Fitting shock cooling lightcurves to probe supernova progenitors

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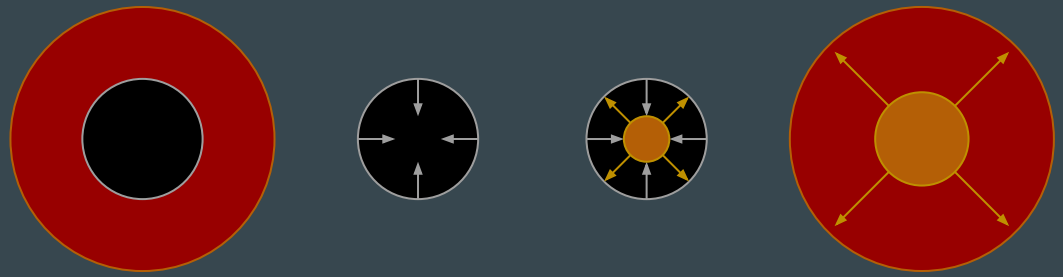
Core Collapse Supernovae



>8 $M_{\odot}$ Iron core

Iron core collapses

Bounce back shockwave

Expansion and explosion

- Spectral and photometric variation
- Few progenitor observations

Shock Cooling Lightcurve

Photons trapped behind shock wave

Shock wave expands and cools
Photons release

All trapped photons released
Supernova explosion

X-ray: seconds
Optical: days

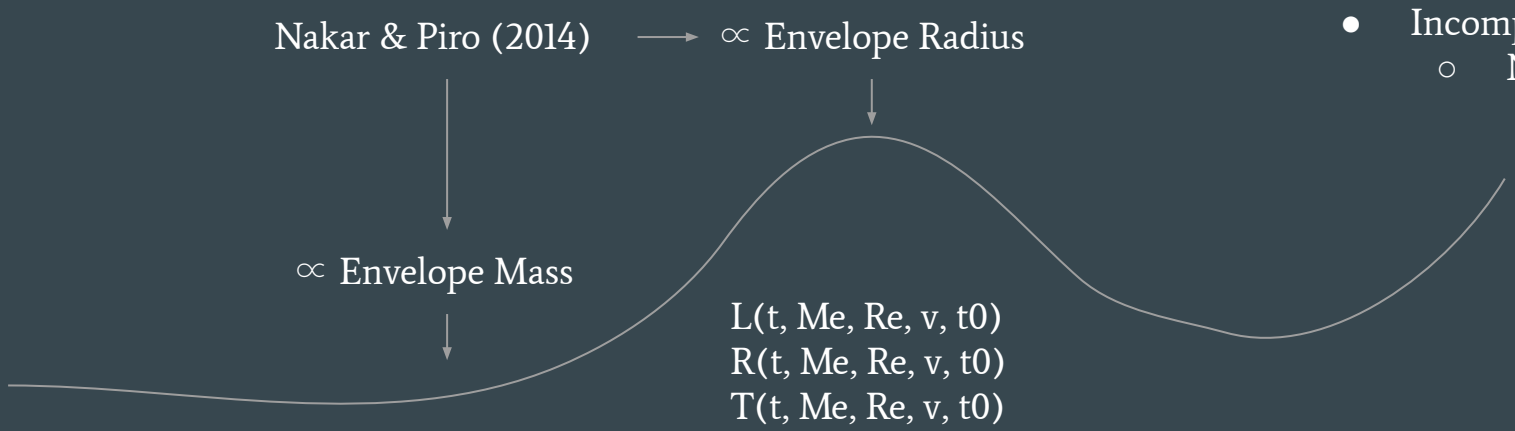
Shock Cooling Lightcurve (SCL)

Core collapse explosion

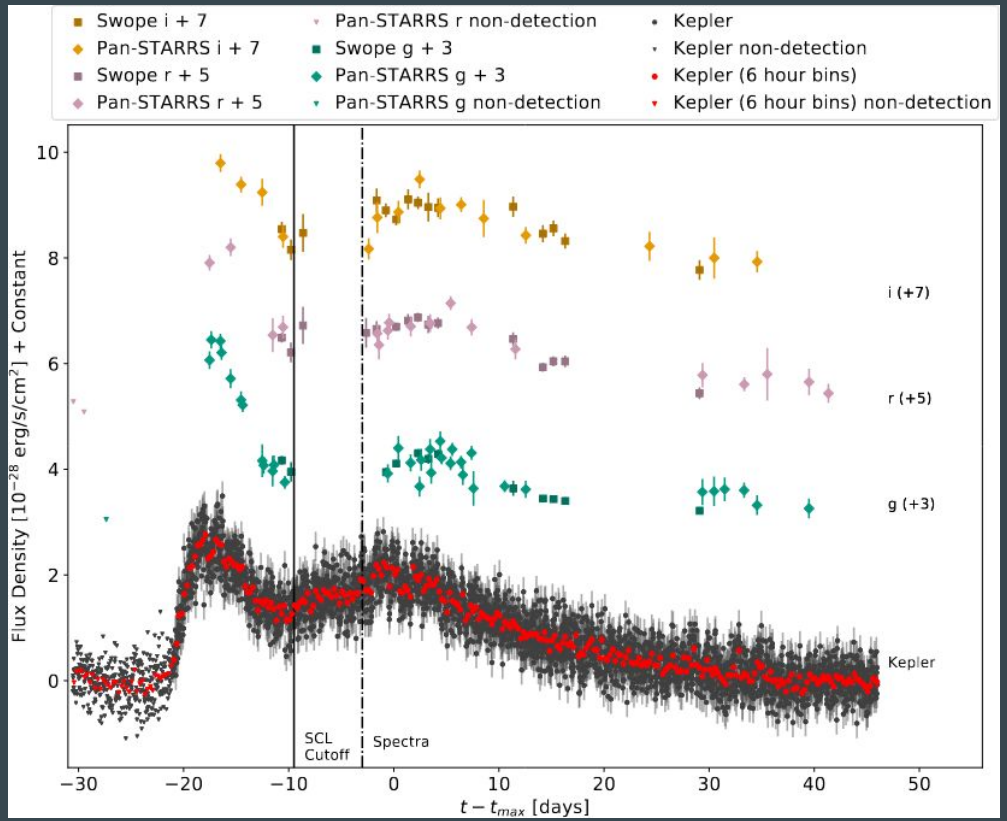
Shock Cooling Lightcurve

- Piro (2015) (P15)
  - No assumption of density profile
  - Simple expanding photosphere
- Sapir & Waxman (2017) (SW17)
  - Polytropic density profile
    - *n=3*: radiative envelope (BSG)
    - *n=3/2*: convective envelope (RSG)
- Piro et al. (2020) (P20)
  - Improved upon P15
  - Two component velocity model
    - Outer material: Steep velocity gradient
    - Inner material: Shallow velocity gradient

- SN1993j
- SN2016gkg
- Incomplete data
  - No rise



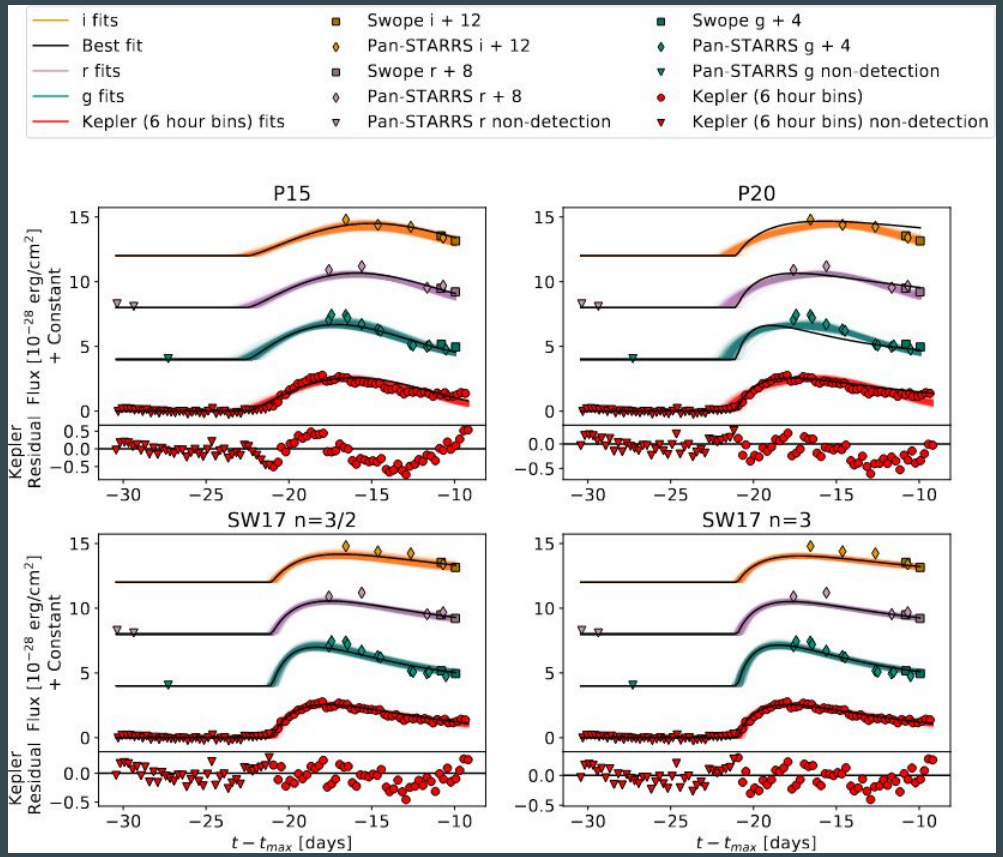
SN2017jgh - First Complete SCL



- Kepler/K2
  - 30 minute cadence
  - 80 day campaign
  - Broad filter (4000 to 9000Å)
  - Many systematic effects
    - Loss of reaction wheels
    - Solar pressure drifting
- Ground Based Photometry
  - Pan-STARRS1 - Discoverer
  - Swope
- Single Gemini Spectrum

Armstrong et al. (2021)

SN2017jgh - Fit to SCL



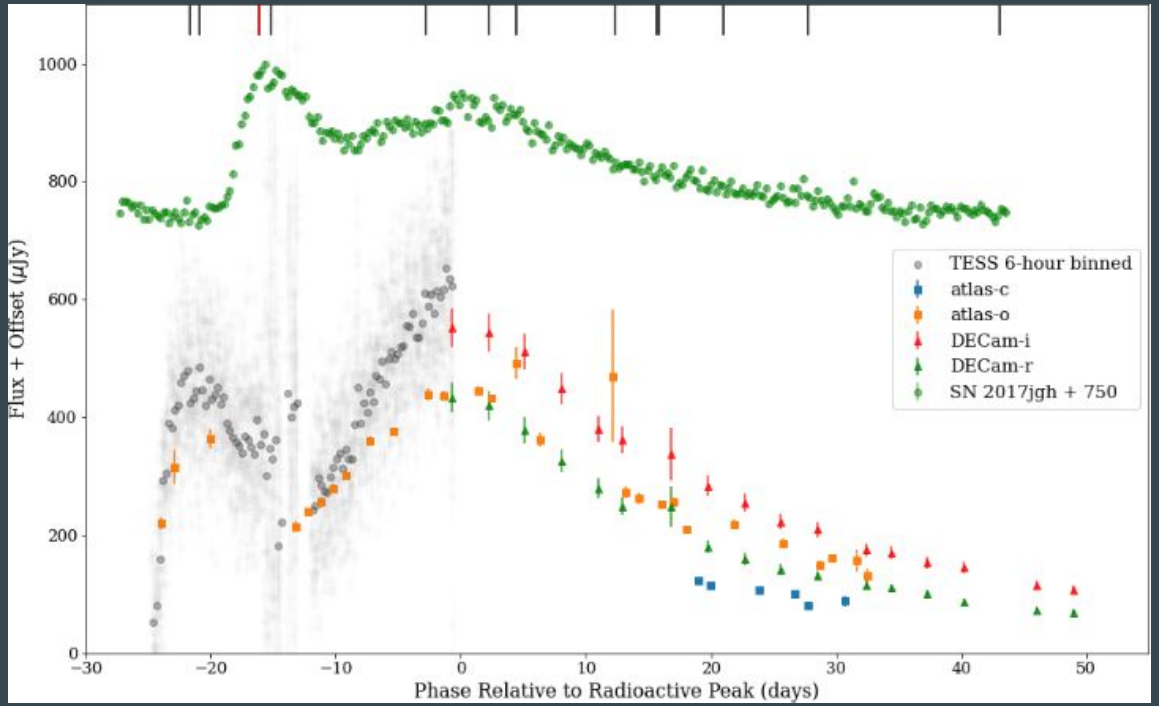
- SW17 Best fitting model
  - Convective (n=3/2) envelope preferred
- P20 next best without density assumption
- P15 too simple

Progenitor likely a yellow supergiant

- Envelope radius of ~50-290$R_\odot$
- Envelope mass of ~0-1.7$M_\odot$
- Shock velocity of (7.5-10.3) x 10^3 km/s

Armstrong et al. (2021)

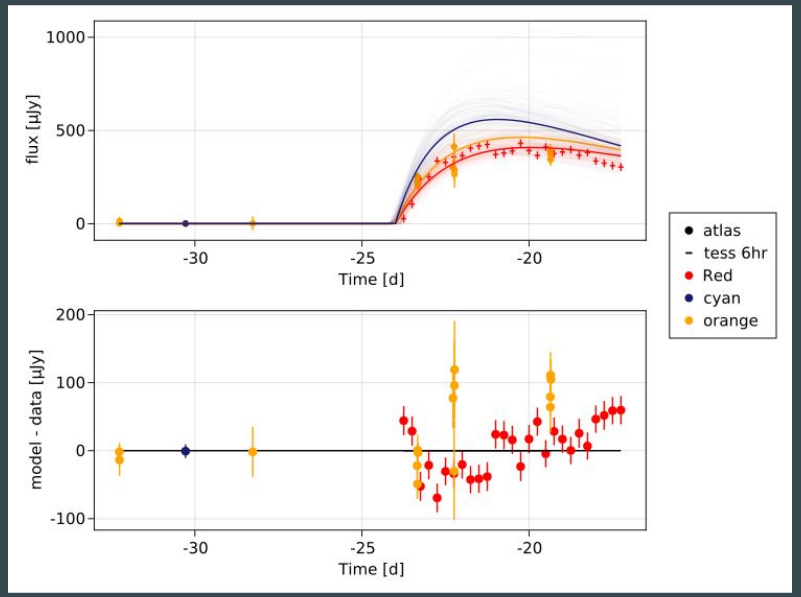
SN2021zby (In Prep - Wang et al.)



- TESS
  - 10 minute cadence
- Ground Based Photometry
  - ATLAS - Discoverer
  - DECam
- Multiple SpeX Spectrum

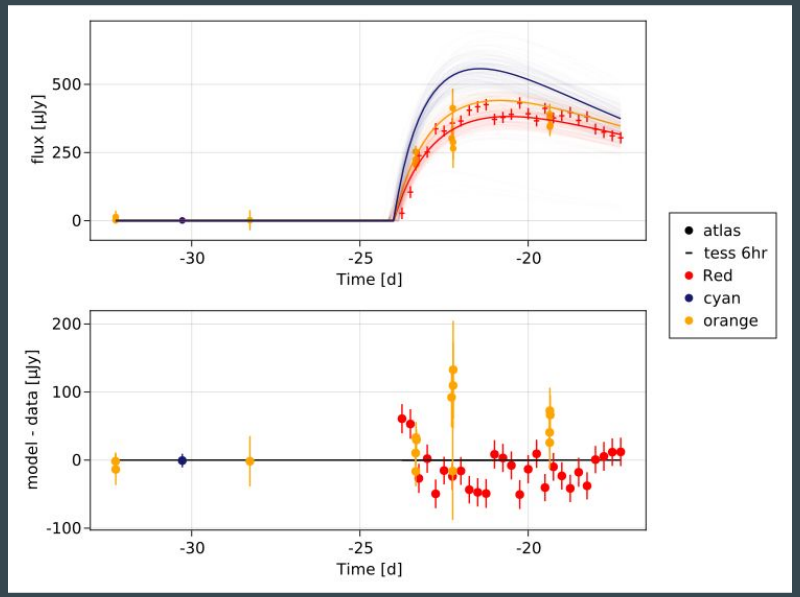
SN2021zby - SCL Fits (In Prep - Wang et al.)

n=3/2: convective envelope (RSG)



- Envelope Radius of ~50-350$R_\odot$
- Envelope Mass of ~0.3-3$M_\odot$

n=3: radiative envelope (BSG)



- Envelope Radius of ~180-420$R_\odot$
- Envelope Mass of ~2.5-5$M_\odot$

Conclusions

- SCL gives insight into core collapse progenitors
- More shock cooling lightcurves expected in the future
- https://github.com/OmegaLambda1998/ShockCooling
  - Free and open source SCL fitter maintained by me

References:

- Nakar E., Piro A. L., 2014, ApJ, 788, 193
- Piro A. L., 2015, ApJ, 808, L51
- Piro A. L., Haynie A., and Yao Y., 2021, ApJ, 909, 209
- Sapir N., Waxman E., 2017, ApJ, 838, 130
- ***Armstrong, P., et al., 2021, MNRAS, 507, 3125***

My paper

Questions?