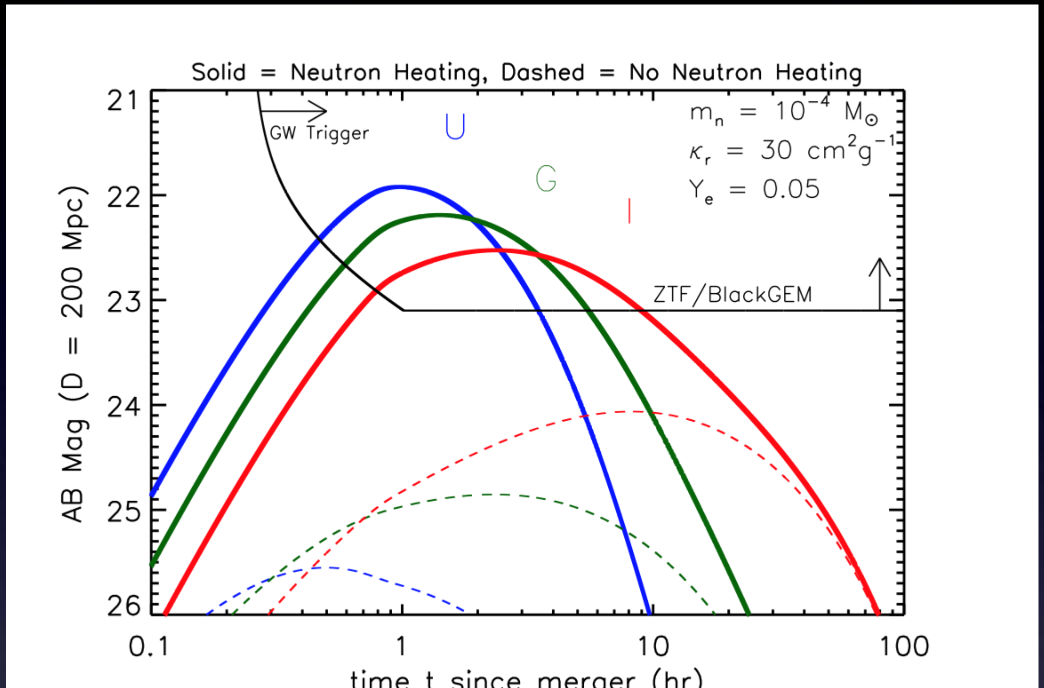
- Swift Short gamma-ray burst in galaxy at z = 0.356
- Detection of "afterglow" - then very faint "glow" 7 days after the gamma rays
- "Kilonova" model – two neutron stars merge, neutron-rich radioactive explosion, not as bright as a supernova
- Will these be the first gravitational wave sources in 2015-17 ?

See also : Berger et al. 2013, arXiv 1306.3960 ; Rosswog 2005

ESO facilities for transients 2015-2025+

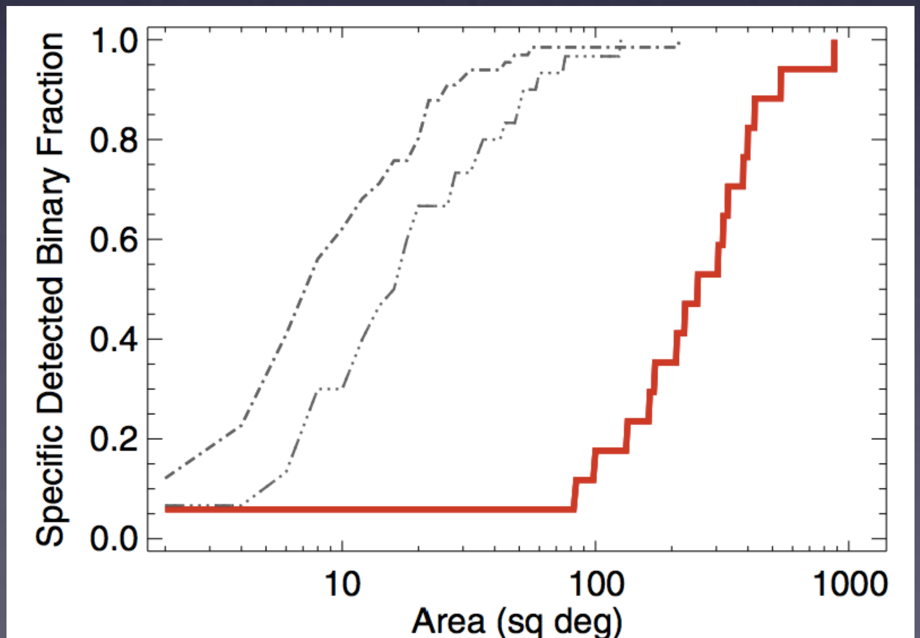
- Low redshift : multi-messenger, multi-wavelength
- High redshift : near infra-red

Multi-messenger astronomy – GW transients



Metzger et al. 14, also see Li & Paczynski 98

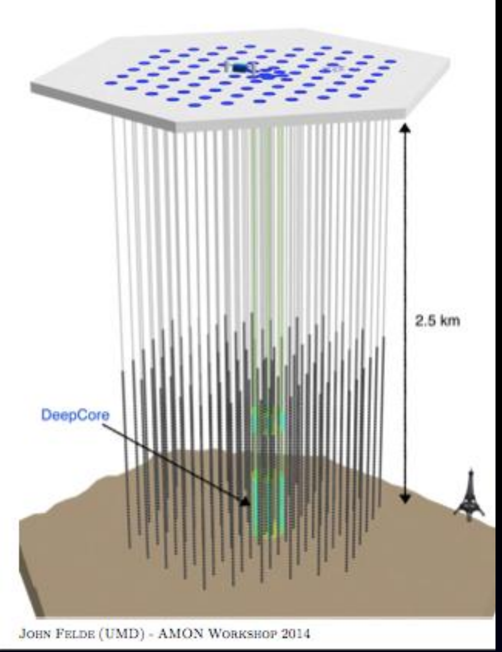
- Advanced LIGO and VIRGO expected to produce GW detections 2015-2020
- Best bet for GW transient sources binary neutron star merges
- “Kilonova” : thermal transient of ~1 week. Faint, and red (1 possible detection)
- Metzger et al (2014) : $10^{-4}M_{\odot}$ expands rapidly, creating free neutrons that β-decay to power ~few hour transient



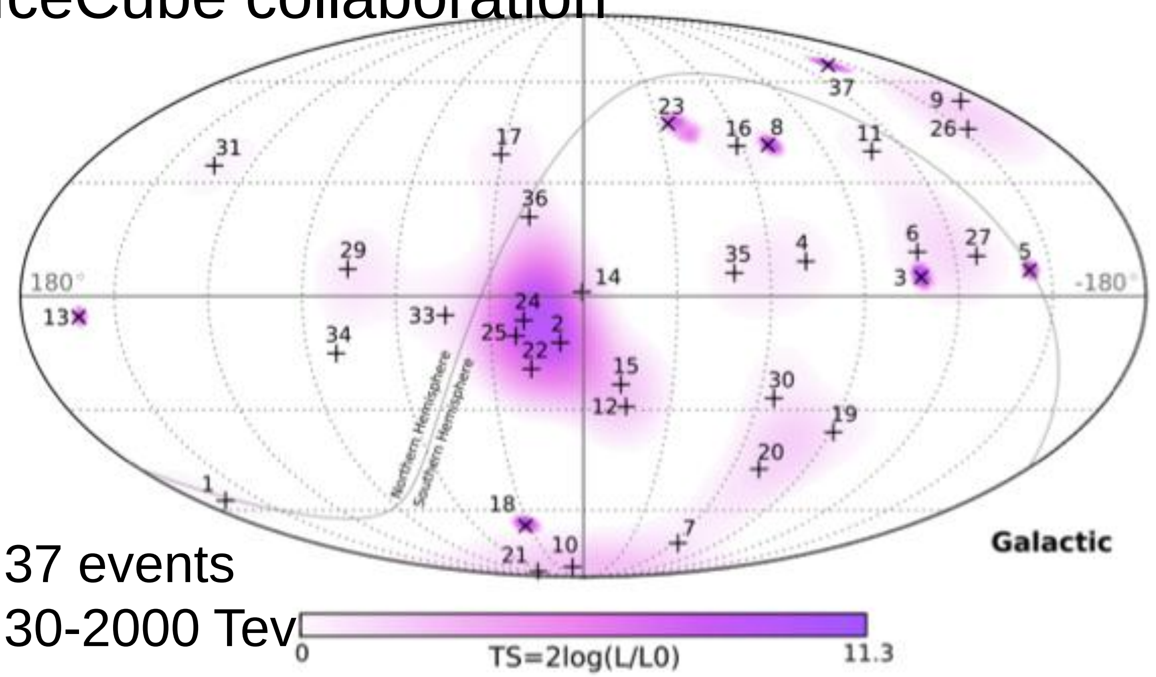
(b) NS-NS mergers: Sky errors

Nissanke & Kasliwal 2014

Multi-messenger astronomy : neutrinos



IceCube collaboration



37 events
30-2000 Tev

- arXiv:1405.5303
- No significant source detected
- Clear opportunity for multi-messenger searches
- ∼ 1 event per month

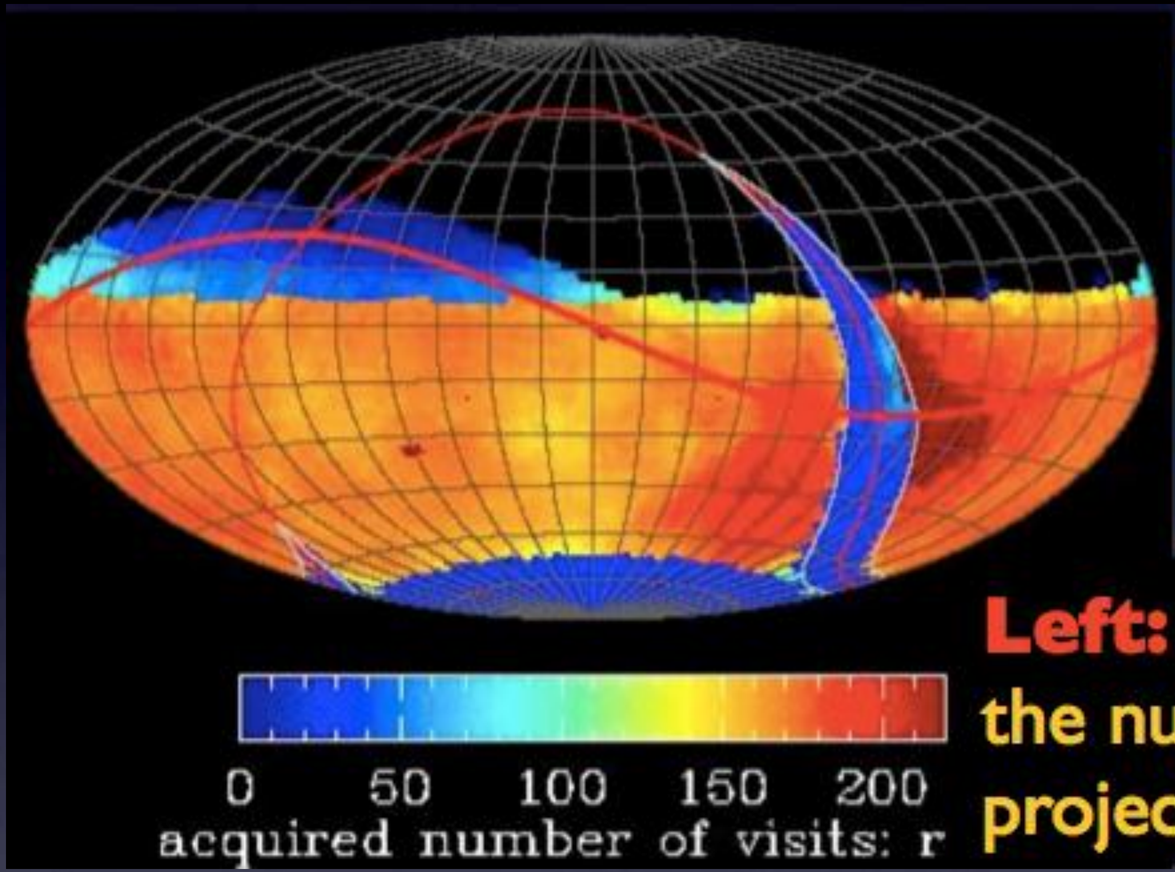
Credit : John Felde, Univ. of Maryland
AMON Workshop, Dec 2014

- IceCube energy range : ~10 Gev to ~PeV
- Now detecting astrophysical high energy neutrinos
- Sources ?
  - GRBs
  - SNe (choked jets)
  - AGN
  - Galactic ?

Astrophysics Multi-messenger Observatory Network (AMON).
Major ESO community interest

LSST

Credit : Z. Ivezic



LSST in one sentence:
An optical/near-IR survey of half the sky in ugrizy bands to r~27.5 (36 nJy) based on 825 visits over a 10-year period: deep wide fast.

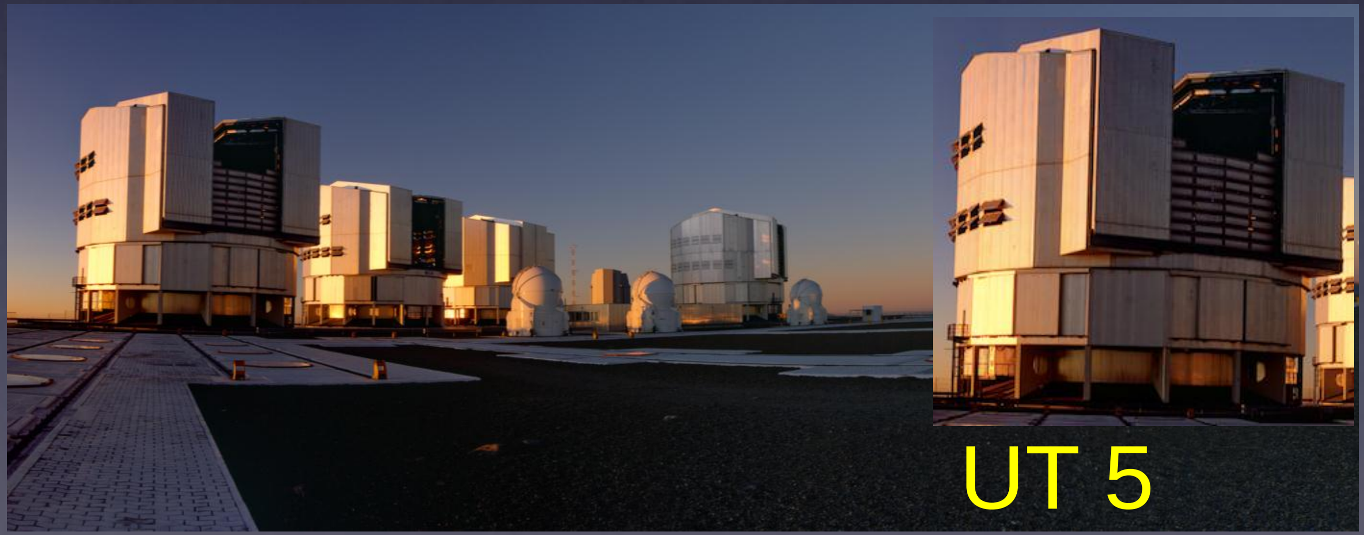
Left: a 10-year simulation of LSST survey: the number of visits in the r band (Aitoff projection of eq. coordinates)

- Single visit is 2x15s, giving a combined depth *r* ~ 24.5
- 20,000 sq degree every 3-4 nights, twice a night
- But need careful consideration of filter cadence
- ~10^6 transients/variable objects, released within 60s
- See talk by P. Antilogus tomorrow
- Plus radio, x-ray and gamma-ray surveys

VLT – proven success in time domain

- FORS + xshooter + HAWKI
- In ToO mode, most flexible, fast response facility there is
- Limitation for time domain science is amount of ToO time

- Dedicated 8-15m survey telescope with high-multiplex : <u>add single IFU for rapid ToO</u>
- Effectively zero perturbation to survey science



SOXS – “Son Of XShooter”

- In response to Call for Ideas for NTT 2016+
- PI Sergio Campana (It, UK, Chile, DK +)
- A dedicated spectroscopic machine for the transient sky @ NTT
- Copy of “NOT Transient Explorer”

Table 1: *Main characteristics of NTE spectrograph mode.*

Wavelength coverage	0.32 – 1.77 µm
Spectral resolution	4,500
Slit length	20”
Pixel scale	~0.4”/pix
Optical/NIR wavelength crossover	0.76 µm
Average blaze peak efficiency	> 30%
Time to reach the sky limit	~15 min

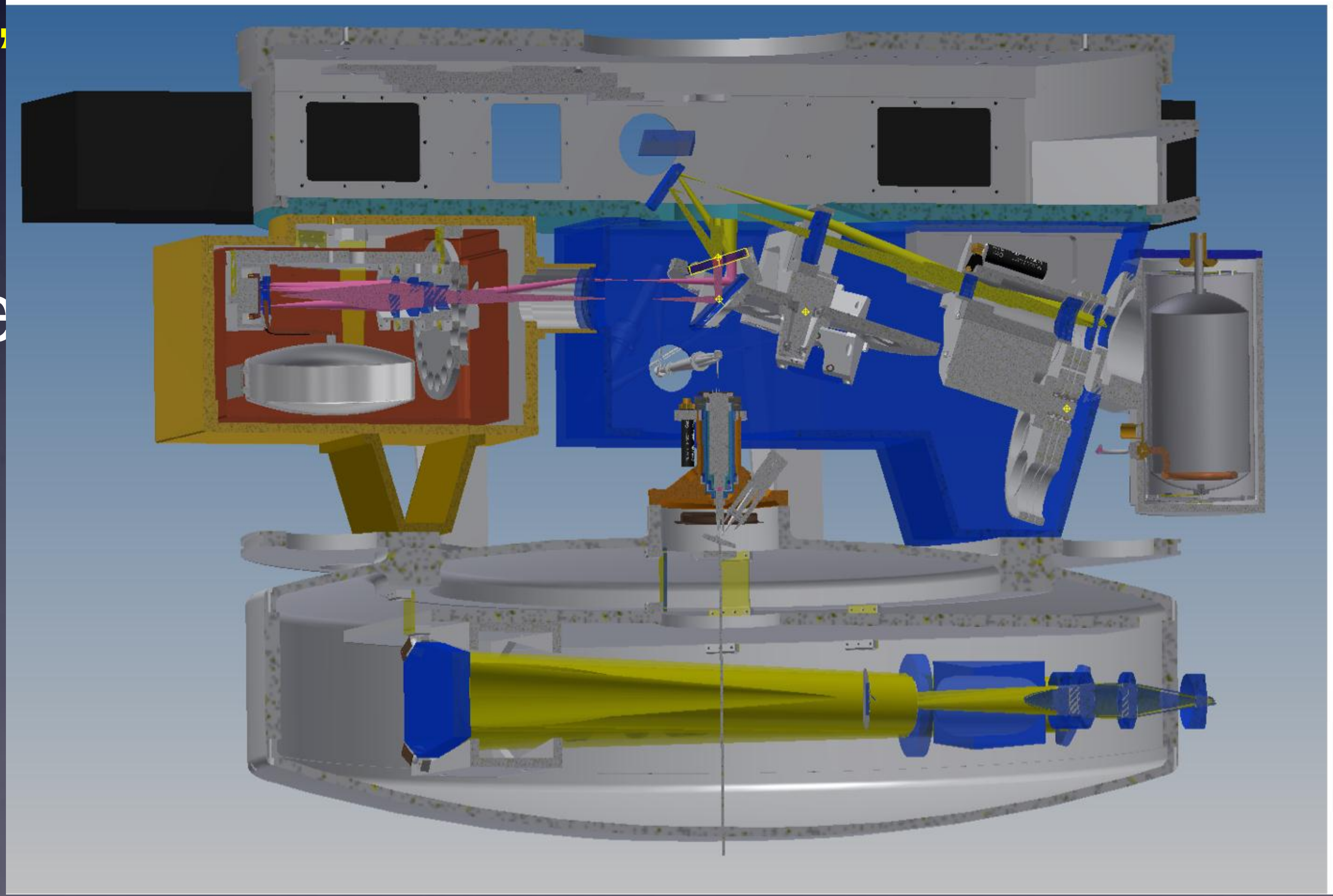
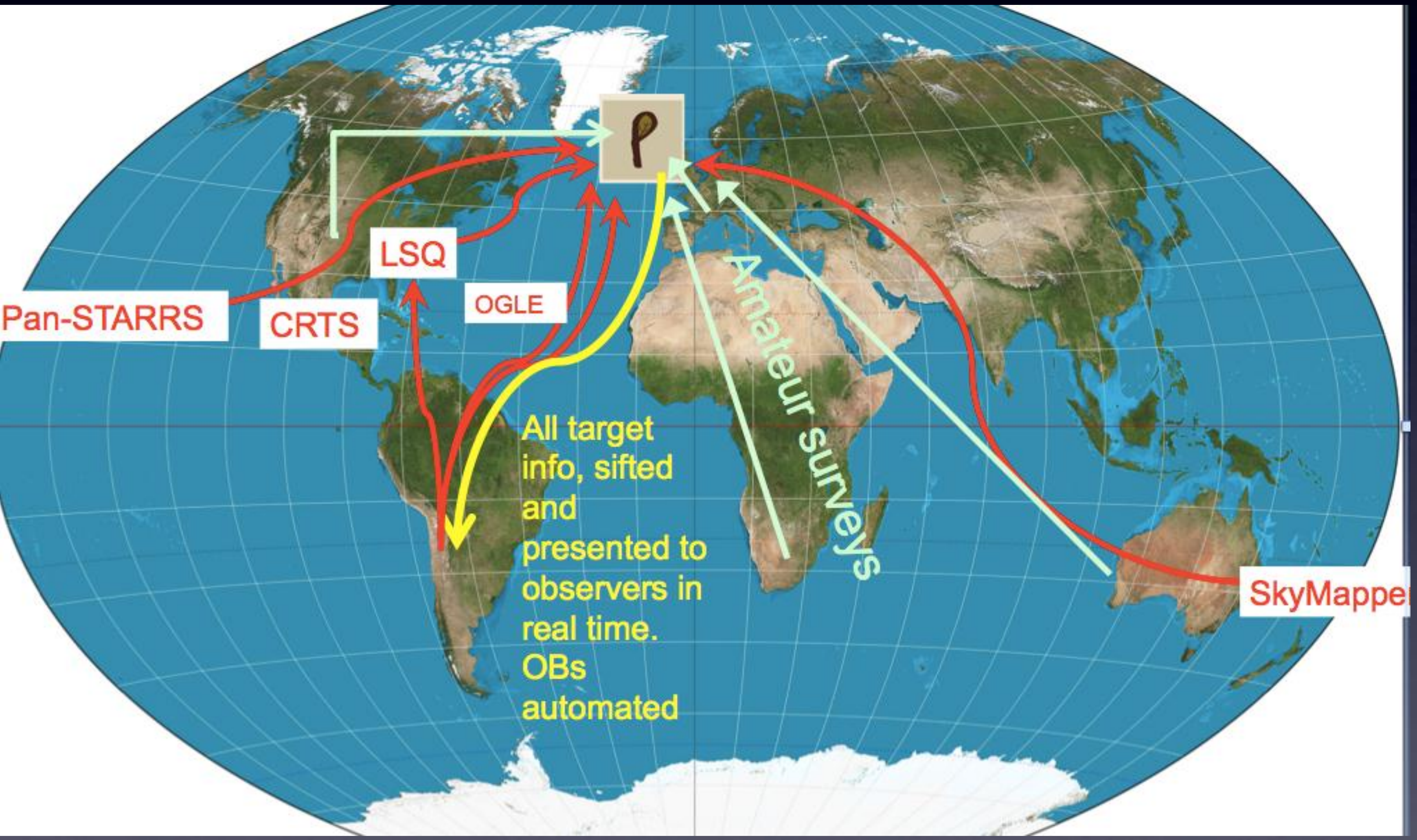


Image credit : S. Campana

Flexible, time-domain optimised operations

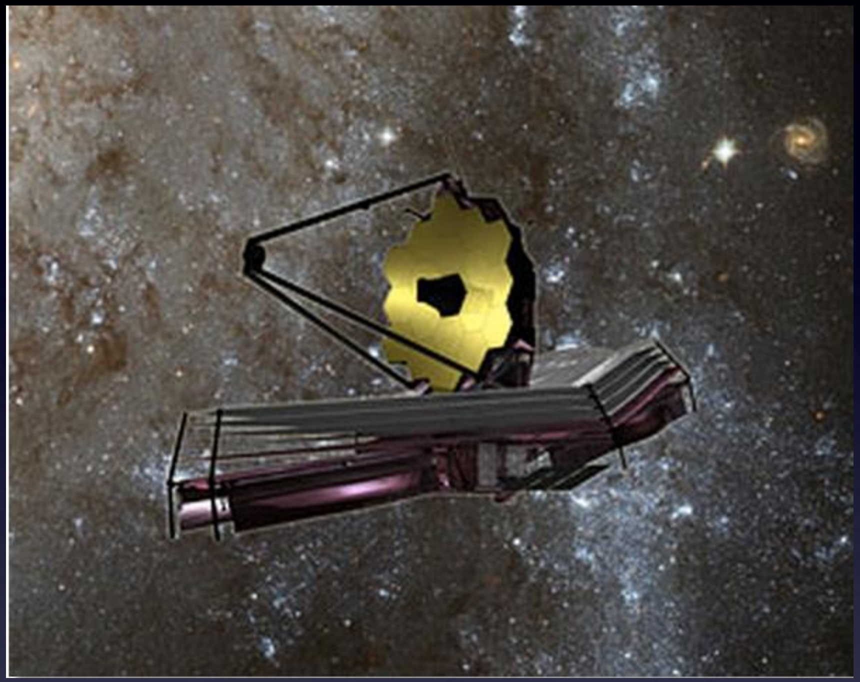


PESSTO : from survey discovery to publicly reduced data in < 24hrs. Every night for 4 years

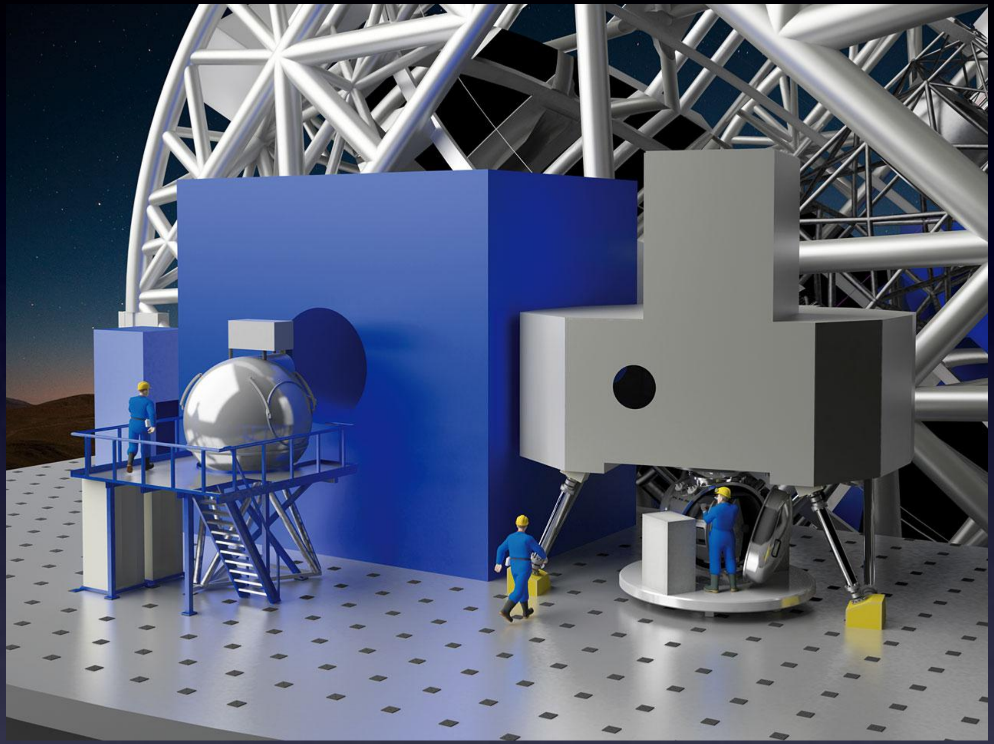
NTT with SOXS : cost effective, competitive science, large ESO community

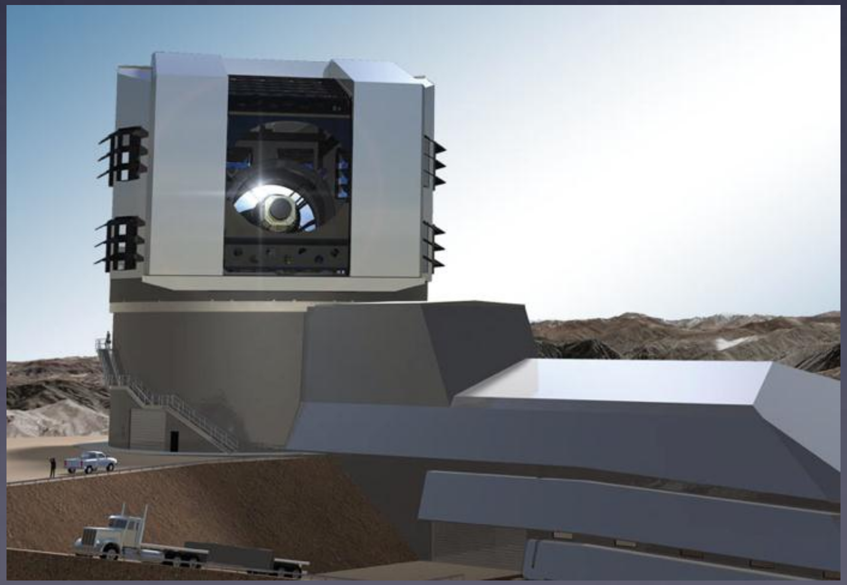
- PESSTO: cheap, efficient, flexible operational model
- Necessary if time domain work is main function of the telescope
- Very competitive science
- Remote observing : even more cost efficient

High-z : JWST, LSST and E-ELT



NIRSPEC
Surveys
$H_{AB} > 25$

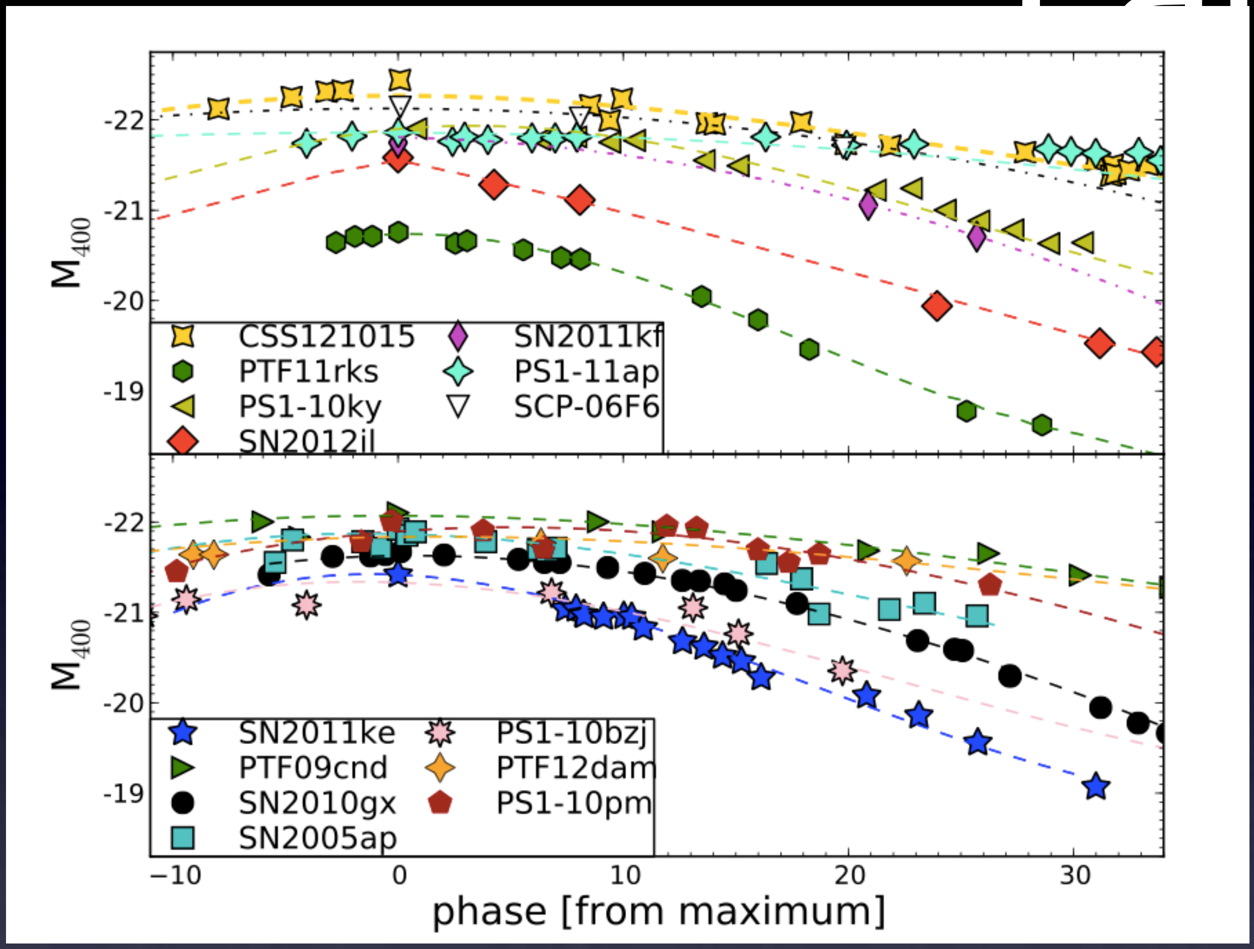


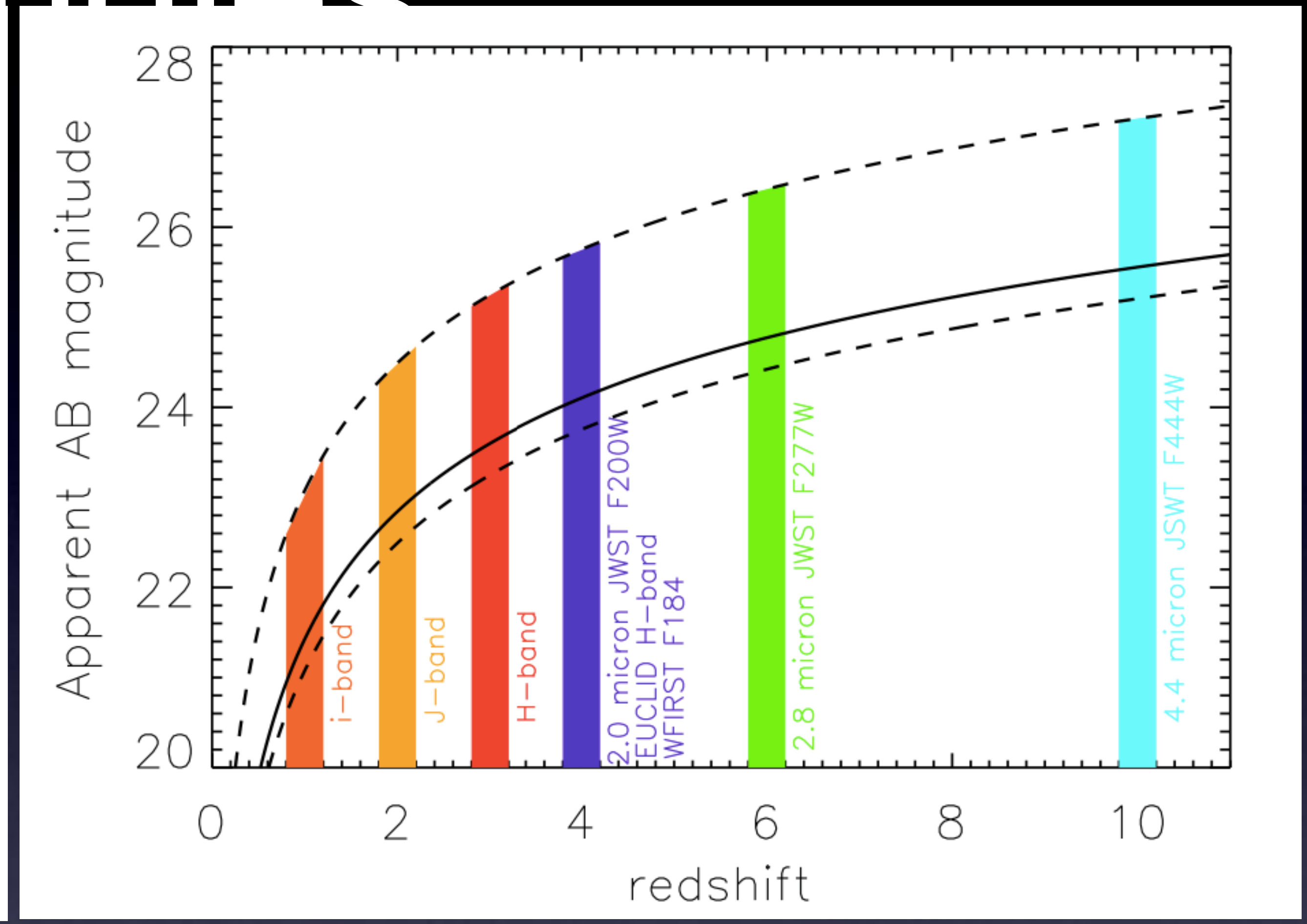


LSST
Surveys
$z_{AB} > 25$

- Feed for ELT spectra
- ELT + HARMONI
- 4hrs gets $H_{AB}=25$ at S/N~20 (R~500)
- Example Superluminous supernovae $z = 6\text{-}10$

SLSNe as standardizable candles



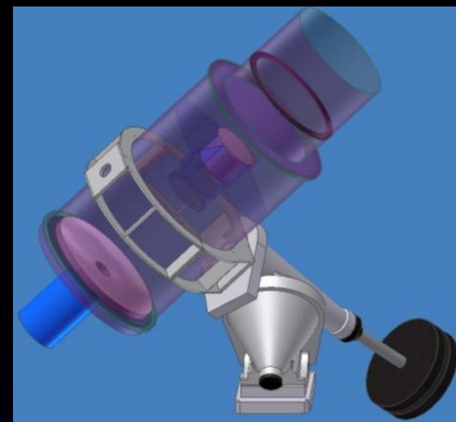


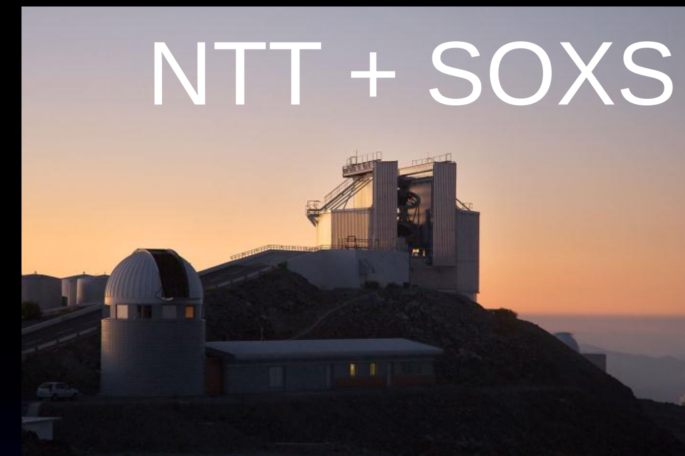
Inserra & Smartt 2014, ApJ, 796, 18

- Super-luminous SNe: hot, UV bright sources, M_{UV} ~ -22 mag
- Peak magnitude is (potentially) standardizable to ± 0.2 mag
- Already shown to be exclusively produced in low metallicity dwarf galaxies ($Z < 0.2Z_{\odot}$)
- Ideal high redshift probes : cosmology, star formation, beyond z > 6 with LSST, JWST, VLT and E-ELT

Multi-messenger triggers : GWs, neutrinos,
gamma, x-ray, radio

0.5-1m with 10-30
Sq. degree camera





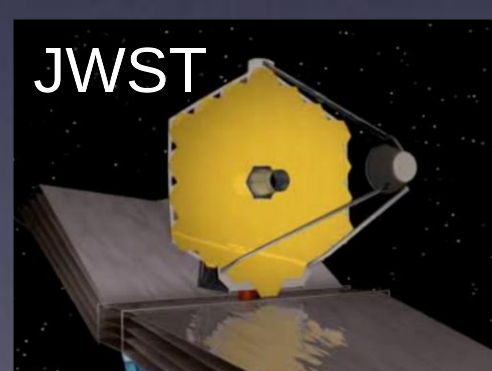
Dedicated,
>50%
PESSTO-
like ops

m<21

m<23

m>23

VLT + xshooter,
FORS, HAWKI
Flexibility, large
fraction of ToO



ELT + HARMONI
Fast response
mode

end