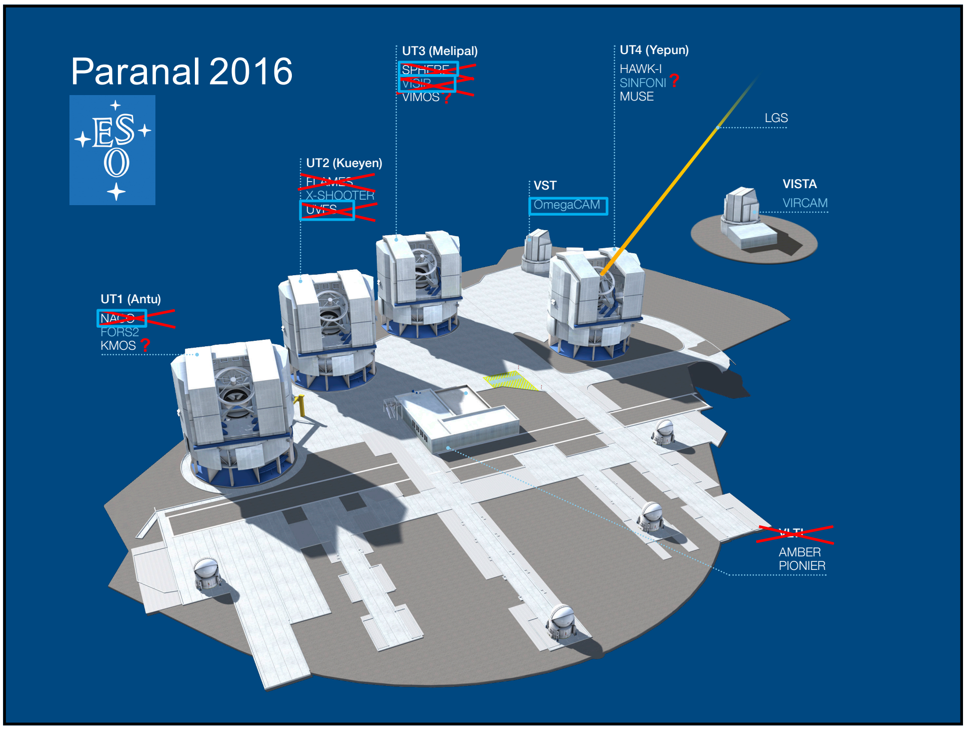
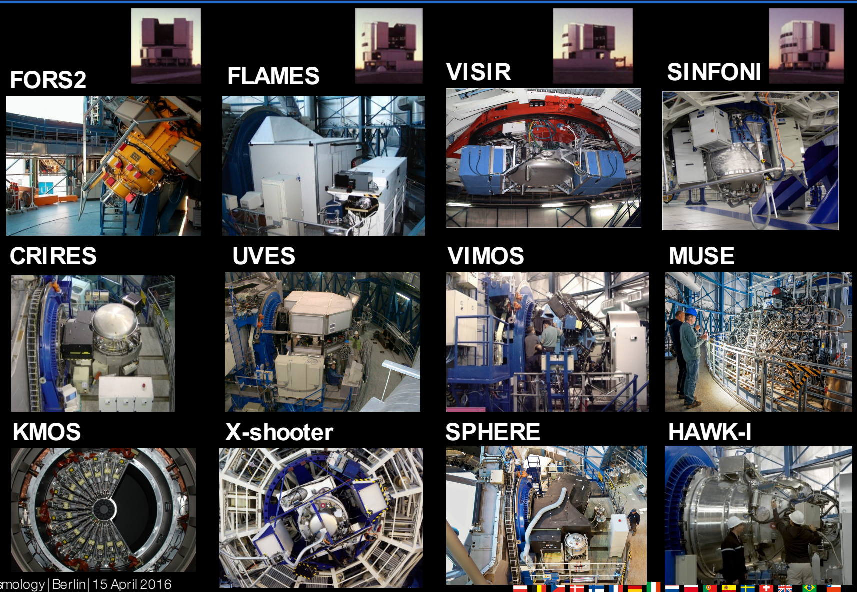

Next Decade of SN Cosmology
ESO Perspectives


Paranal 2016
UT3 (Melipal)
~~SPHERE~~
~~VISIR~~
VIMOS ?
UT4 (Yepun)
HAWK-I
SINFONI ?
MUSE
LGS
UT2 (Kueyen)
~~FLAMES~~
X-SHOOTER
~~UVES~~
VST
OmegaCAM
VISTA
VIRCAM
UT1 (Antu)
~~NACO~~
FORS2
KMOS ?
~~VLTI~~
AMBER
PIONIER

VLT Instruments 2016



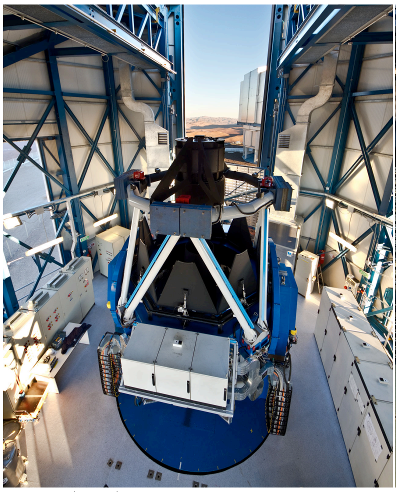
Individual objects

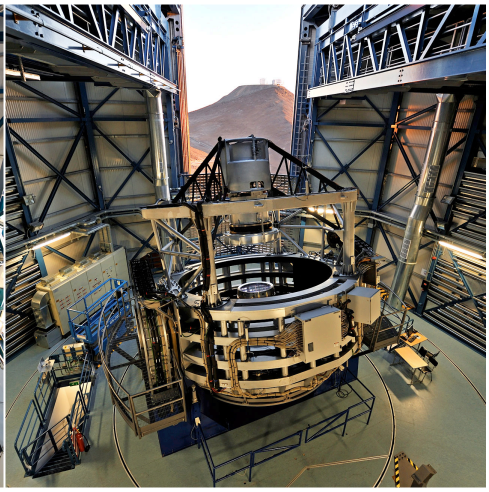
- Most VLT instrumentation is for follow-up observations
- Large instrument complement for nearby SNe
  - NACO – progenitors
  - FORS2 – SN spectra
  - UVES – environments, abundances
  - XSHOOTER – redshifts (CANDELS SNe), late phases
  - VISIR – mid-infrared
  - MUSE – SN environments (SN Refsdal)
  - HAWK-I – near-IR follow-up
  - EFOSC2/SOFI - PESSTO

→ Detailed investigations of individual objects

The Survey Telescopes

- VST 2.6m for optical and VISTA 4.1m for infrared observations
- Coordinated sky surveys in 5-year projects

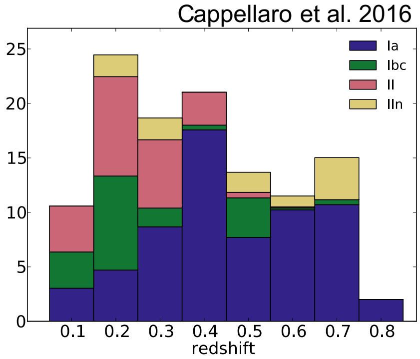




Survey Telescopes

- VST
  - SN search SUDARE

Cappellaro et al. 2016

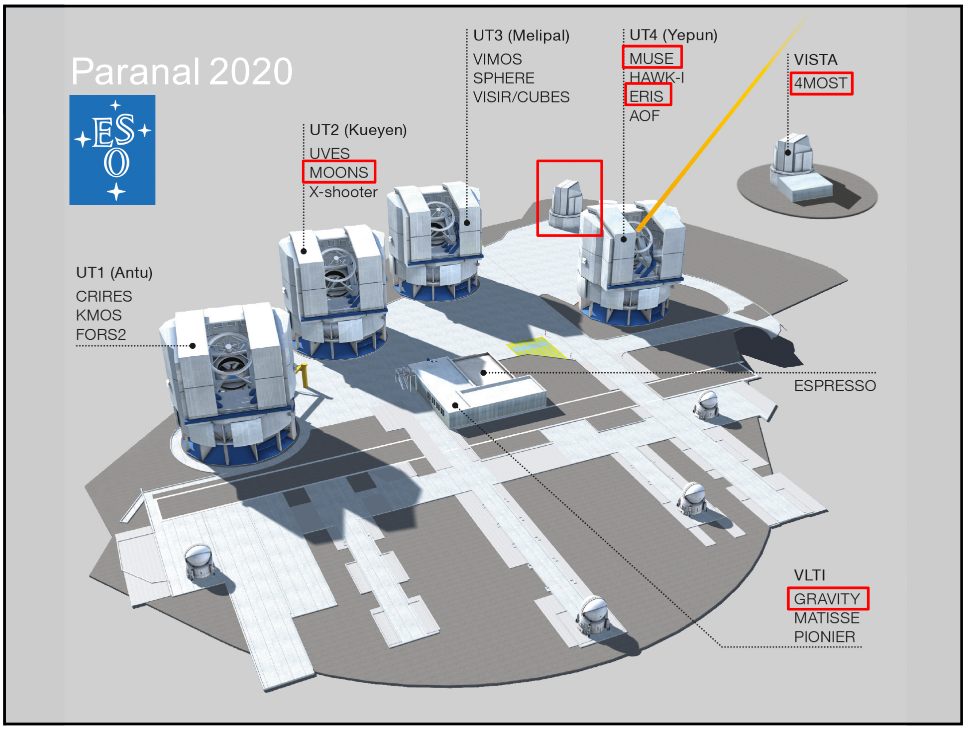


- VISTA
  - VVV SNe behind bulge
- VLT follow-up of DES SNe
  - HAWK-I provides IR
  - X-SHOOTER for host galaxy redshifts

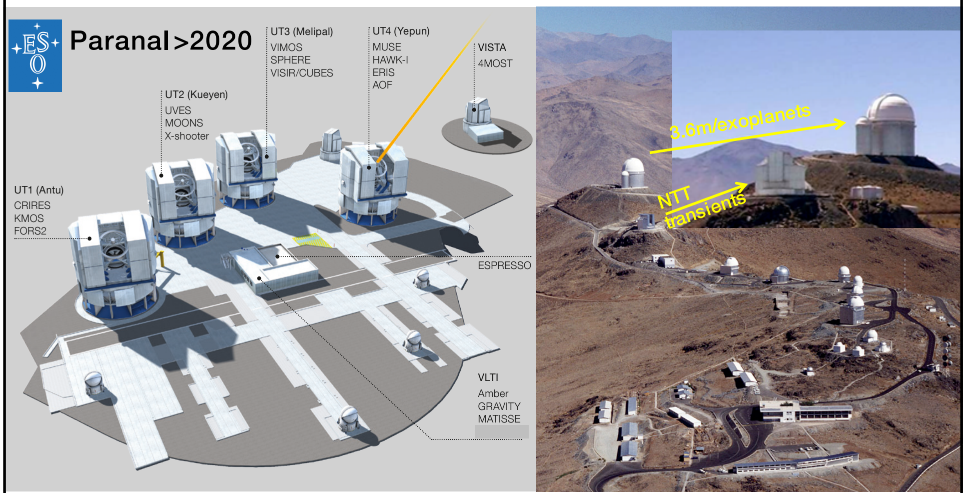
Long-Term Monitoring Programs

- Supernovae
  - Key Program in 1980s
  - Several Large Programs
    - Turatto et al., Benetti et al.
  - Public Spectroscopic Survey
    - PESSTO
      - 90 nights per year for spectroscopic SN follow-up
      - concentrate on peculiar and rare types of supernovae

SN Cosmology | Berlin | 15 April 2016



ESO Optical/NIR Telescope System after 2020



The ESO Transient Sky

- Traditionally challenging for community observatories
- Adapt operational modes
  - flexible scheduling
  - variable timescales
  - large Target of Opportunity fraction
  - rapid response mode
  - ➔ service mode operations
  - ➔ dedicate telescopes
- Systematic archiving
  - time series

Strategic Changes - next decade

- Move towards a systems approach
  - Big problems need coordinated observations
    - Milky Way dynamics
      → Gaia astrometry plus velocities and abundances
    - Cosmology
      → EUCLID and redshifts
    - Particle Physics
      → messengers and electromagnetic follow-up
  - Coordination between different observatories
    - Multi-wavelength and multi-messenger approach
    - Complex astrophysical sites
      → e.g. star formation regions, SN remnants, galaxy clusters, distant universe

SOXS on the NTT

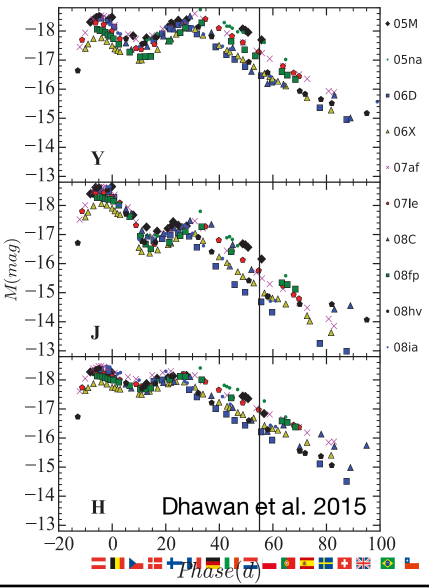
- Negotiations with a consortium to provide a single-object spectrograph for the NTT - SOXS
  - copy of Xshooter
  - simultaneous coverage from 400nm to 1.8μm
  - significant investment of observing time over many years
  - continuation of PESSTO-like survey

Future SN Cosmology

- Promise of the (rest-frame) infrared
  - Reduced absorption
  - Greater uniformity in the light curves

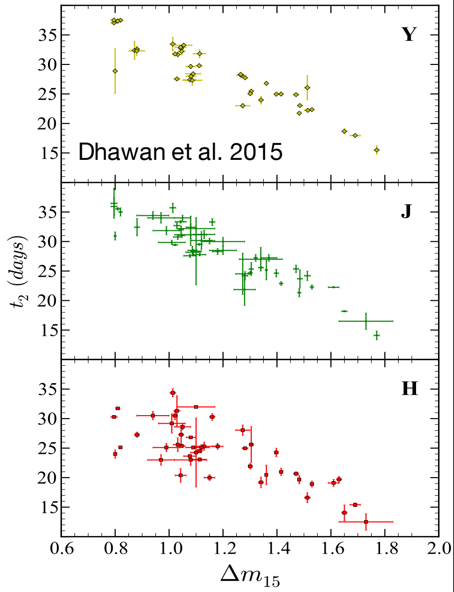
SN Ia infrared light curves

- IR light curves from the literature
  - mostly Carnegie Supernova Project
- Individual evolution after first maximum
- Uniform late decline rate



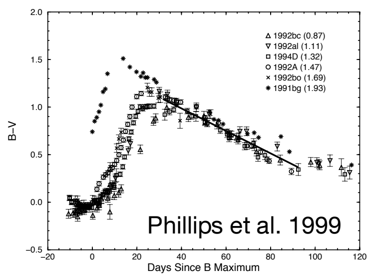
Correlations with the optical

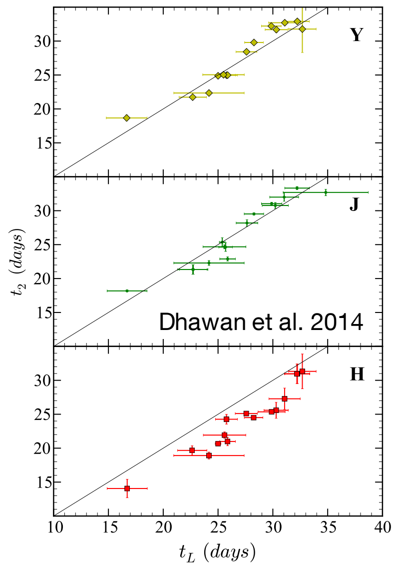
- IR properties correlate with optical decline rate
- Phase of secondary maximum strongly correlated Δm_{15}



Correlation with colour evolution

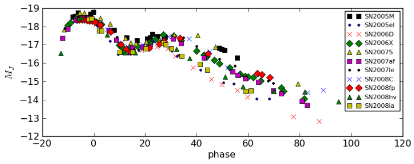
Phase of second maximum and beginning of the Lira relation are also tightly linked





Consistent picture emerging

- Second peak in the near-IR is the result of the recombination of Fe++ to Fe+ (Kasen 2006)
  - he predicted a later second maximum for larger Ni masses
- Optical colour evolution faster for objects with lower nickel mass (Kasen & Woosley 2007)



- Ejecta structure uniform
  - late declines very similar

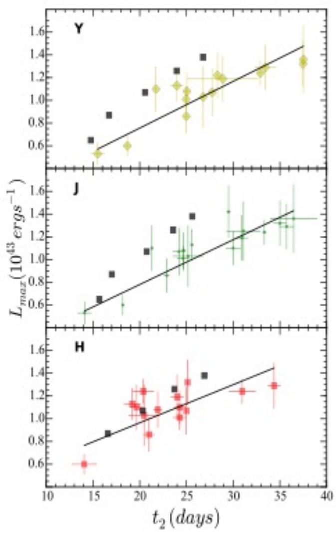
→ higher luminosity indicates a higher Ni mass
→ later secondary peak also indicates higher Ni mass
→ Ni mass and (optical) light curve parameters correlate (Scalzo et al. 2014)

Dhawan et al. 2015

Nickel masses

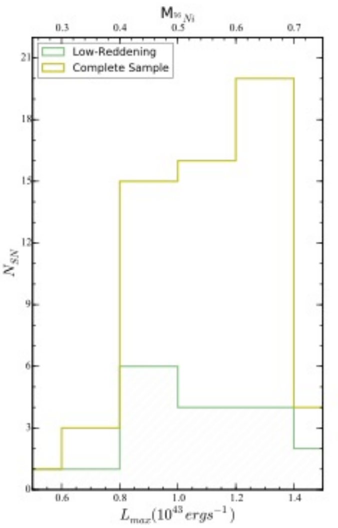
- Using a timing parameter for nickel masses
  - completely independent on reddening and multiple light curves
- Test with a sample of unreddened SNe Ia
- Explore different methods to calculate the nickel mass (currently still all Chandrasekhar-mass progenitors)

Dhawan et al. 2016



Luminosity and mass functions

- Reddening independent distribution functions
  - fails for super-Chandra objects
    - SN 2007if
    - Different physics? Interactions?
- Luminosity from second IR maximum?

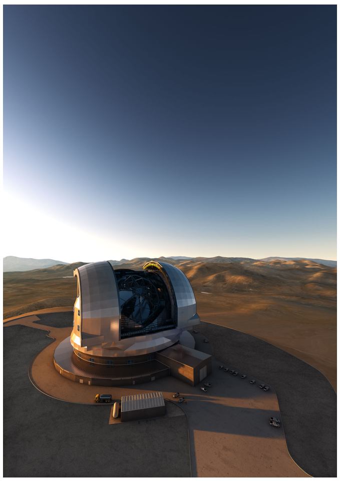


EUCLID

- Use EUCLID deep fields to provide IR light curves
  - Rest frame Y out to z~0.8; J to z~0.5
- Monitor/shadow the fields from the ground in the optical
  - Full optical light curves
  - Exact phases
    - Important for the (sparse) IR light curves
- Spectroscopic follow-up programme
  - FORS2 would be ideal

Future Facilities

- MOONS (VLT) and 4MOST (VISTA)
  - Massive multi-object spectrographs
  - Follow-up spectroscopy
    - Host galaxies
    - Supernovae?
      - 'random phase'
      - No systematic follow-up
- E-ELT
  - Operational from 2025
  - First-light instruments
    - HARMONI – spectrograph
    - MIKADO – camera (0.8-2.4μm)
  - Individual objects (0.5-2.4μm)
  - High redshift



Astronomy in the 2020s

- OIR sky measured to ~25 mag
- Thousands of transient alerts per day
- Matching capabilities at (almost) all other wavelengths
  - angular resolution
  - sensitivity
  - sky coverage
- Astroparticle detections
- Diverse astronomical community with considerable overlap with other sciences (chemistry, biology)