Estimating explosion properties of normal hydrogen-rich core-collapse supernovae

Ondřej Pejcha

Lyman Spitzer Jr. Fellow, Department of Astrophysical Sciences, Princeton University

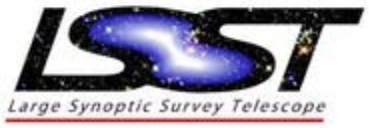
With Jose Prieto (UDP), Tomas Muller (Catolica)

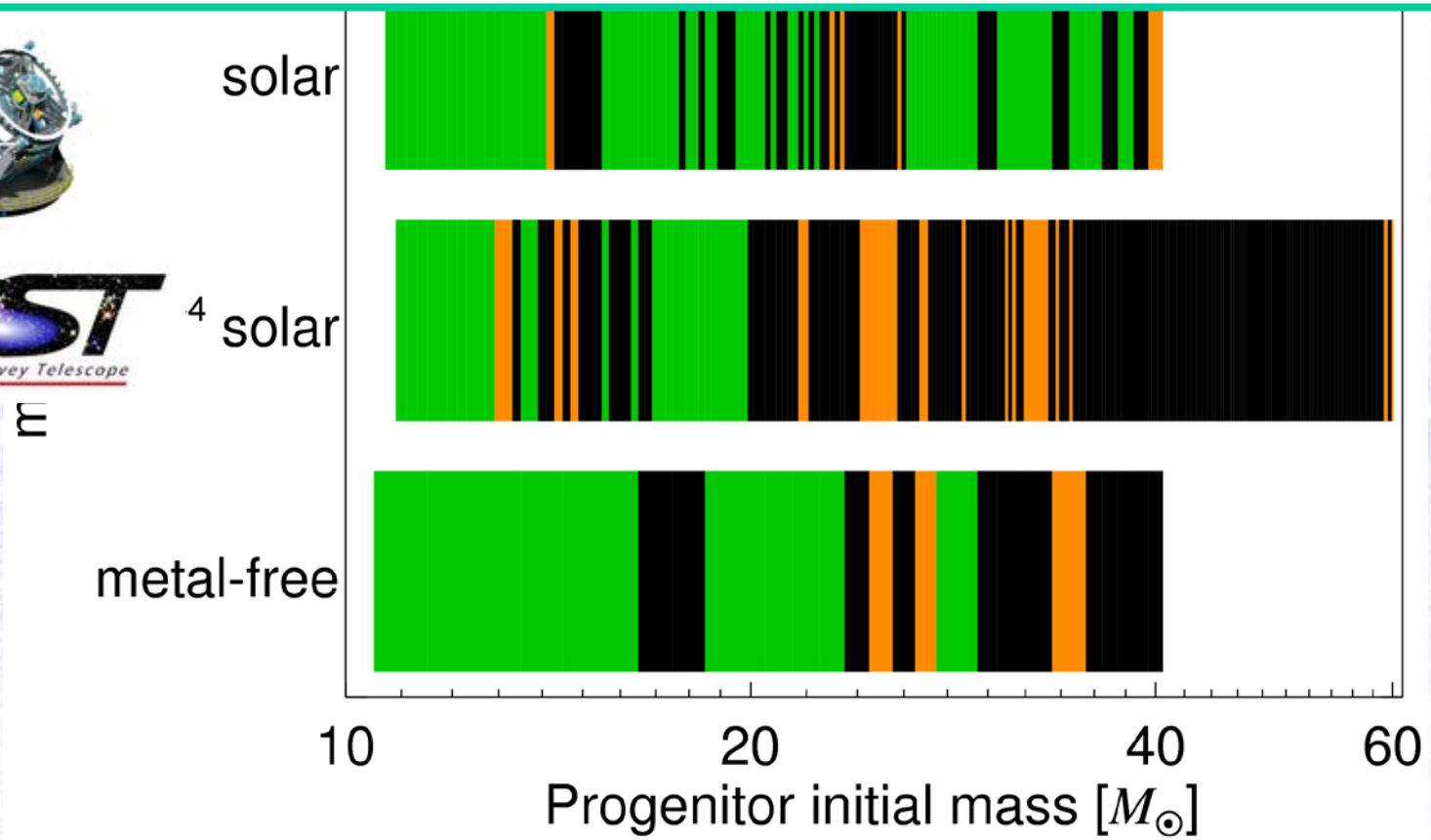
Also with Todd Thompson (OSU), Christopher Kochanek (OSU), Arjun Raghavan (UNC/Duke)

Other work:

- Explosion mechanism of core-collapse supernovae
- Stellar mergers and their transients
- Global models of light curves and velocities
- Stellar dynamics (Kozai)
- Transient astronomy

- Need to understand the whole population
- GW/neutrino detections for several objects at most
- Direct progenitor detections: red supergiant problem (Kochanek et al. 2008; Smartt 2009, 2015)
- But implications for explosion properties: explosion energy, nucleosynthesis (Nickel-56), compact remnant properties, etc.



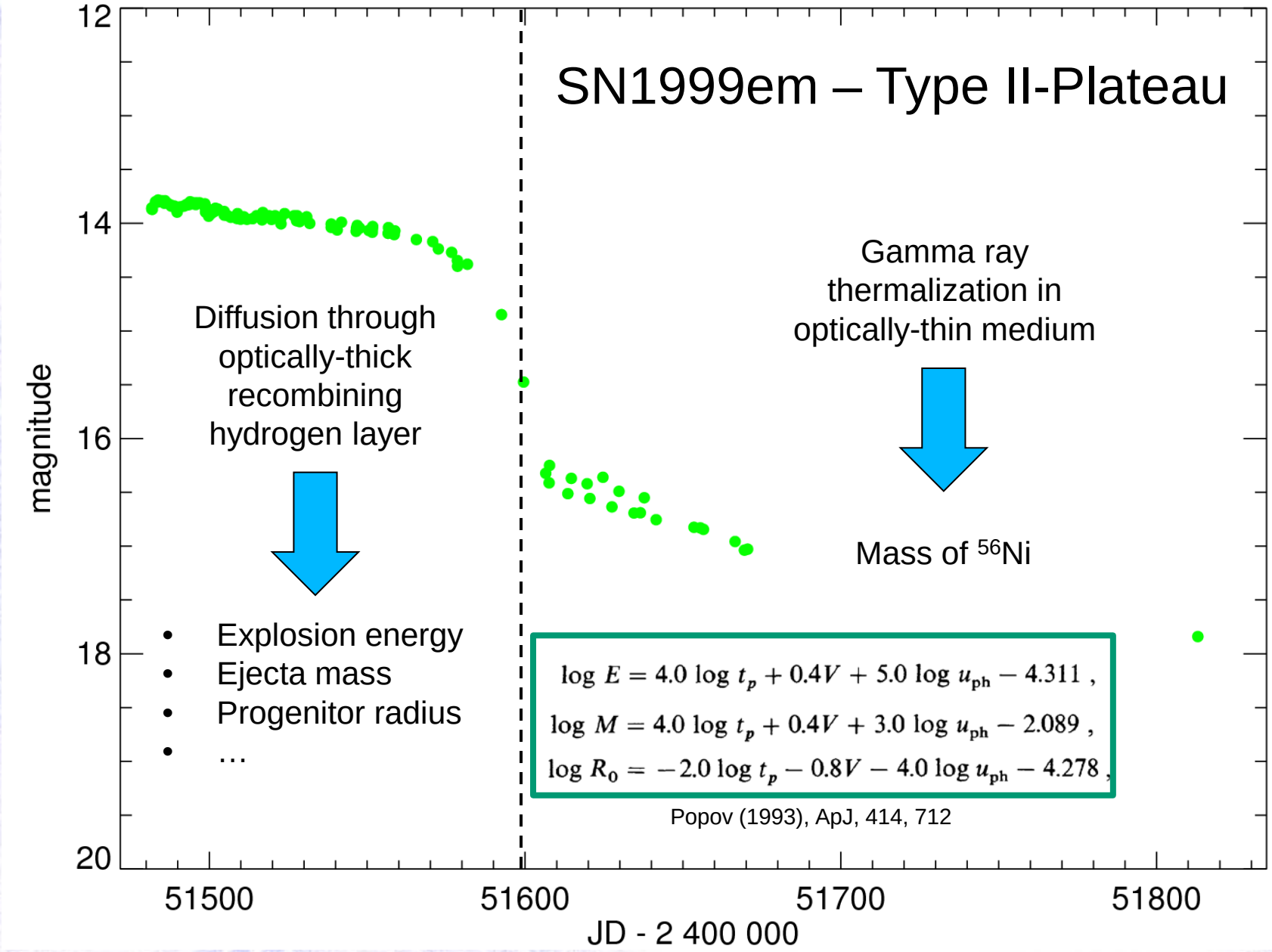


Woosley et al.(2002) progenitors

Pejcha & Thompson (2015) - one parameterization

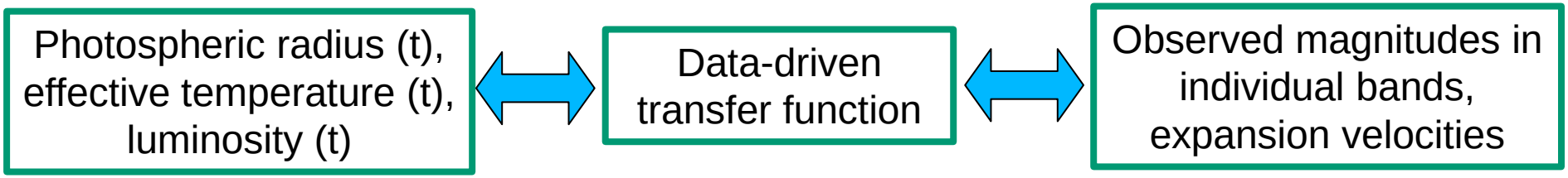
Similar results: compactness - O'Connor & Ott (2011), Ugliano et al. (2012), Ertl et al. (2015), Nakamura et al. (2014), Muller et al. (2016), Sukbold et al. (2016)

Inferring supernova properties from light curves

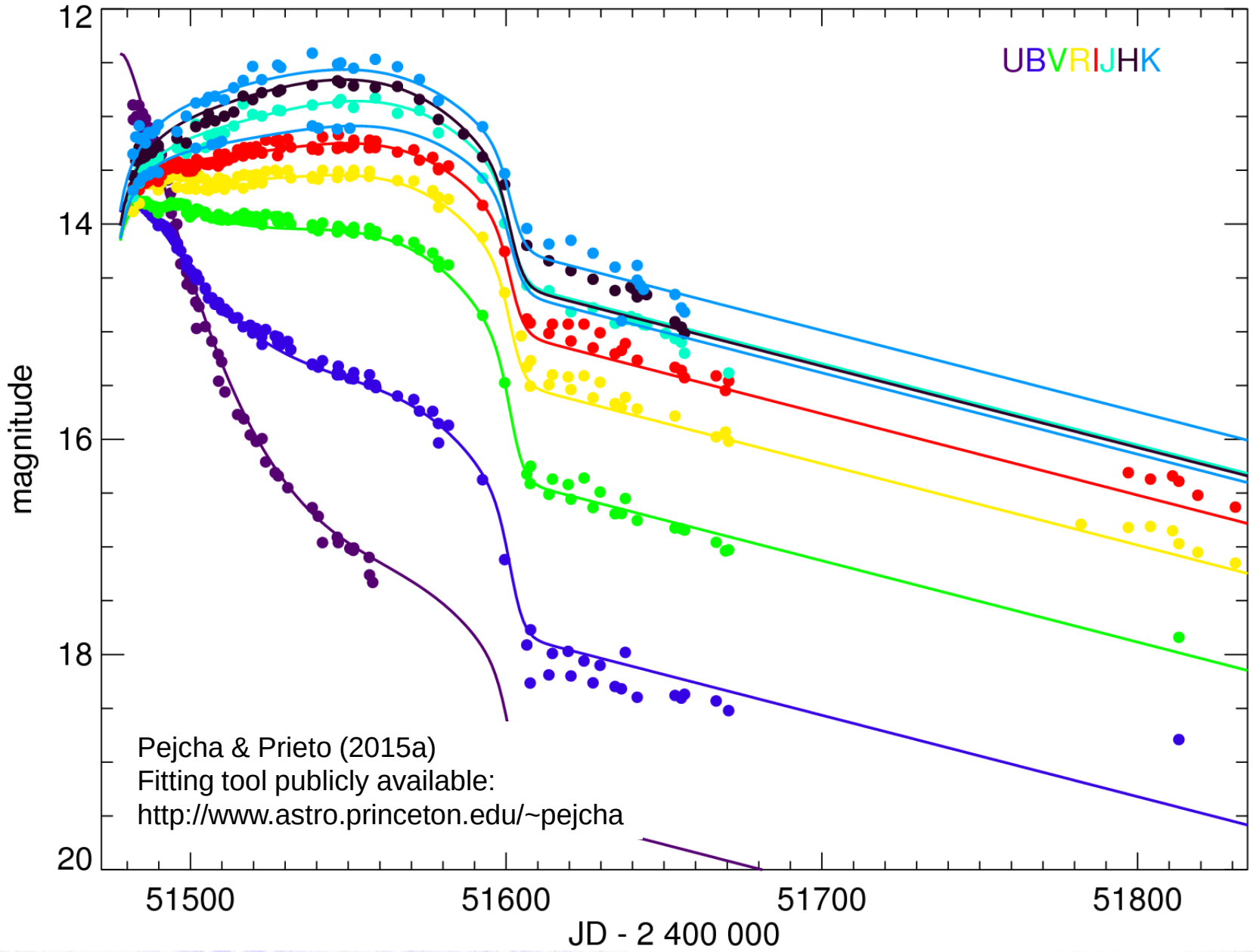


Global model of Type II-Plateau SNe

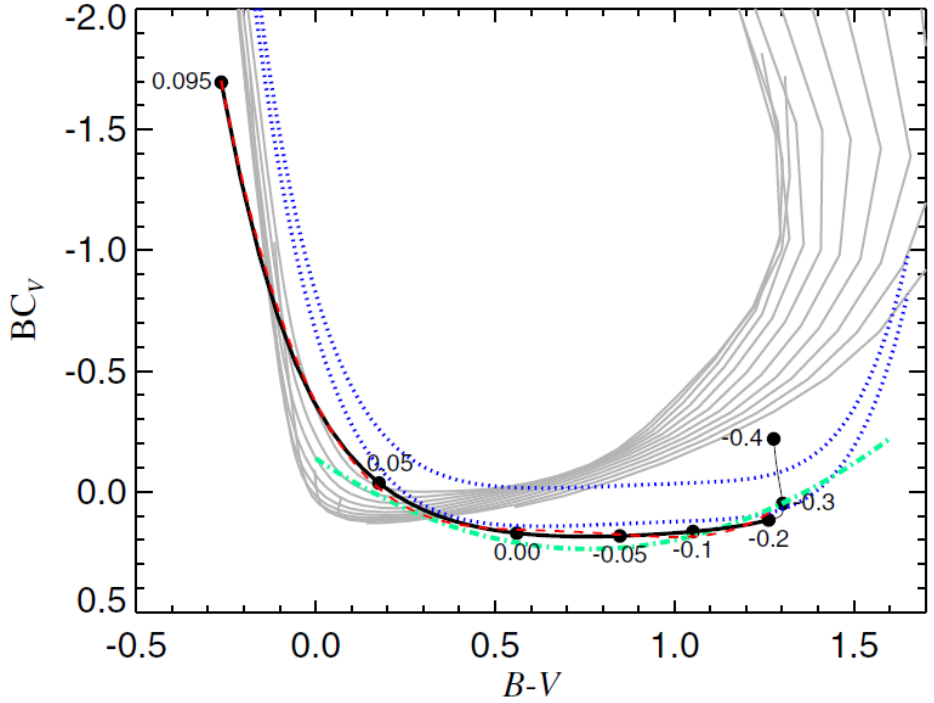
- Make all information part of the model -> complete self-consistent hierarchical phenomenological model of light curves and expansion velocities -> all covariances and uncertainties exposed
- Building template light curves: global formulation of expanding photosphere method
- Training set:
  - 26 well-observed nearby supernovae in 24 host galaxies
  - ~6300 magnitude measurements in 21 photometric bands from 0.19 to 2.2 μm
  - ~230 expansion velocity measurements
  - 391 free parameters

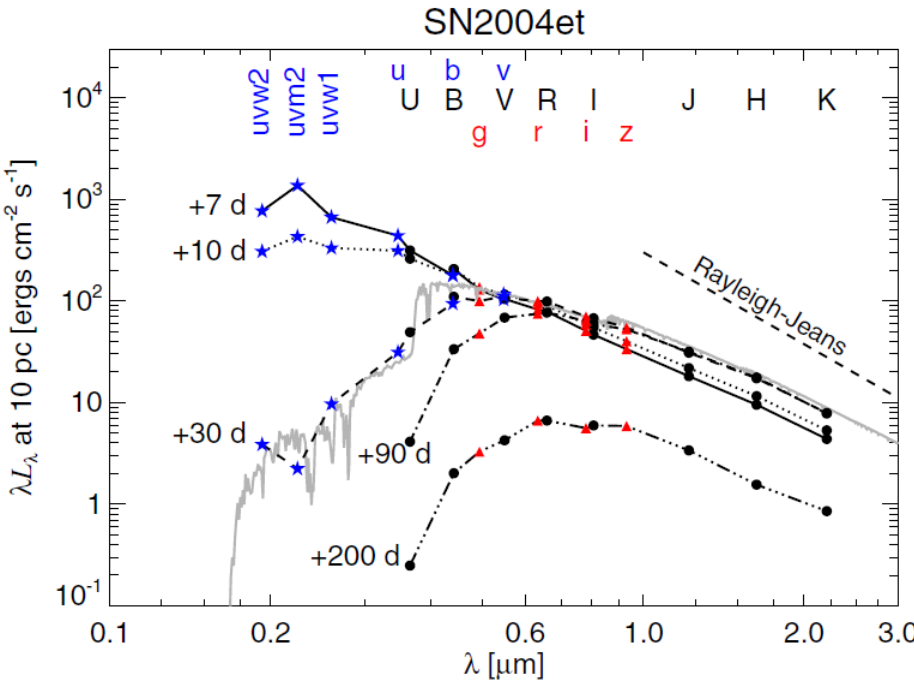


A global model of light curves and expansion velocities



Advantages of a global model
(sequence of SED evolution)

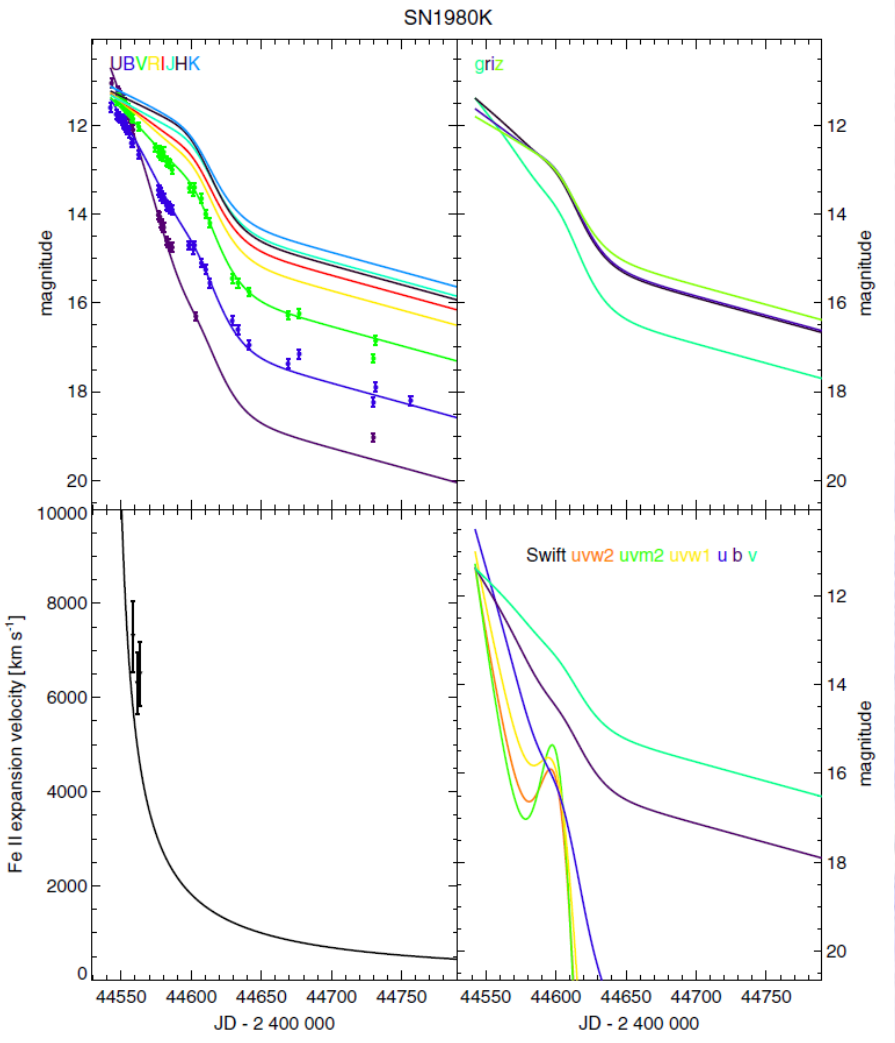




Immediately available for magnitude difference of any two bands in the model

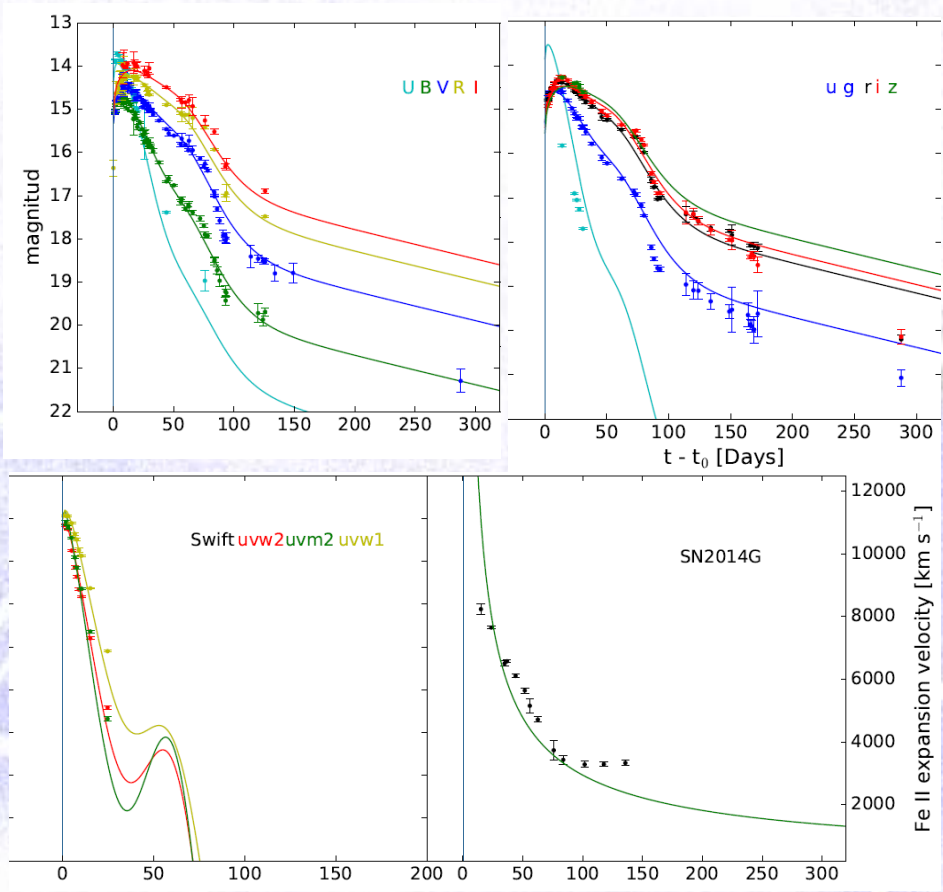
Utilizes global information from all SNe in the sample to “predict” magnitudes in bands not directly observed

Diversity of plateau slopes



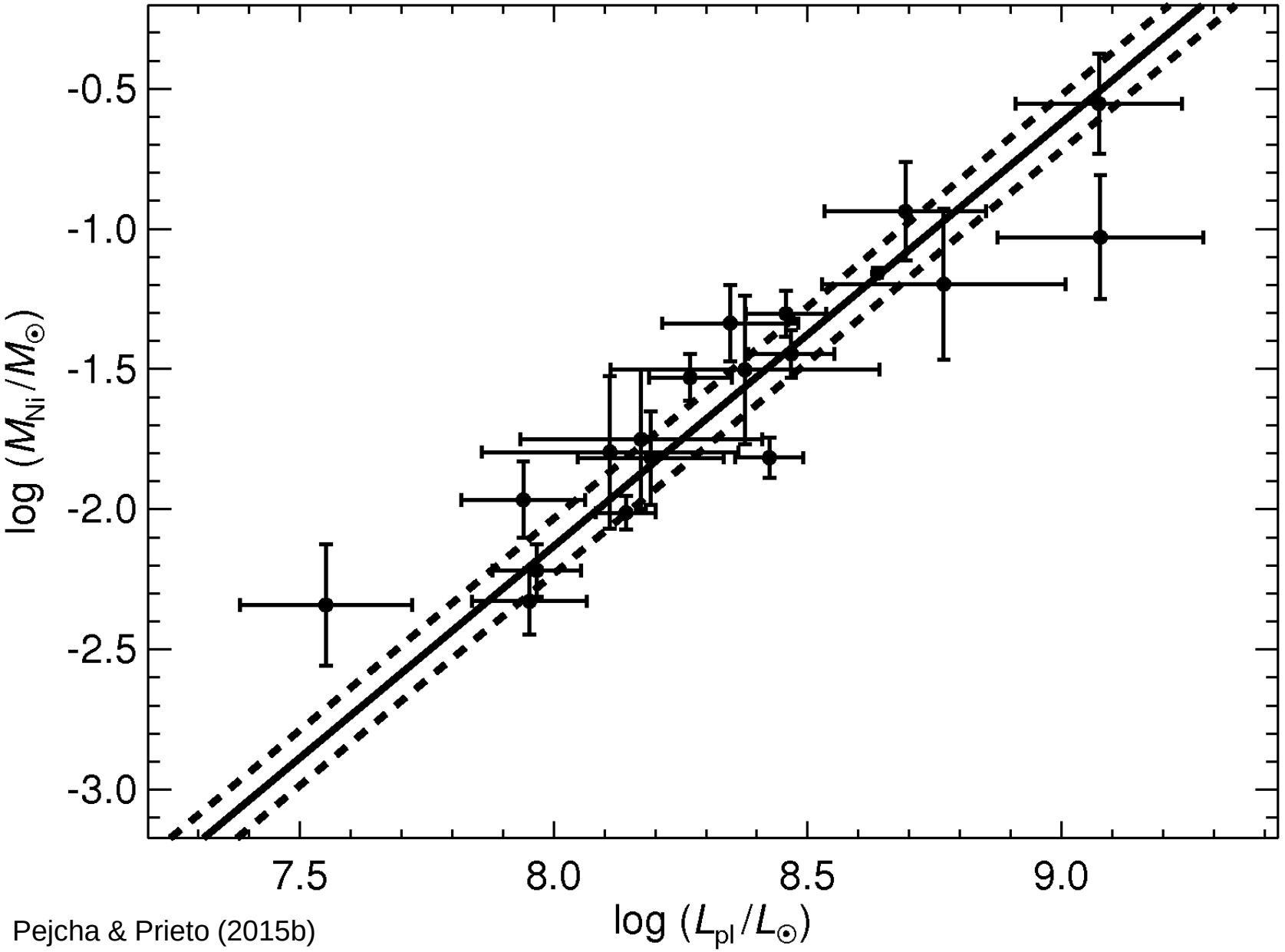
Pejcha & Prieto (2015a)

SN2014G



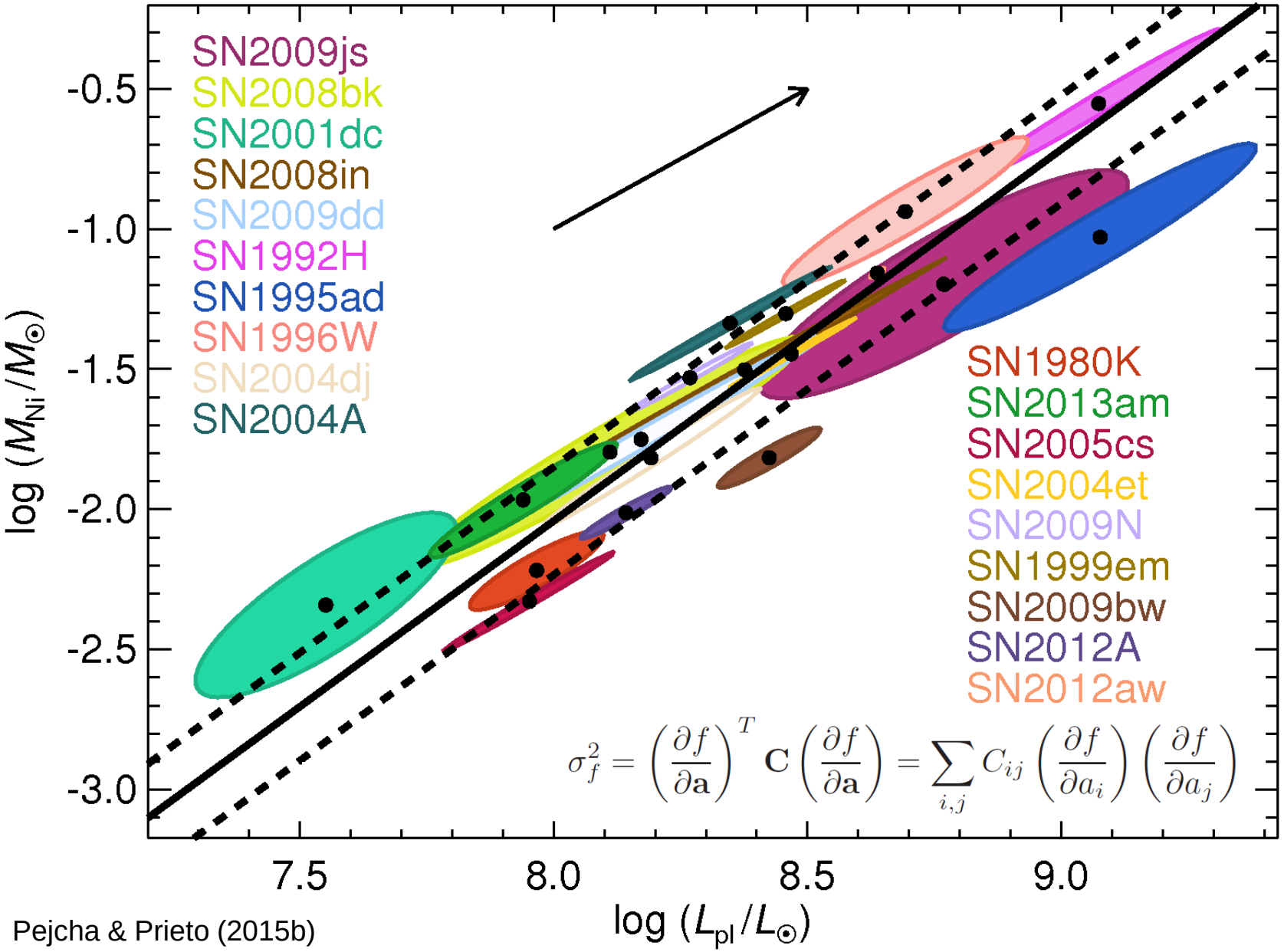
Muller et al. (2017)

What are the properties of the explosions?



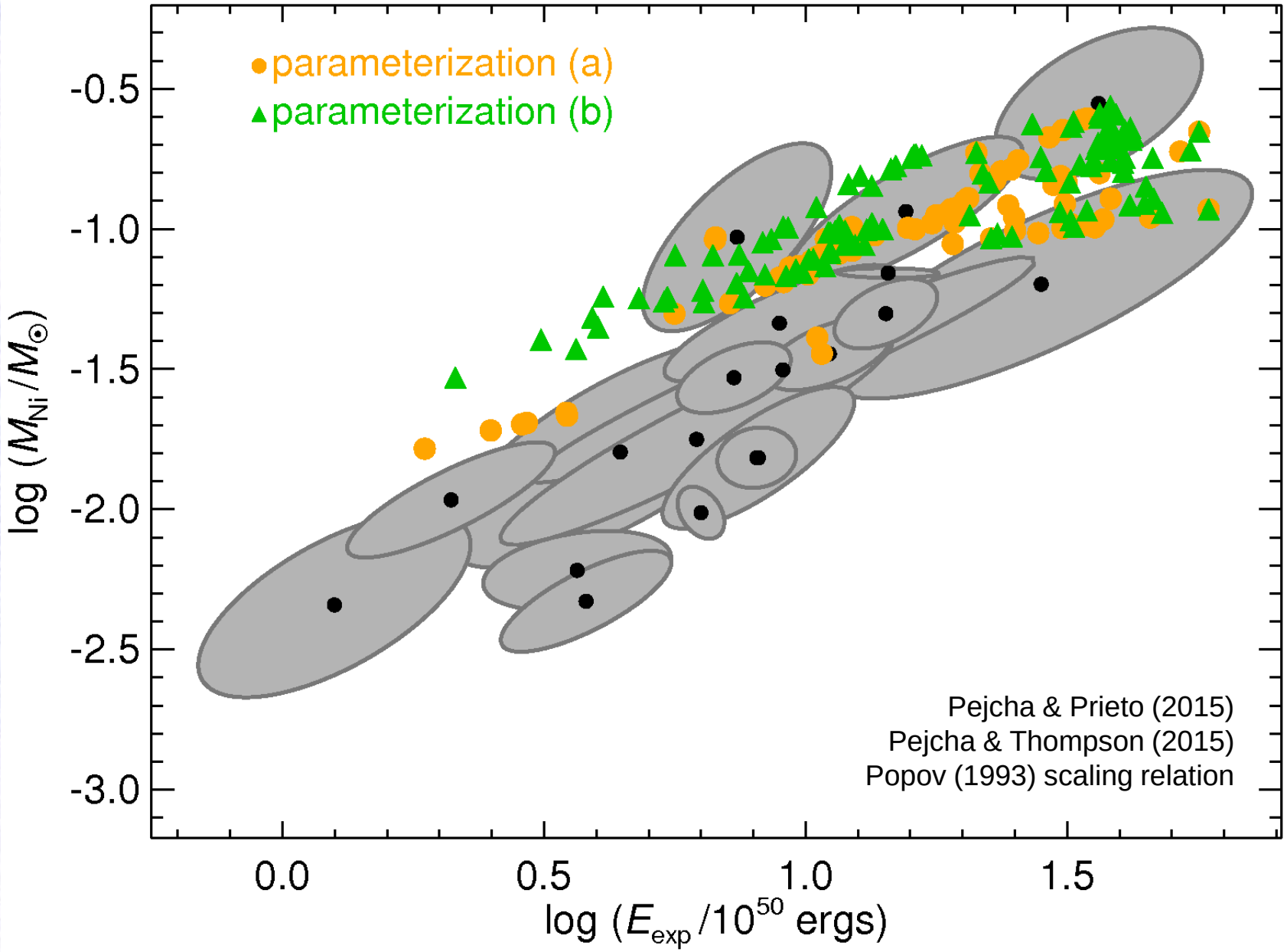
Pejcha & Prieto (2015b)

What are the properties of the explosions?

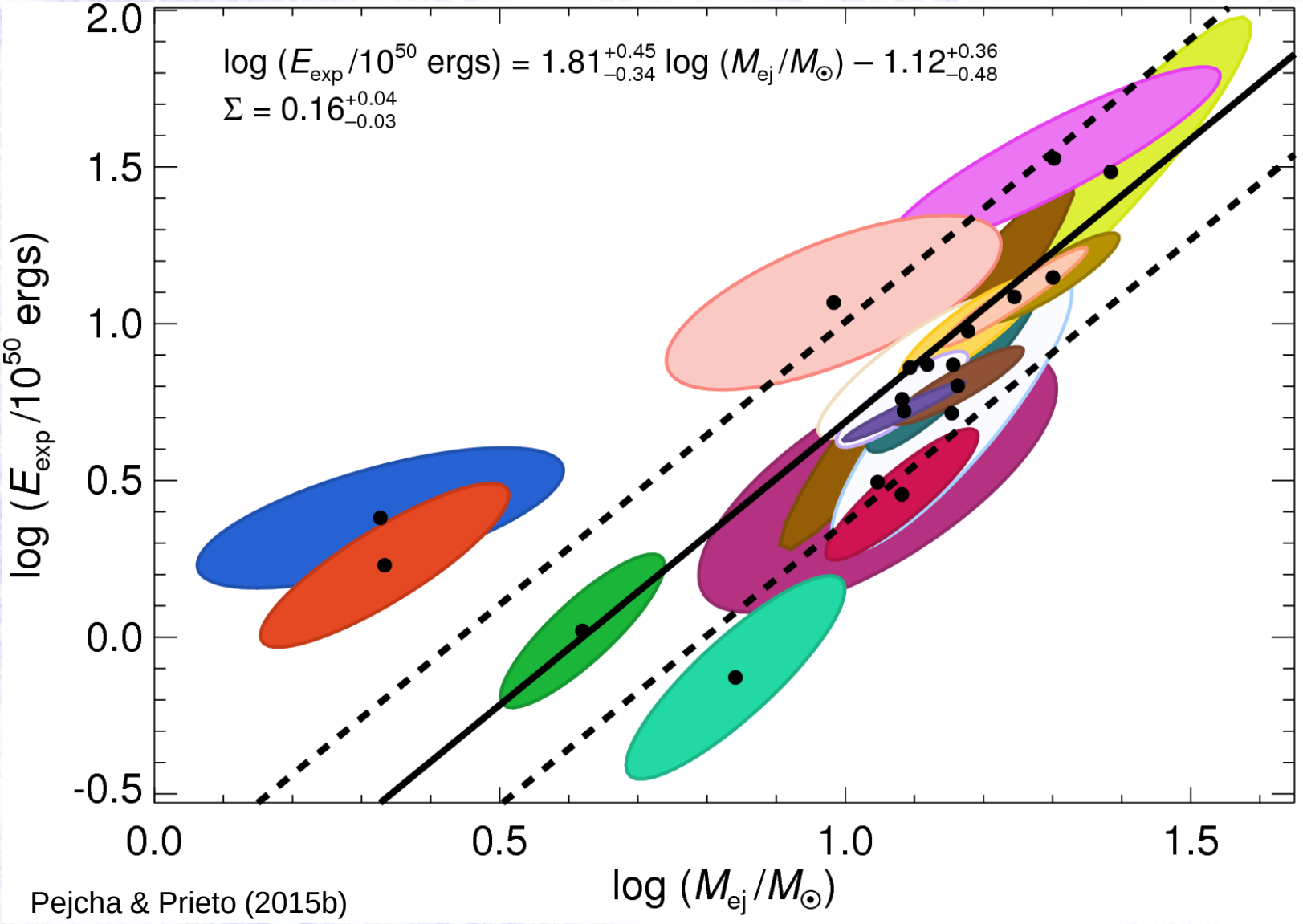


Pejcha & Prieto (2015b)

What are the properties of the explosions?



What are the properties of the explosions?



Pejcha & Prieto (2015b)

Degeneracies also found by Nagy & Vinko (2014, 2016)

Core-collapse supernova light curves in the era of big time-domain surveys

- LSST ccSN discovery rate ~10^5/yr
- Magnitude every few days, spectrum rarely
- Model improvement:

Explosion energy, ejecta mass, nickel mass, metallicity, …

Photospheric radius (t), effective temperature (t), luminosity (t)

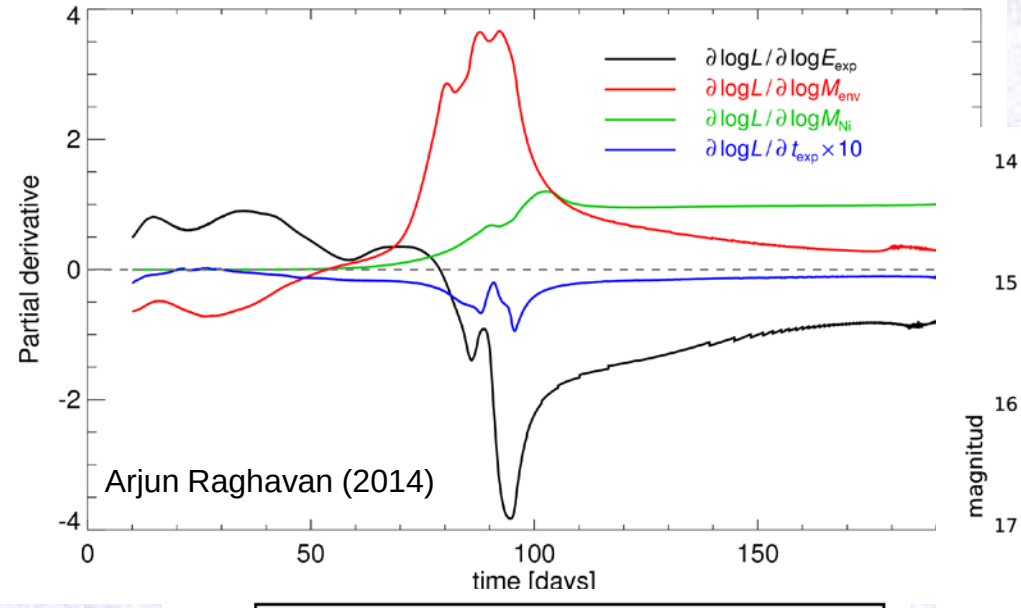
Data-driven transfer function

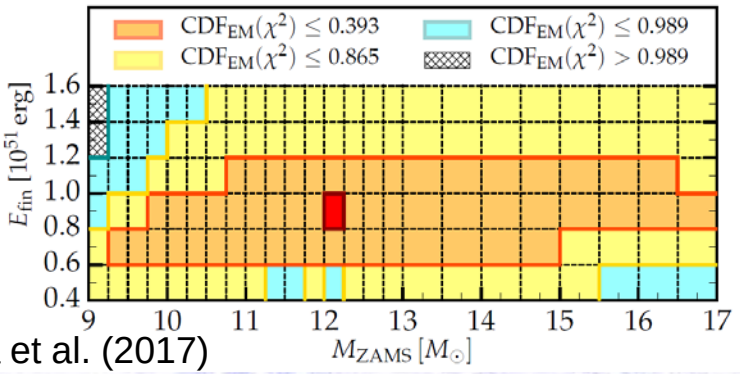
Observed magnitudes in individual bands, expansion velocities

Morozova et al. (2017)

Core-collapse supernova light curves in the era of big time-domain surveys

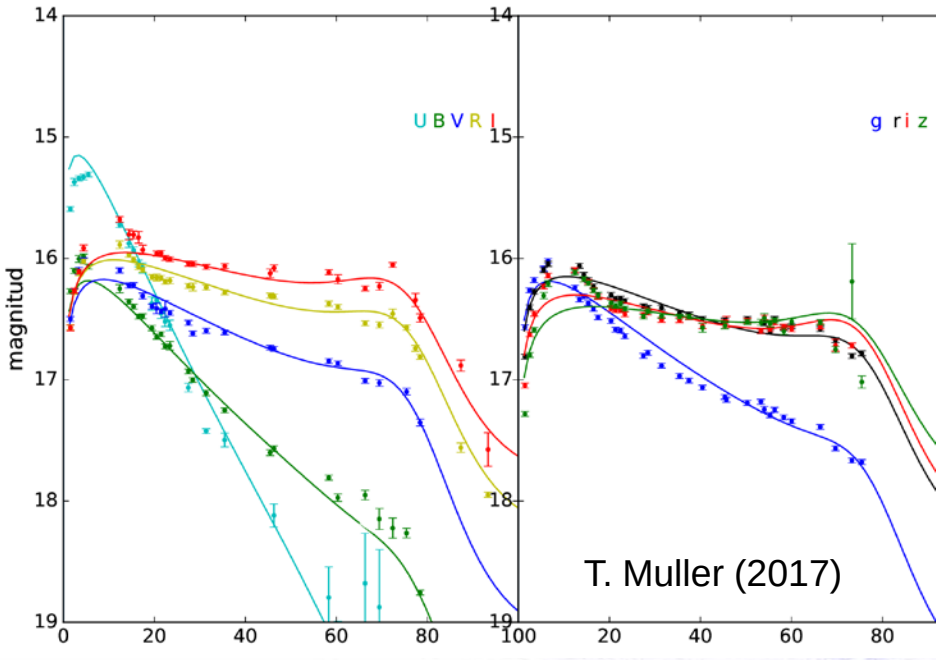
- LSST ccSN discovery rate ~10^5/yr
- Magnitude every few days, spectrum rarely
- Supernova properties as a function of star formation, galaxy type, …





Morozova et al. (2017)

SN2013fs



Yaron et al. (2017), Morozova et al. (2017), Moriya et al. (2017)

Conclusions

- Successful and failed explosions intertwined in a complex non-monotonic pattern (Pejcha & Thompson 2015)
- A new method to determine parameters of type II-Plateau supernovae (Pejcha & Prieto 2015a,b), fits also II-L
- Manipulation of fit coefficients readily provides: SED evolution, bolometric corrections, dilution factors, …, while estimating self-consistently relative distances, reddenings, …, for each supernova
- And also physical parameters (explosion energy, nickel mass, ejecta mass ,…), where uncertainties from all quantities can be properly propagated
- Future: combination of phenomenological and physical approaches