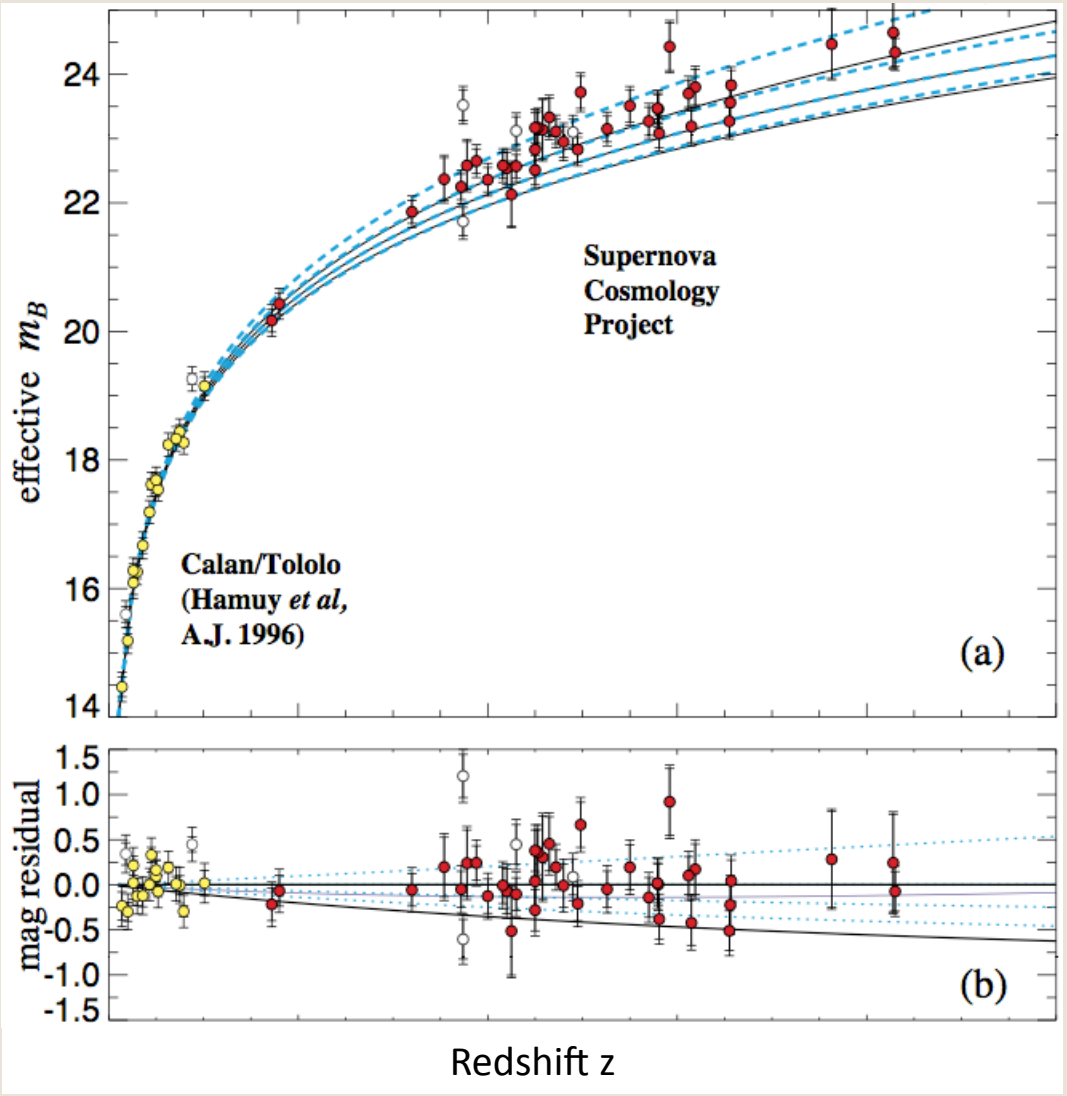
Confronting Simulations and Observations of Type Ia Supernovae

Benedikt Diemer, 10th GLCW, 06/15/2010

Studying dark energy with Type Ia



$\Omega_\Lambda = 0.5$

$\Omega_\Lambda = 0$

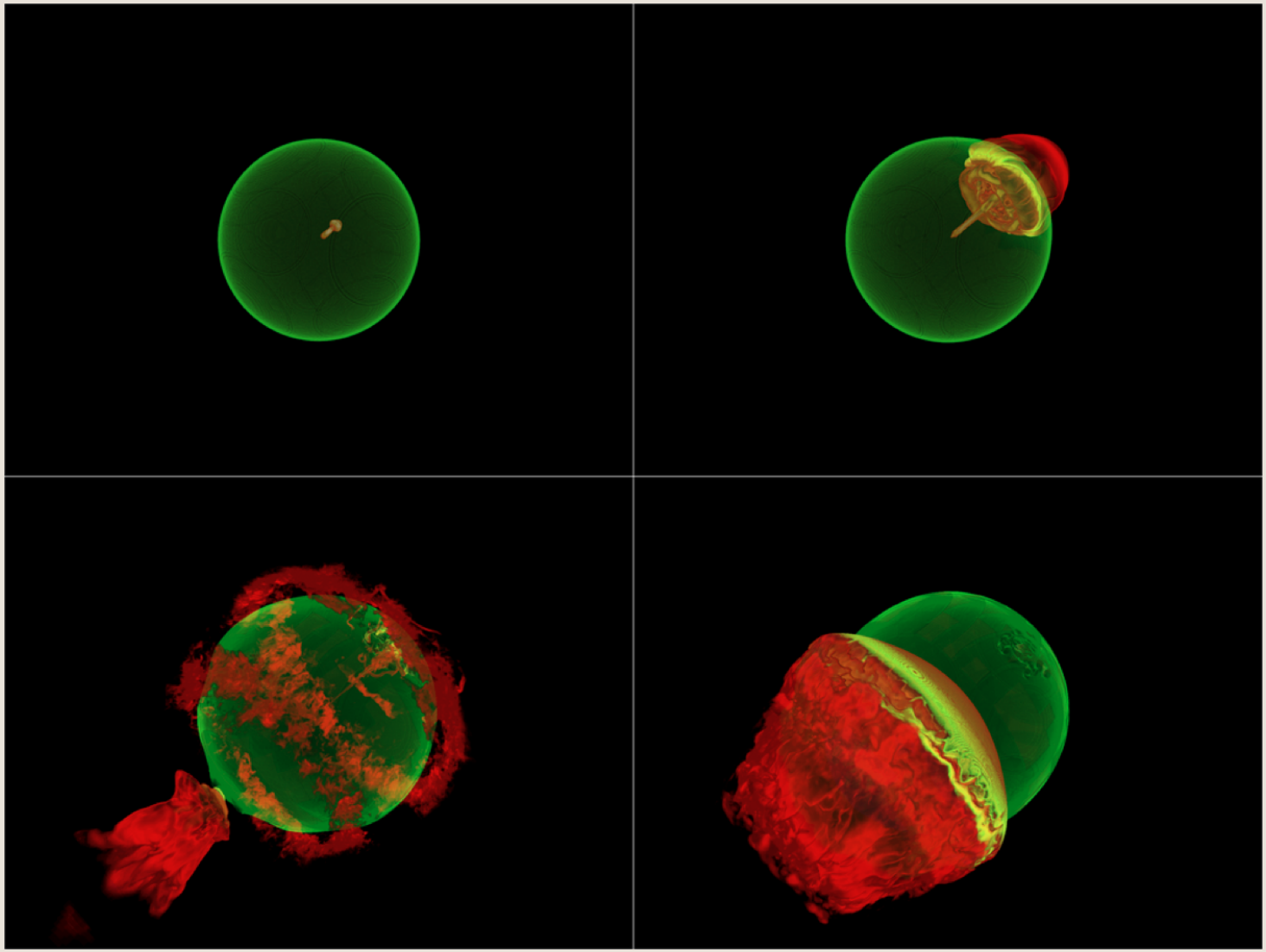
- Predictive theoretical models of SN explosions may improve calibration for use as standard candles

Riess et. al. 1998,
Perlmutter et. al. 1999 (Figure)

Explosion models

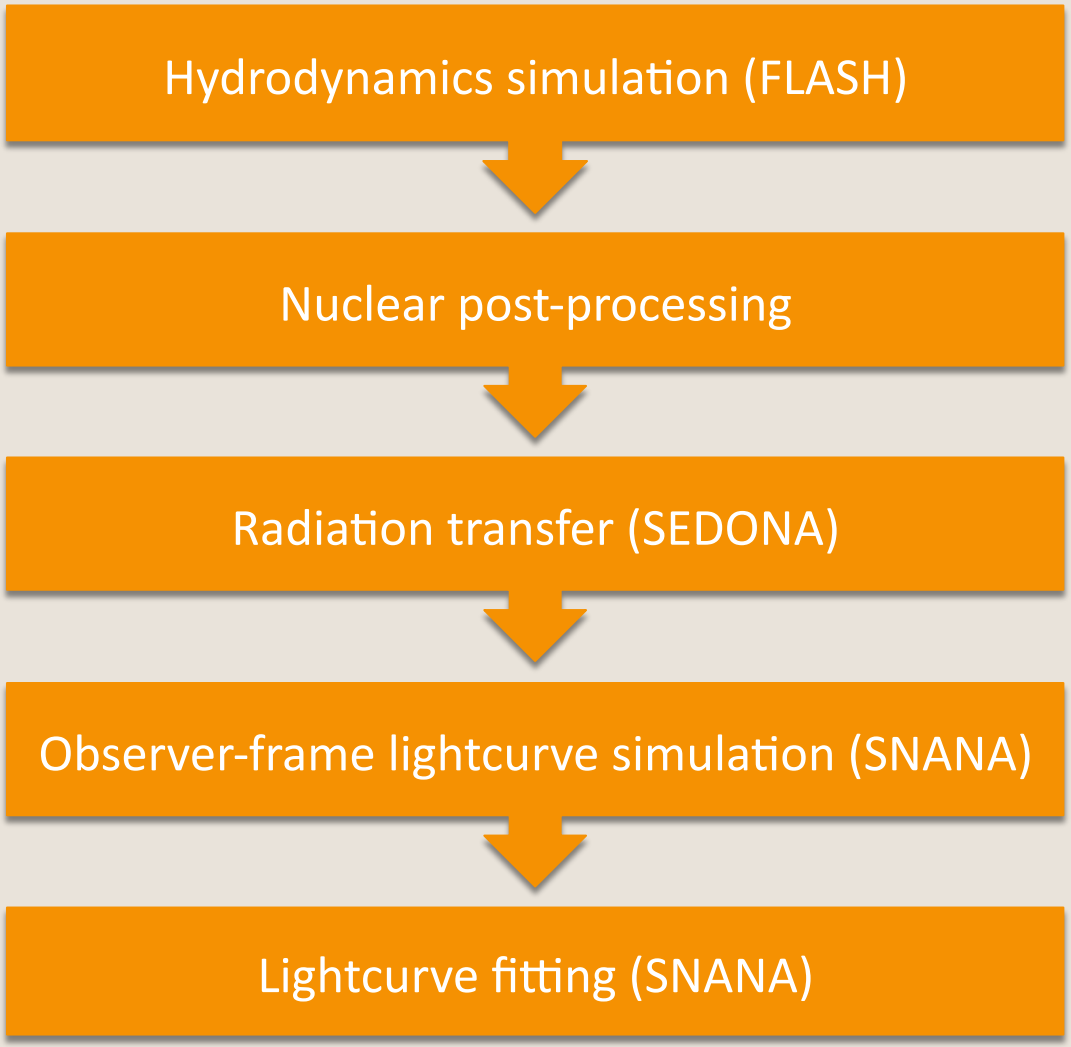
- Pure Deflagration
  - Can only account for low-luminosity outliers
- Deflagration-Detonation-Transition (DDT)
  - Detonation caused by turbulence tearing flame apart
  - Symmetry depends on flame ignition points
- Gravitationally Confined Detonation (GCD)
  - Detonation caused by pulsation / contraction and inward jet
  - Inherently asymmetric with azimuthal symmetry

The GCD model



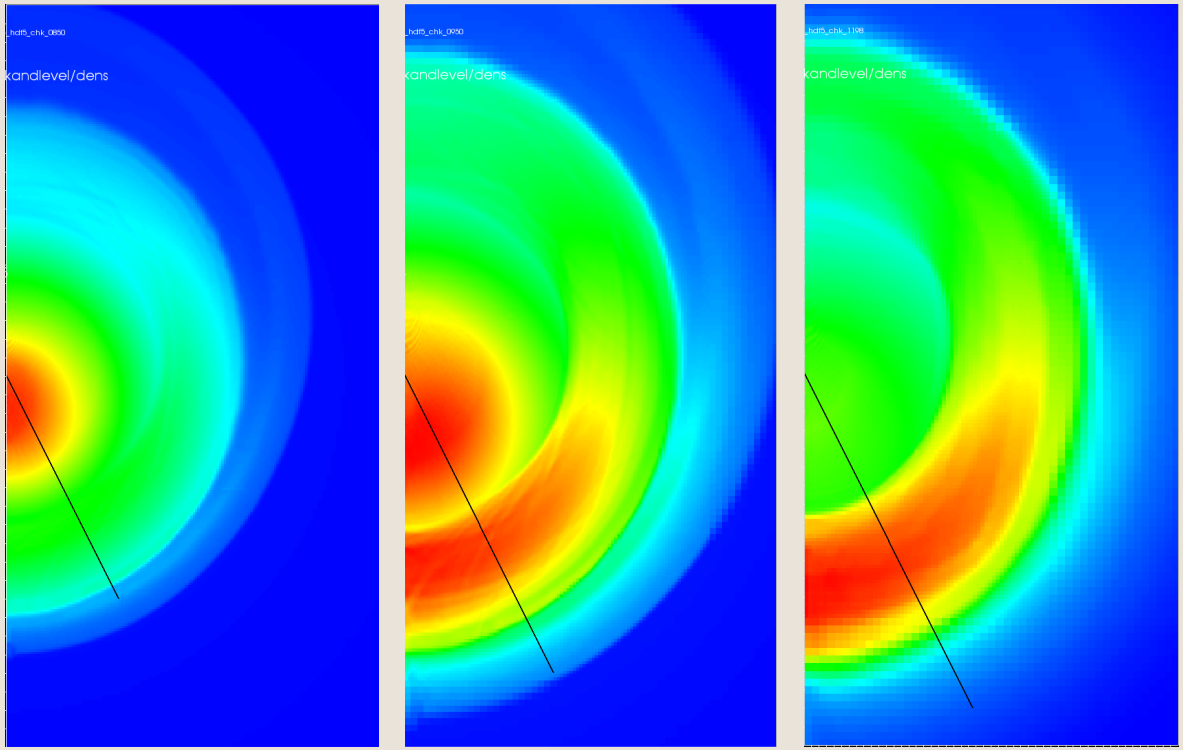
Jordan
et. al. 2008

Simulation pipeline



Simplified 2D models

- Deflagration phase replaced by artificial pre-expansion
- No ash on the surface (reduced opacity)
- Density structure for model with $M_{Nickel\text{-}56} = 0.75\ M_{Sun}$:



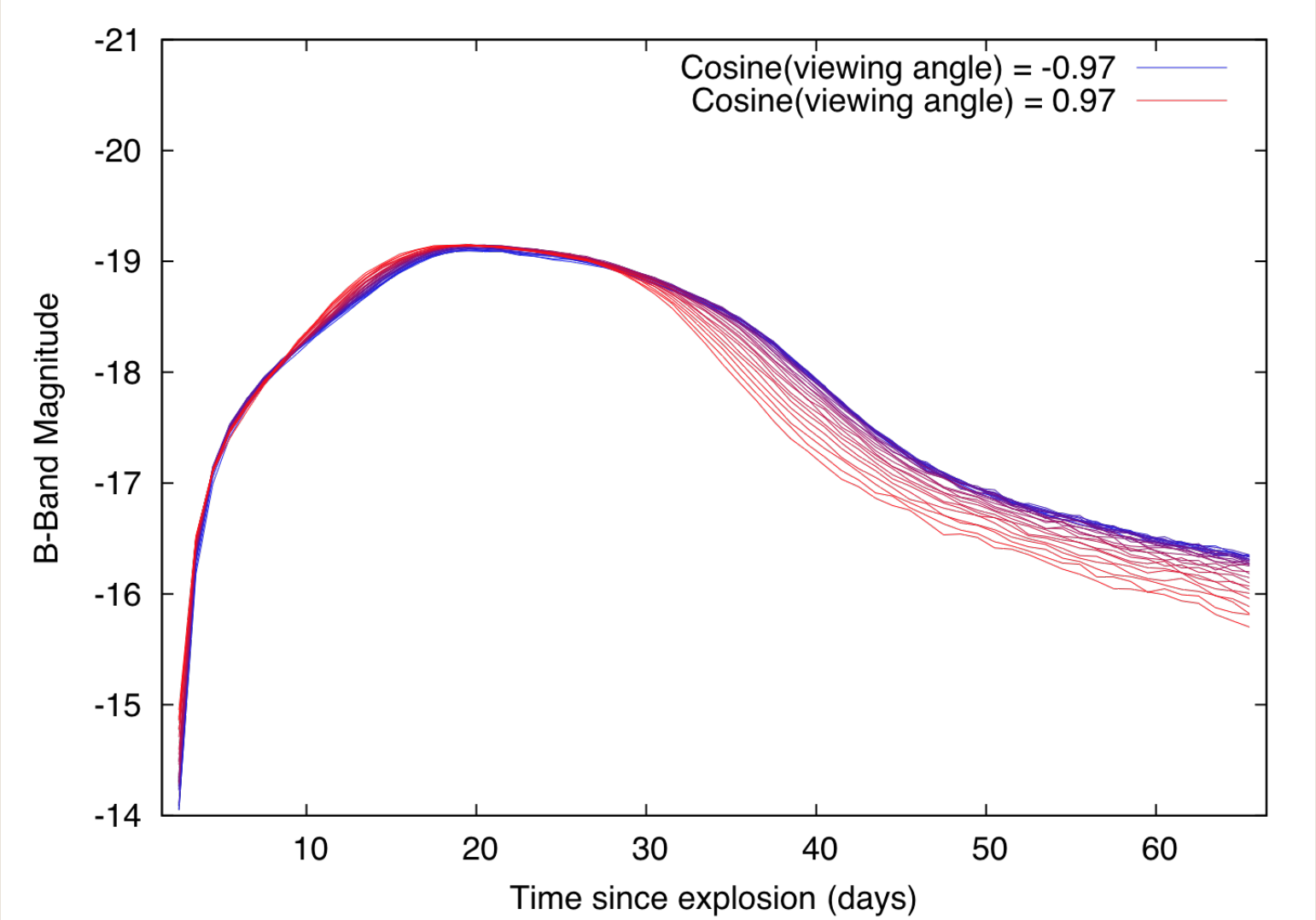
t = 1.5 s t = 2.5 s t = 5 s

- Viewing angle:

θ = 0°

θ = 180°

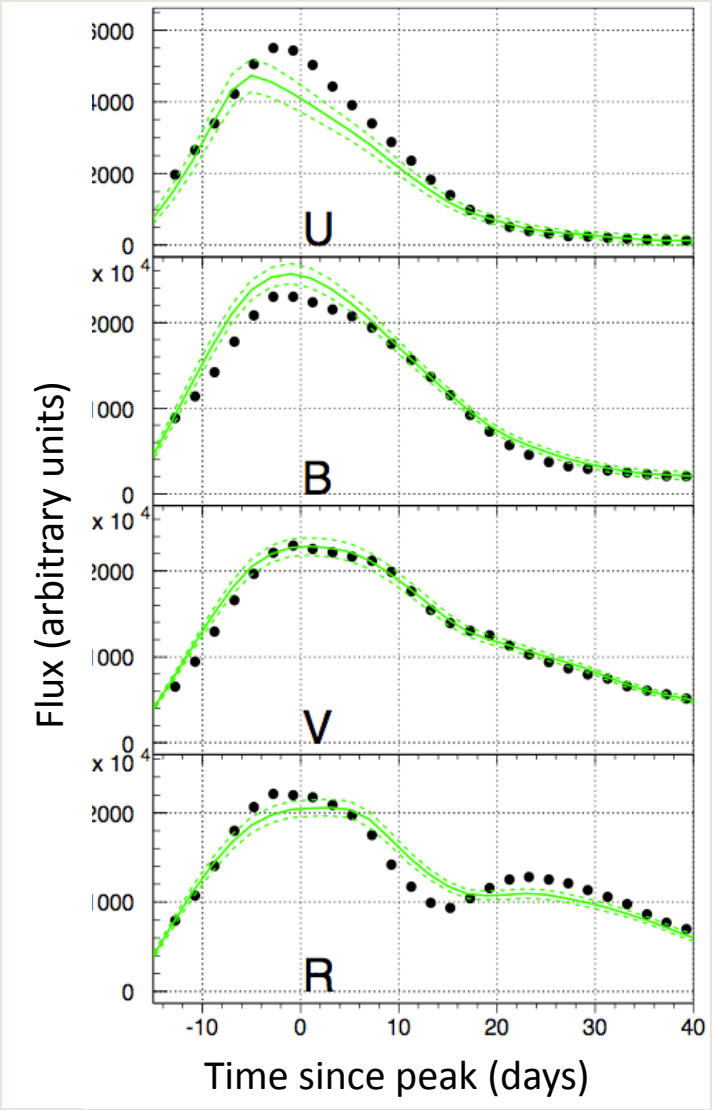
Lightcurves (B-Band)



Comparison with observations

- Comparison with overall population of observed SNae rather than individual ones
- Lightcurve fits with data-driven models represent SN as two-parameter family
  - Stretch (rise / fall-off time)
  - Color

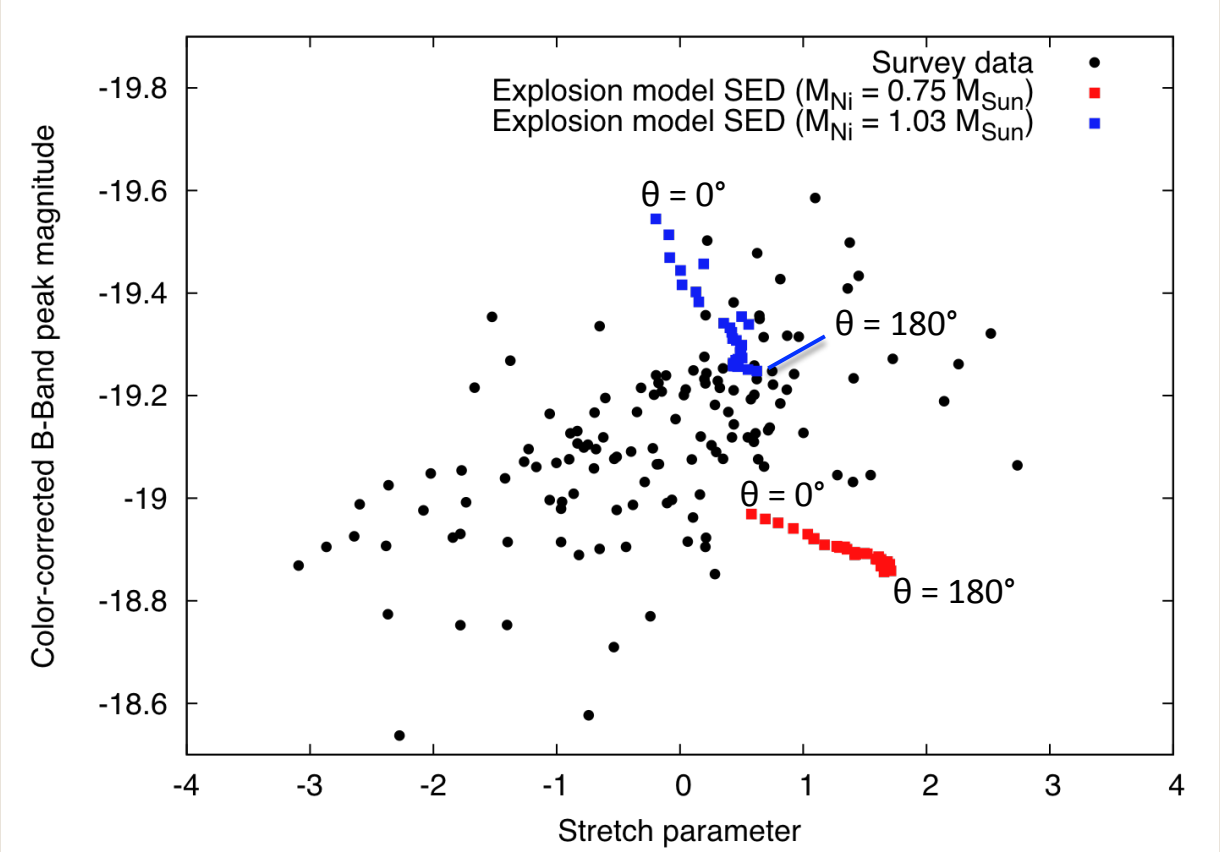
Data-driven models



• • • • 2D Model with $M_{Ni} = 0.75\ M_{Sun,}$ viewed from near the South Pole (θ = 165°)

SALT2 lightcurve fit

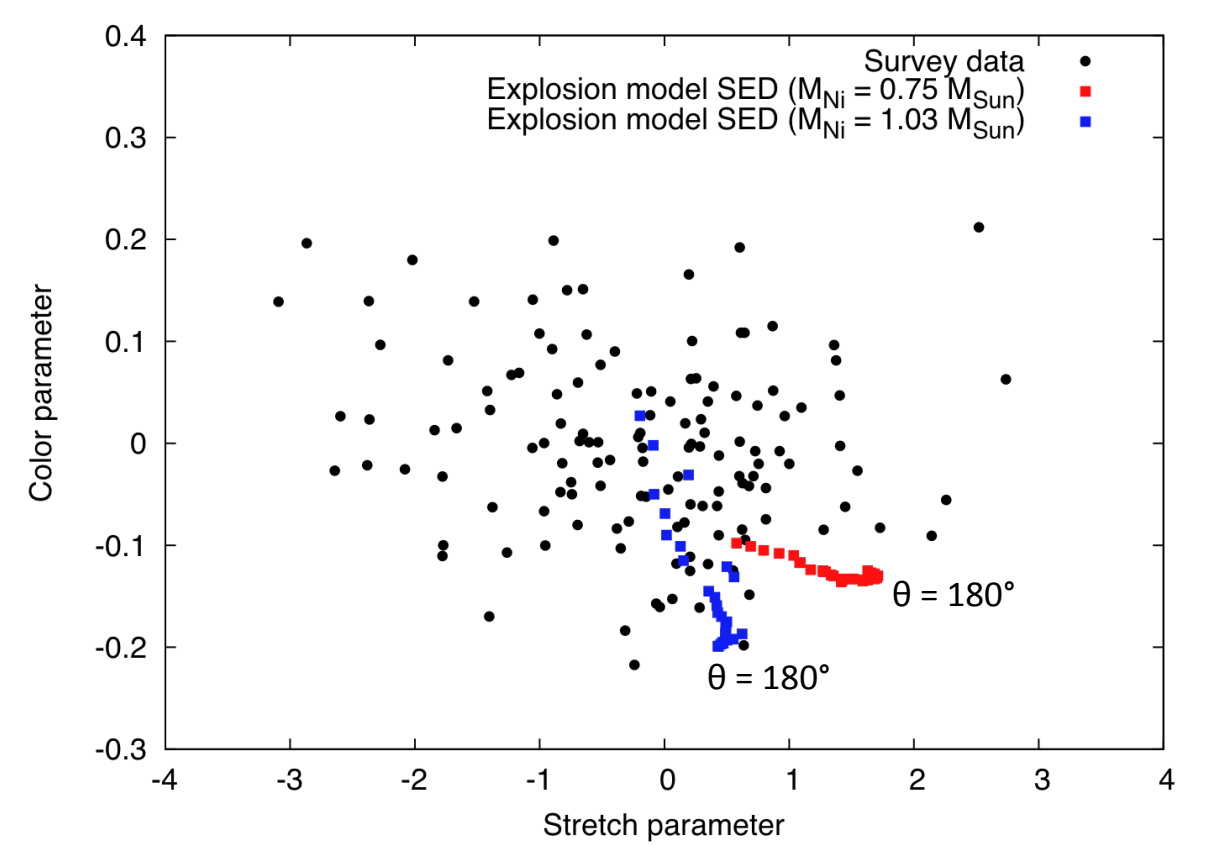
Stretch-magnitude relationship



Survey data from Kessler et al. 2009

- Parameters from fitting explosion models and survey data with SALT2
- Philips relation not obeyed by explosion models
- Viewing angle dependence could contribute to intrinsic scatter in Philips relation

Stretch-color relationship



Survey data from Kessler et al. 2009

Next steps

- Verify validity of simplified 2D models vs. proper deflagration calculations
- Systematically compare to other models (like DDT) and observations

Conclusion

- Together with Rick Kessler, enhanced SNANA and developed pipeline to enable comparisons with observations
- Lightcurves match data-driven model predictions
- Significant dependence of lightcurve properties on viewing angle
  - 1D simulations are spherically symmetric and hence inadequate
  - May be contributor to scatter in Philips relation