

Chasing Transients with Kepler

Armin Rest (STScI)

KEGS: Peter Garnavich, Brad Tucker, Dan Kasen, Ed Shaya, Richard Mushotzky, Gautham Narayan, Steve Margheim, Alfredo Zenteno, Ashley Villar
Many Others!!!



SN 1604!



Johannes Kepler's original drawing from "de stella nova" (1606)

The Kepler Telescope

- ~100 deg² FOV
- 2K
- 4"/p
- Exo
- cur
- 1 m
- cad
- Only selected pixels downloaded!

Not only Planets!!

- SN Ia: early light curve
- Core-collapse SN: shock breakout, cooling envelope, CSM interactions
- Exotic transients

See Session 8 Friday

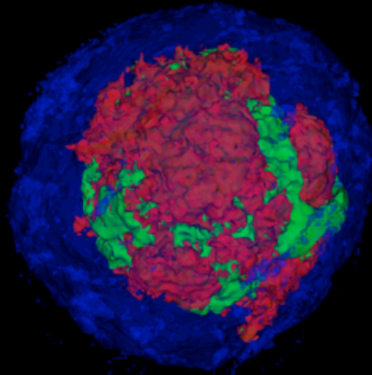
See Gaston Folatelli and Francisco Foerster talk



Kepler: SN Ia

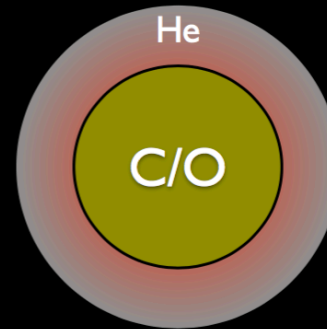
Progenitors of SN Ia

variety of progenitors/explosions



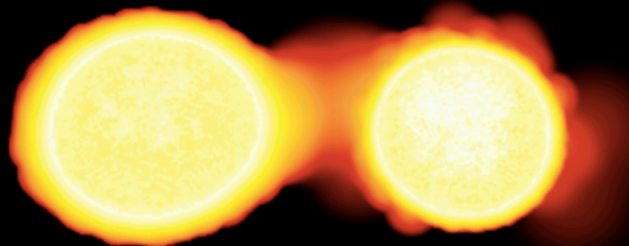
M_{ch} model

C/O grows to near M_{ch}
then ignites near center



sub- M_{ch} model

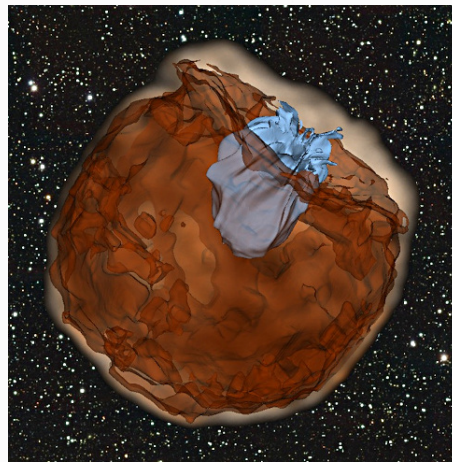
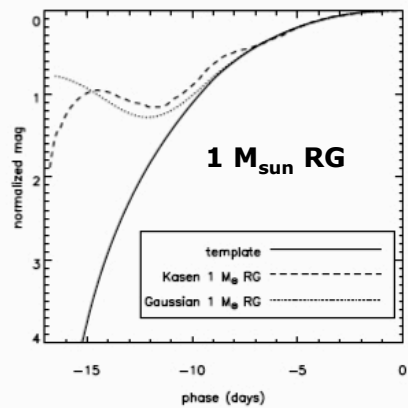
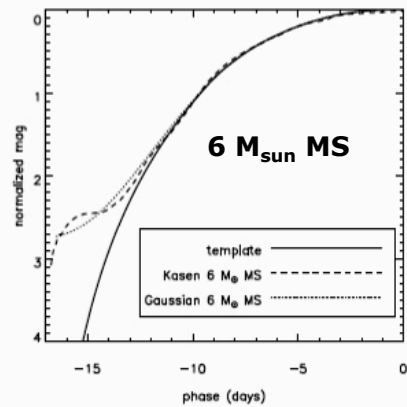
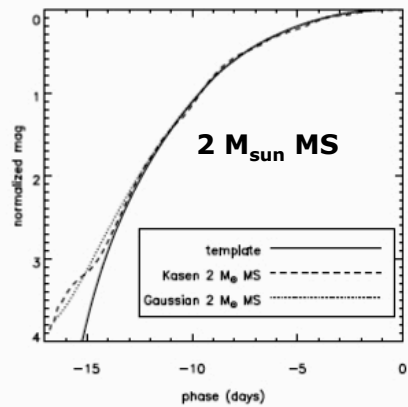
surface helium ignition
triggers C/O detonation



super- M_{ch} model

coalescence of
two C/O WDs

Early LCs of SNe: Constraining progenitors of SN Ia

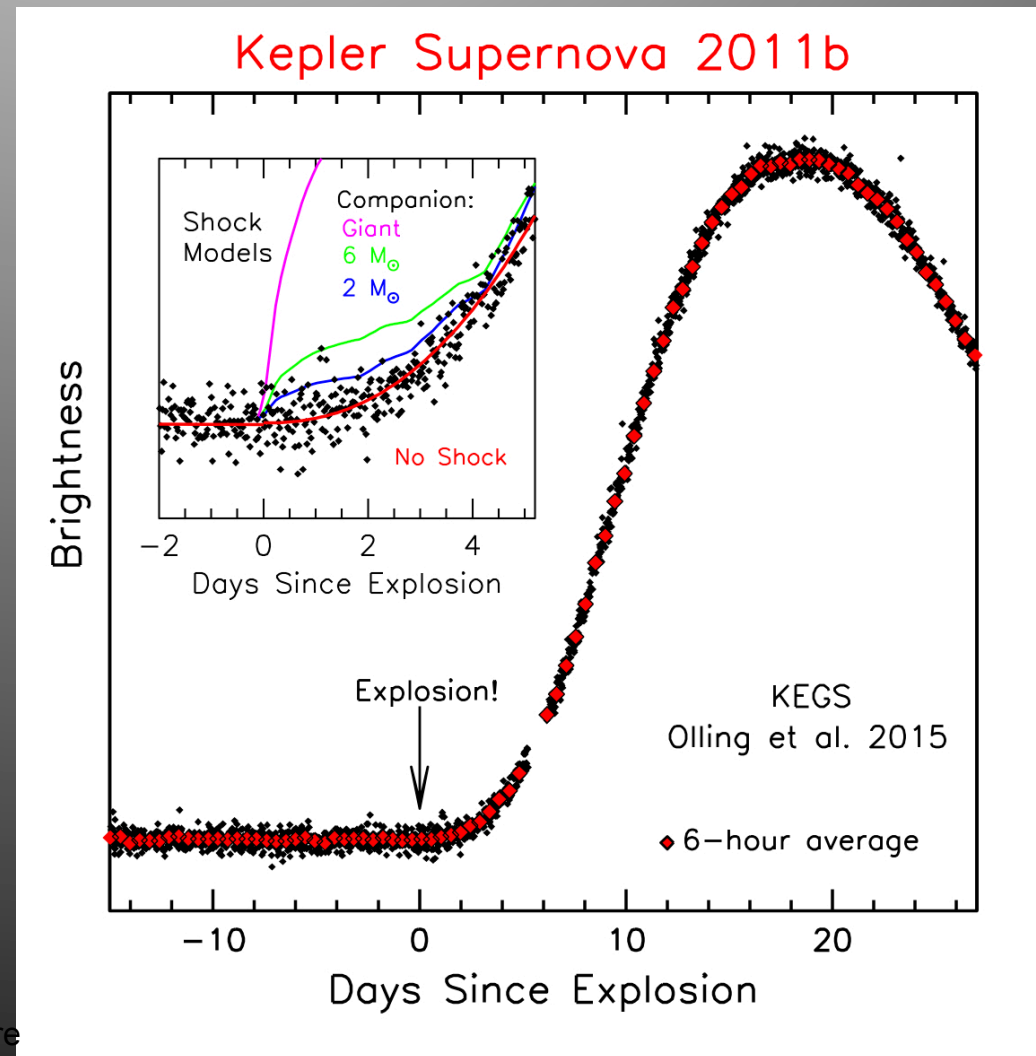


- From the Ground: difficult to get early lightcurves
- High precision photometry difficult (seeing, clouds, etc)
- SN Ia single-degenerate channel
 - Shock signature depends on viewing angle and companion mass (radius)

Kasen 2010: shock light curves (B-band) added to normal SN Ia

Kepler SN Ia: No signature of SD binary companion!

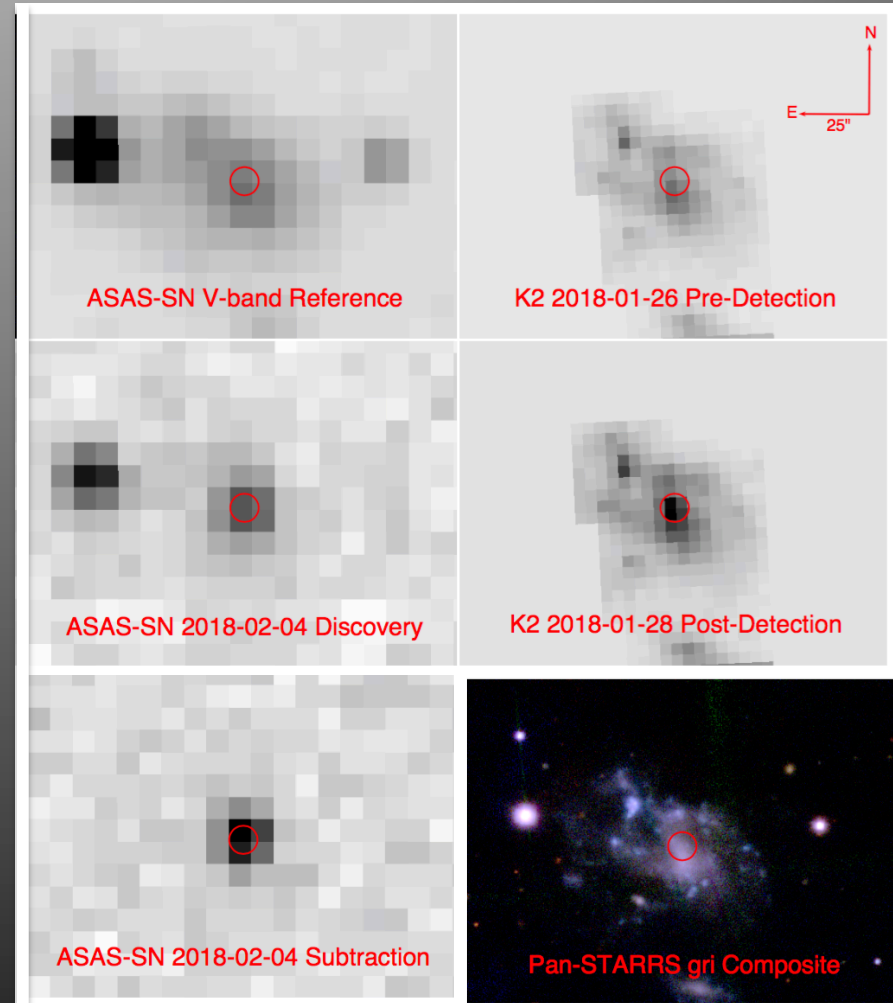
- 3 SN Ia in first Kepler mission
- No spectroscopy!
- 2 out of 3 SN Ia have high S/N
- None show any excess flux!
- Favors DD model



K2 C16: SN 2018oh (ASAS-SN18bt)

- SN 2018oh/ASAS-SN18bt discovered by ASAS-SN (Brown+18)
- UGC 4780 (49 Mpc)
- SN Ia @ $z=0.011$

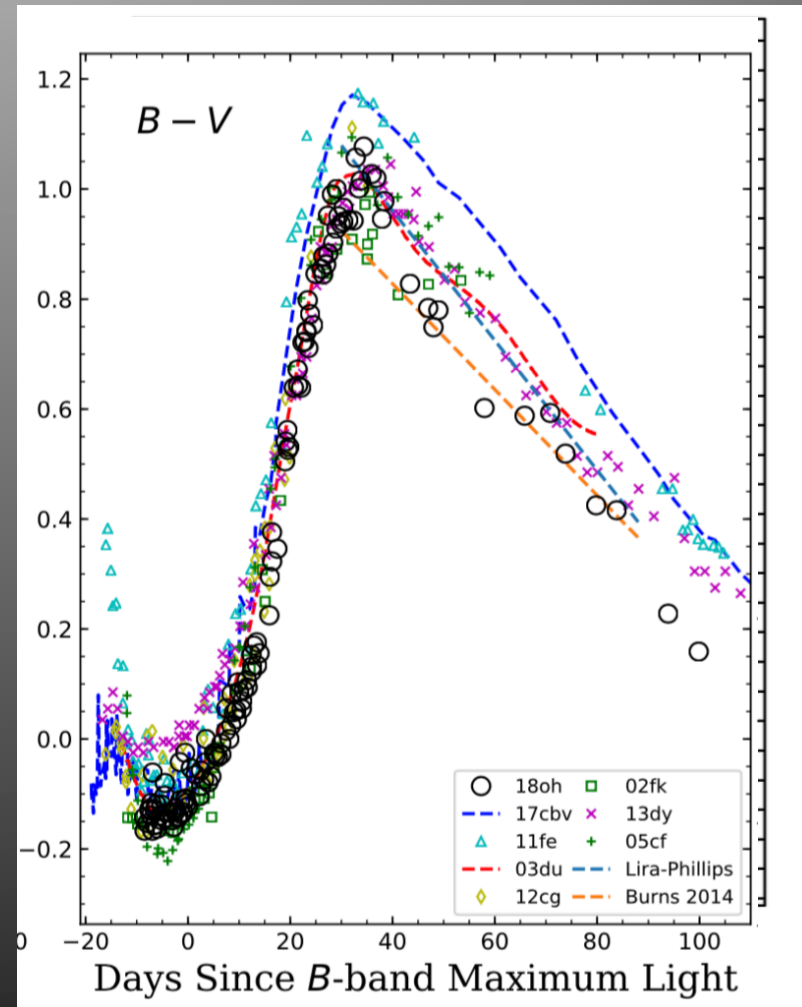
Discovered by ASAS-SN, Shappee+18, in press



K2 C16: SN 2018oh

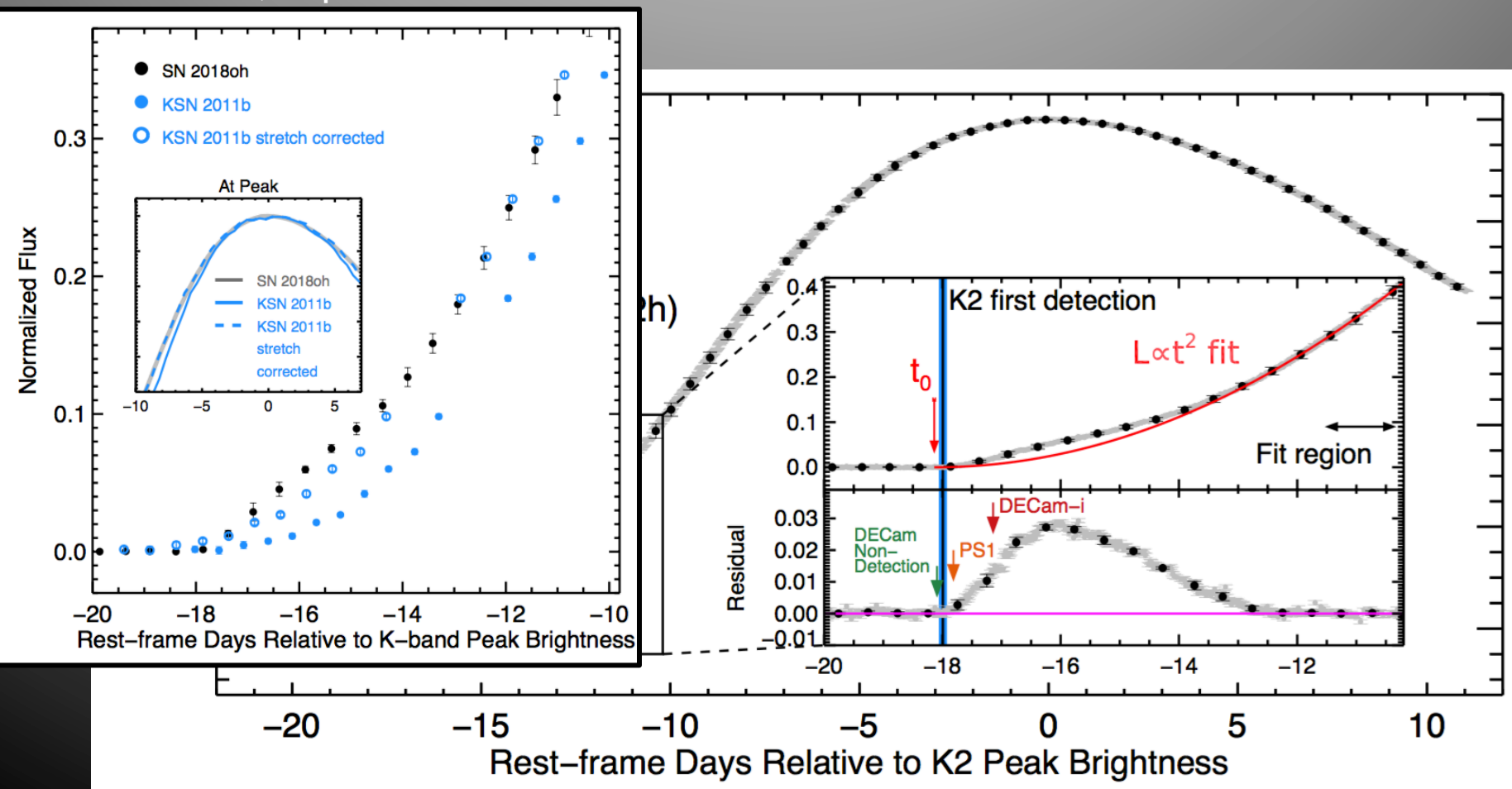
- SN 2018oh/ASAS-SN18bt discovered by ASAS-SN (Brown+18)
- UGC 4780 (49 Mpc)
- SN Ia @ $z=0.011$
- Properties (Li+18):
 - Normal SN Ia
 - $\Delta m_{15}(B)=0.96$
 - Bluer $B-V$
 - Persistent Carbon absorption (up to 3 weeks after peak): unburned carbon

Li+18, in press.



K2 C16: SN 2018oh (SN Ia @ z=0.011)

Dimitriadis+18, in press

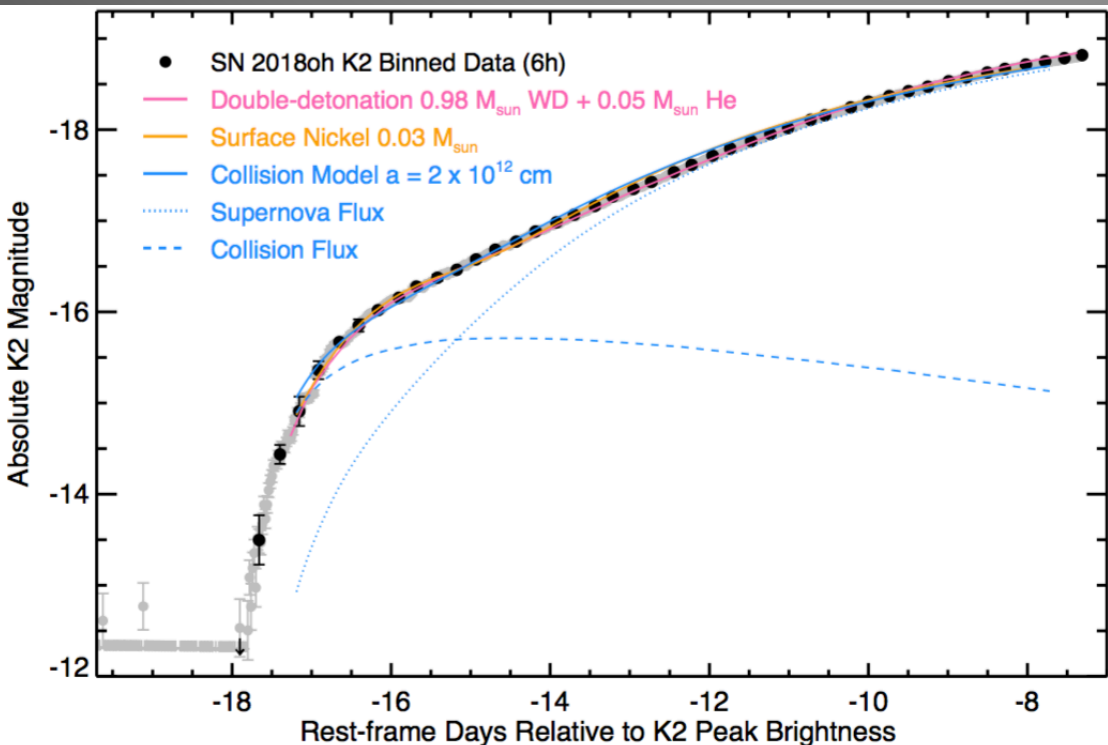


SN 2018oh: Source of Excess Flux?

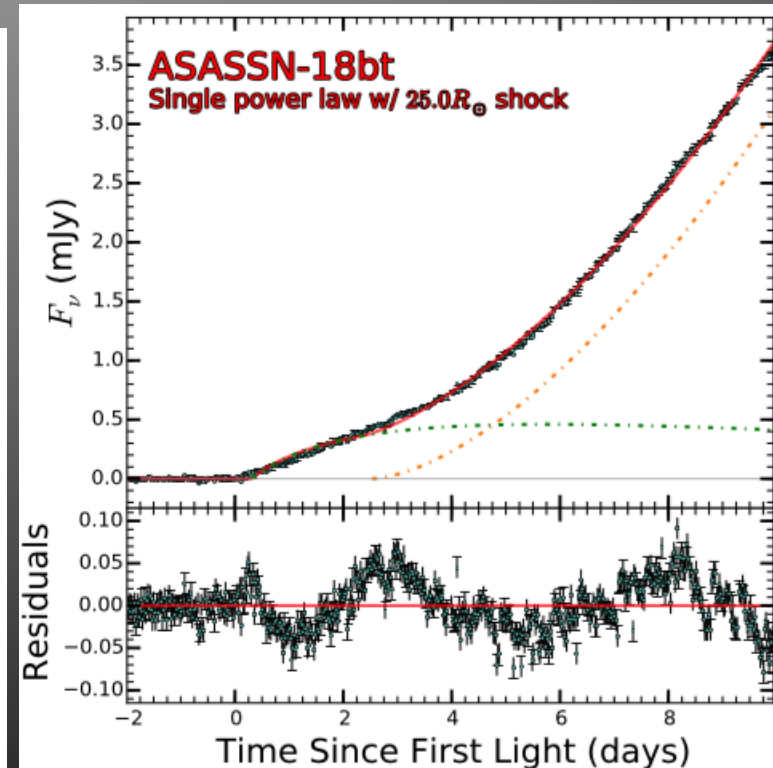
- Collision w/ binary companion?
- ^{56}Ni distribution?

- CSM interaction?
- Double-Detonation?

Dimitriadis+18, in press



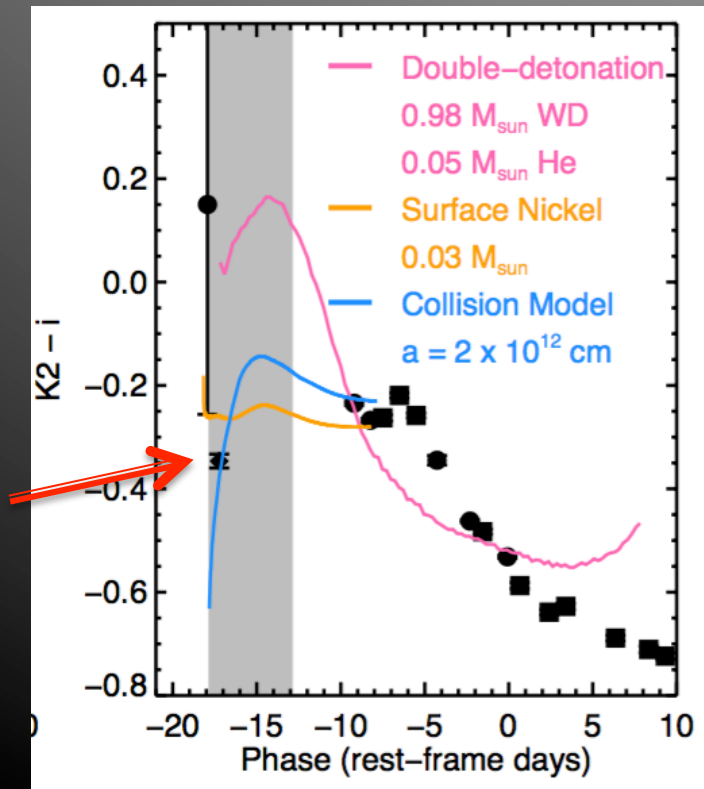
Shappee+18, in press



SN 2018oh: Source of Excess Flux?

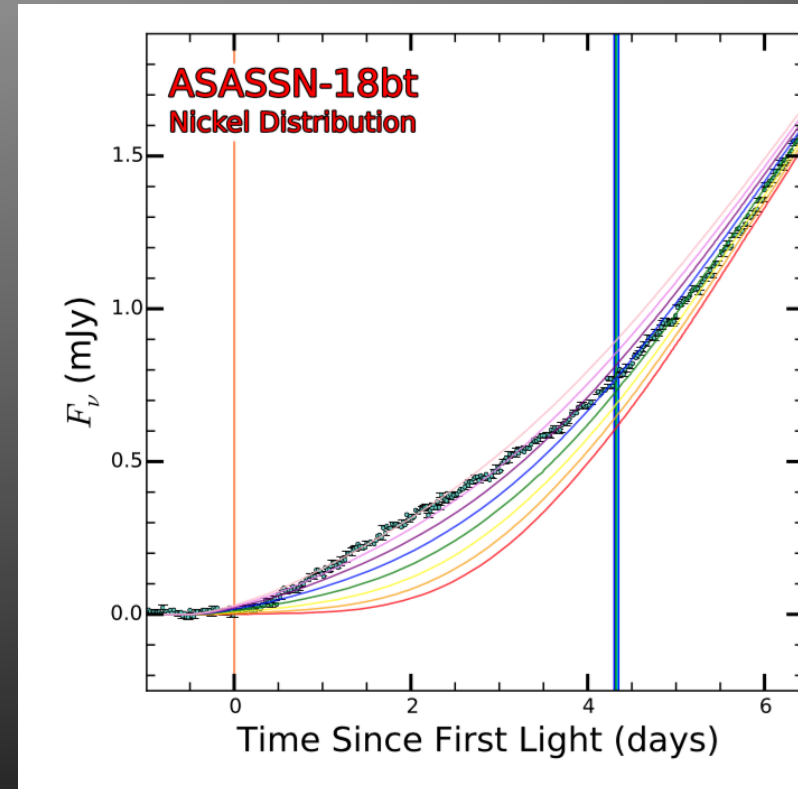
- Collision w/ binary companion?
- ^{56}Ni distribution?

Dimitriadis+18, in press



- CSM interaction?
- Double-Detonation?

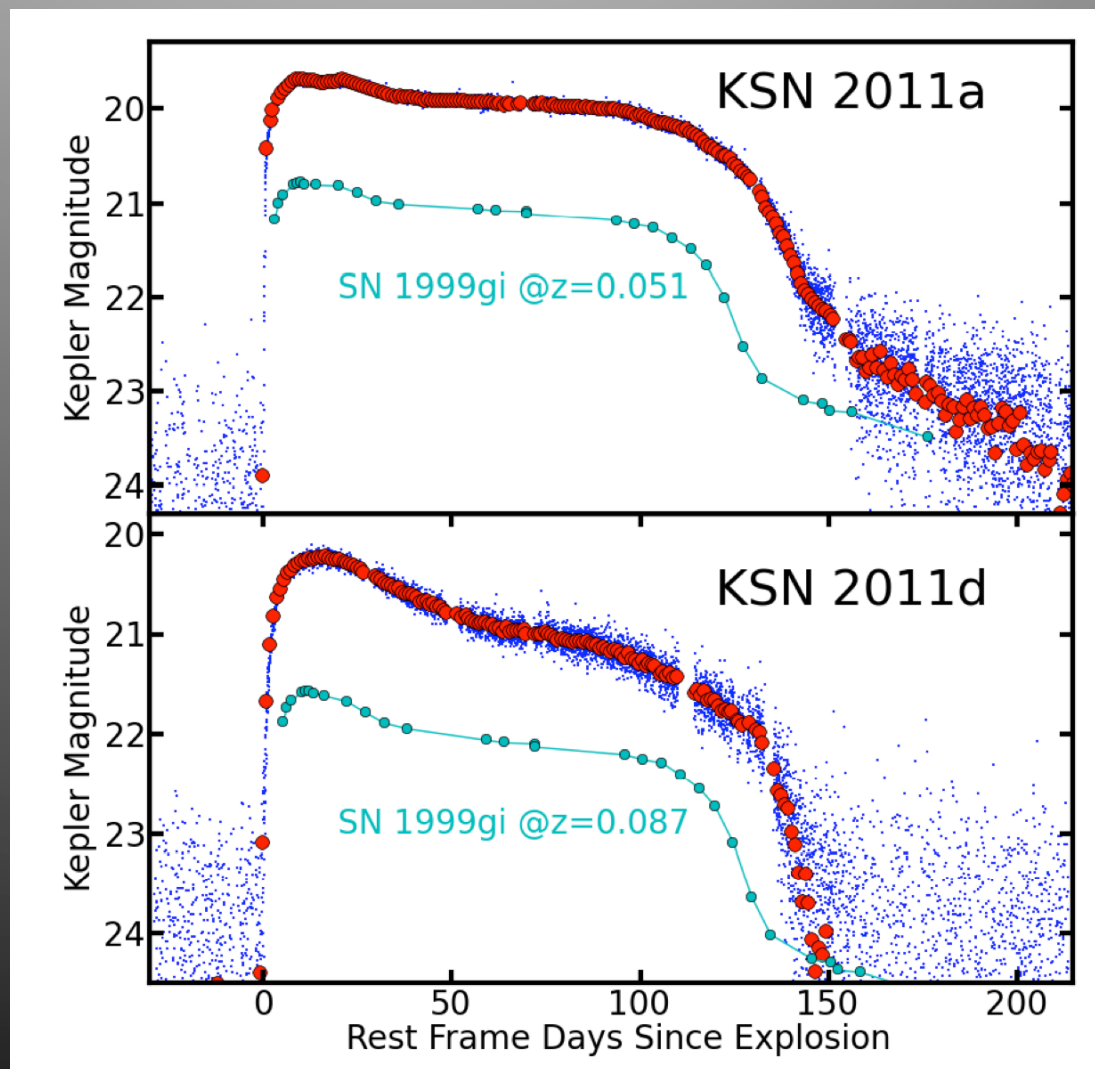
Shappee+18, in press



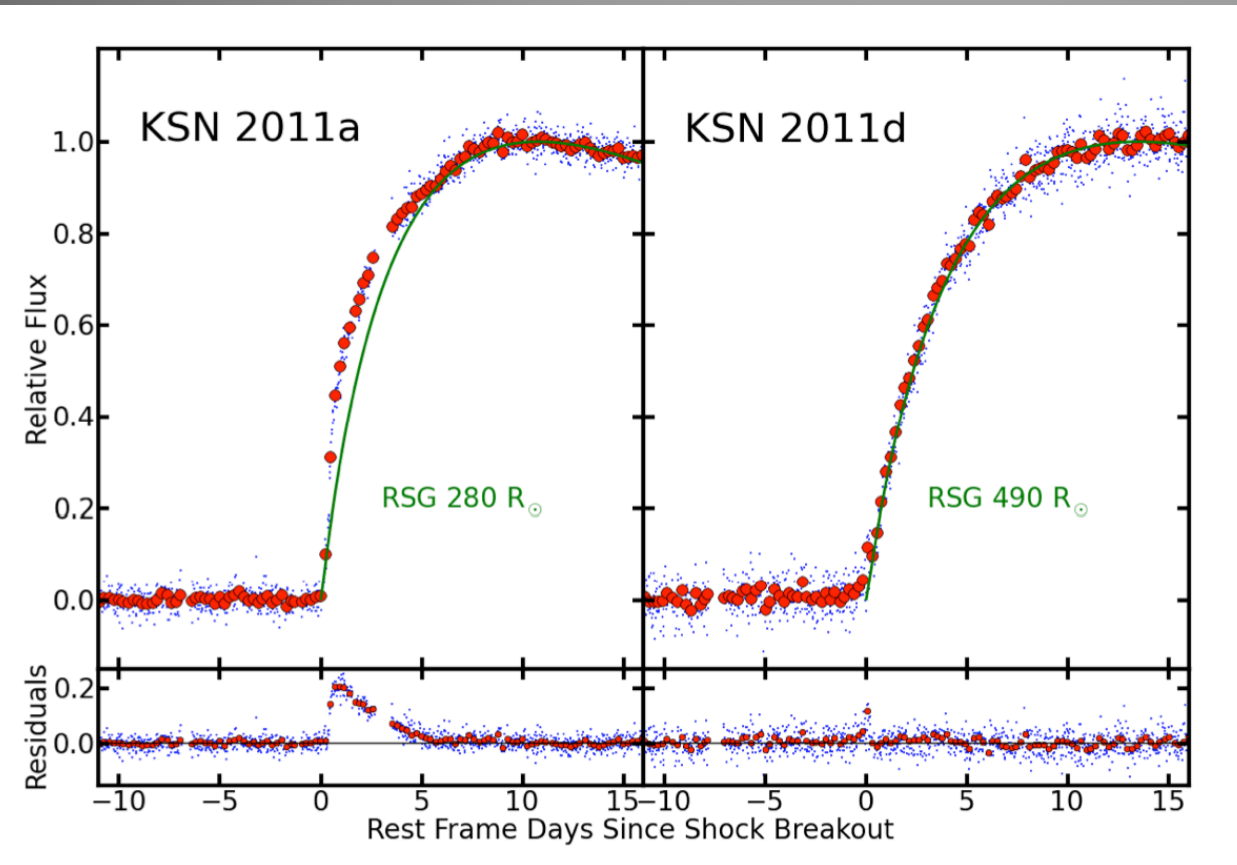
Kepler: Core-collapse SNe and exotic Transients

Kepler SN IIP

Garnavich+16
Tucker+18, in prep.



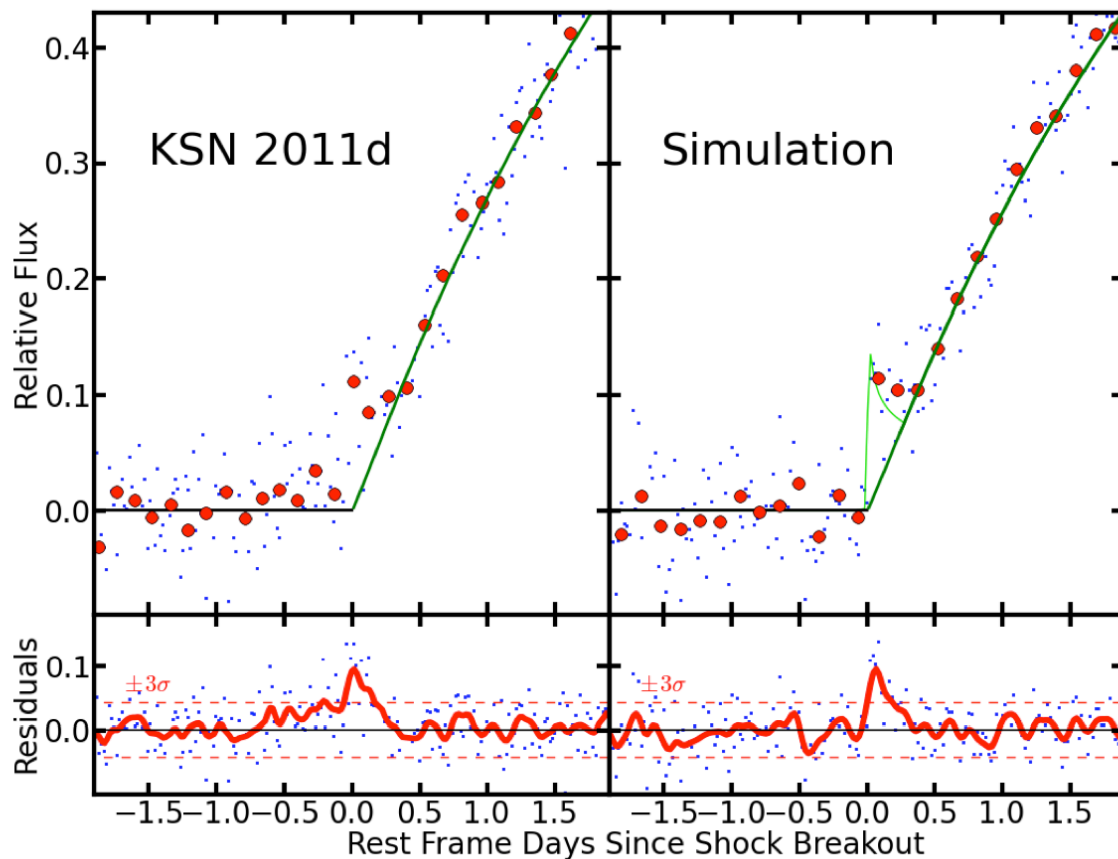
Kepler SN IIP



- SN IIP light curves
- Rabinak & Waxman 2011 red supergiant models
- KSN 2011a shows excess flux: interaction with stellar wind?
- Rubin & Gal-Yam 2016 with newer theoretical models
 - KSN 2011a BSG with $R_S = 10 R_{\text{solar}}$
 - KSN 2011d RSG with $R_S = 150 R_{\text{solar}}$

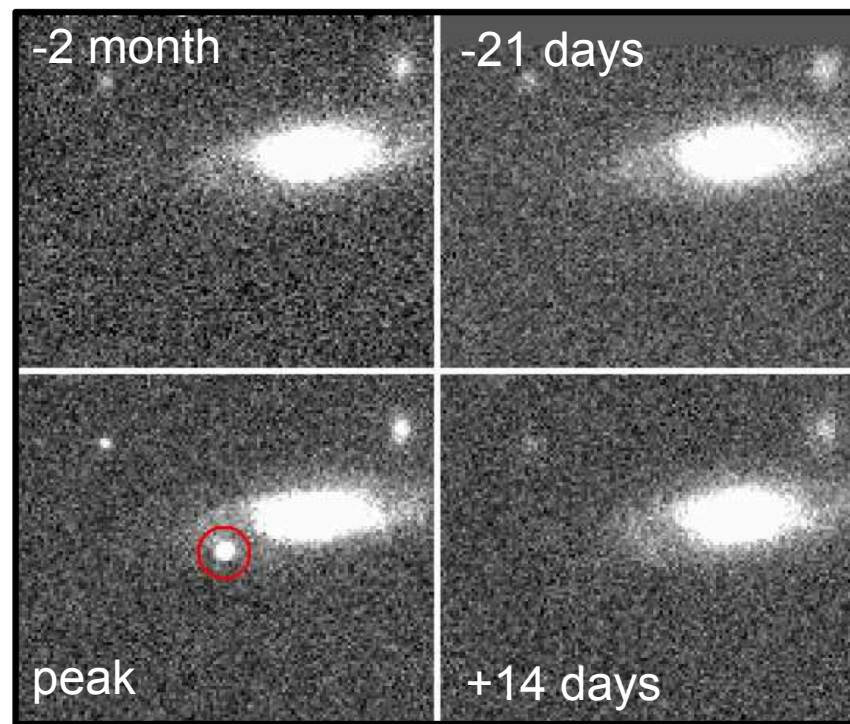
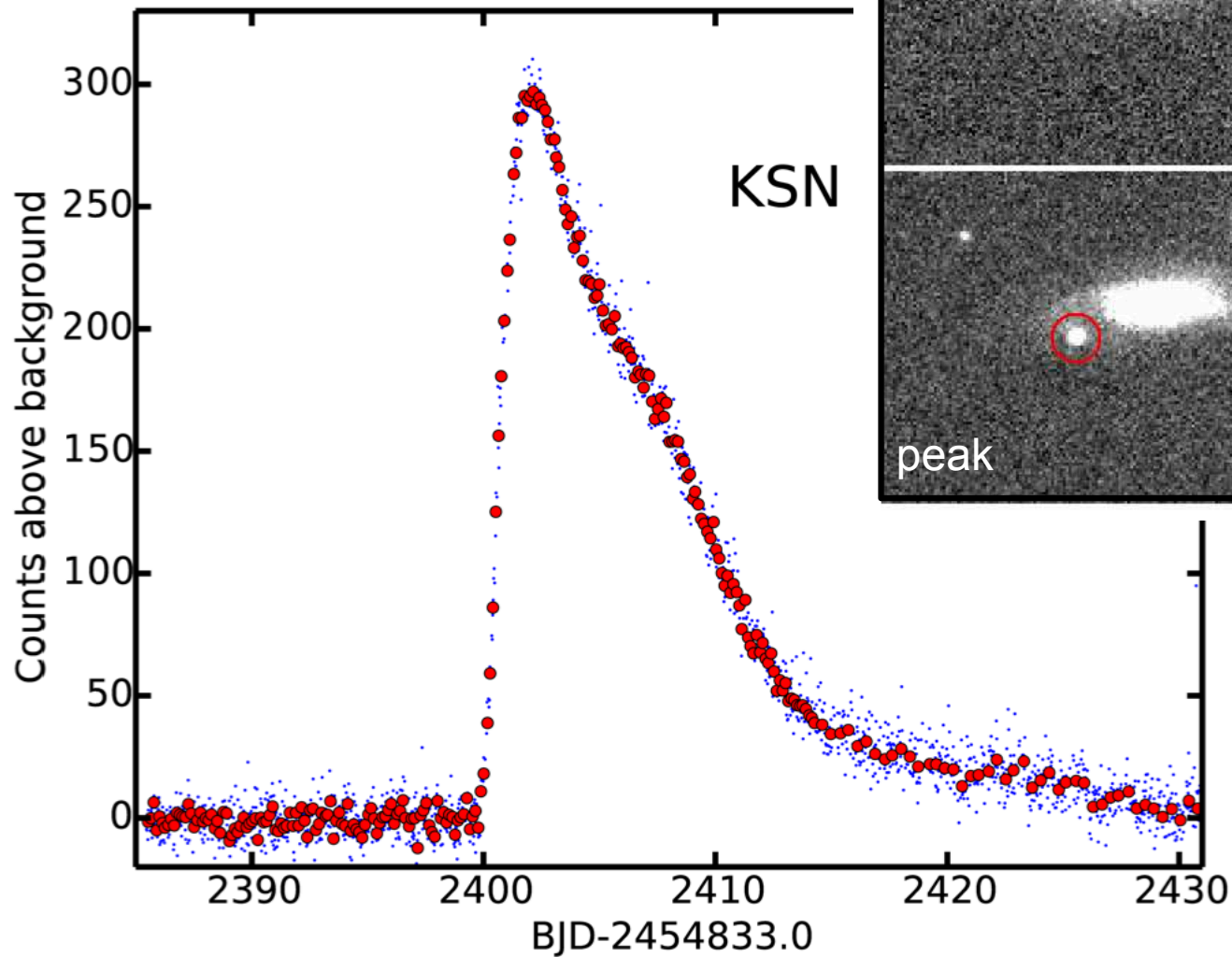
Garnavich+16

Kepler SN IIP: KSN 2011d shock breakout



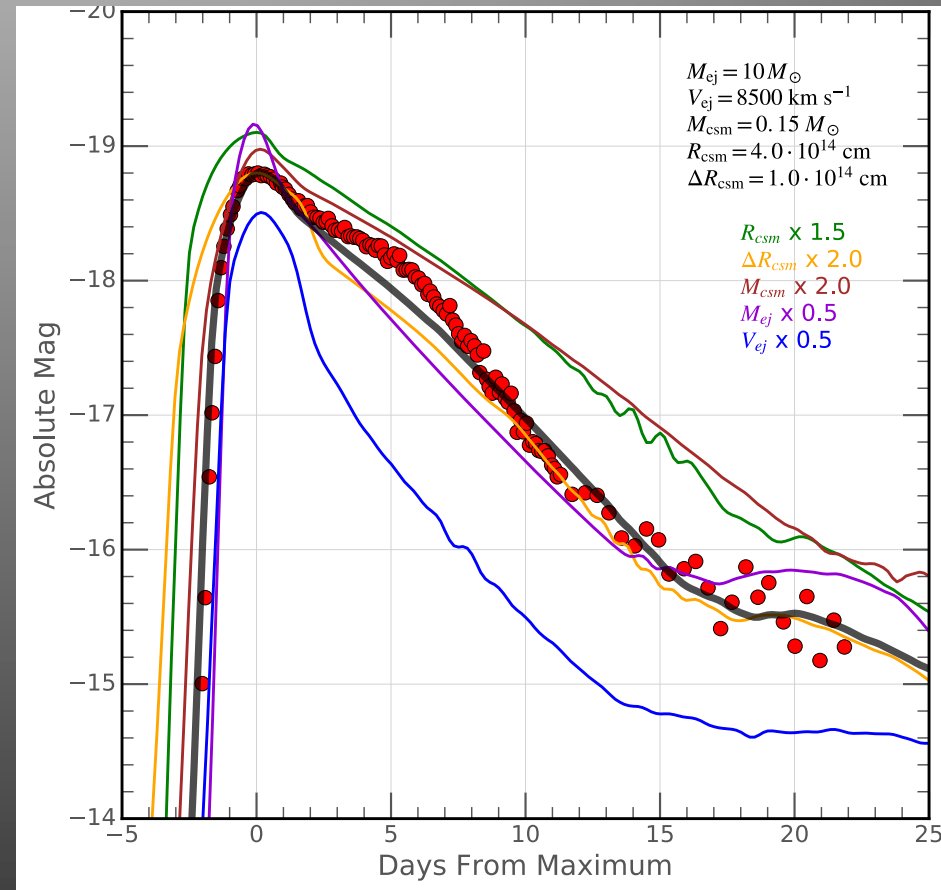
- KSN 2011d shows 5sigma excess flux at $t \sim 0$
- Agrees with theoretical predictions of IIP shock break out.

KSN 2015K ($z=0.00$)



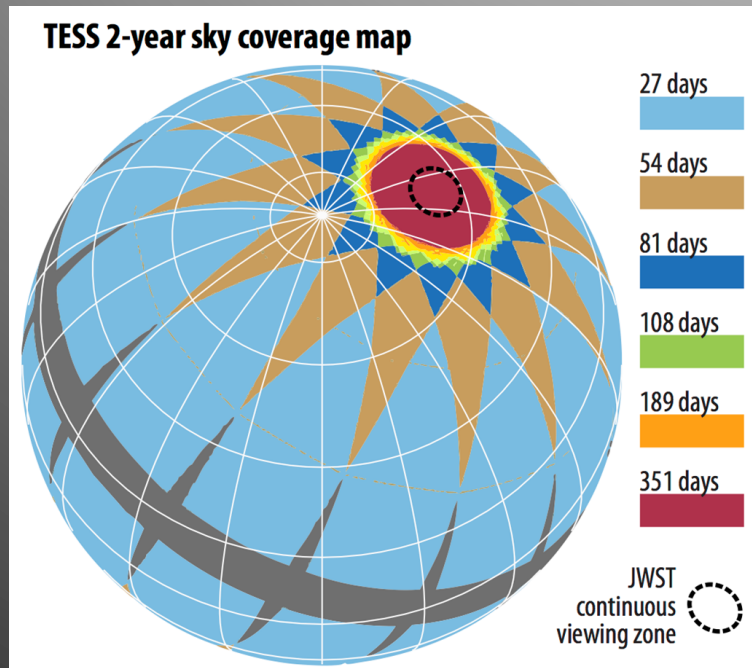
KSN 2015K

- Possible explosion mechanisms
 - Radioactive decay
 - .Ia model
 - Kilonova
 - Central engine (magnetar or accreting black hole)
 - Shock-breakout into CSM shell



Rest+18

TESS: The Next Step



- 85% of the sky in main mission
- 2400 deg² FOV
- Precision
 - 1 mmag @ T=12
 - 10 mmag @ T=15
 - 0.05 mag @ T=17

Magnitude Limit (T-band)	Number of SNe to 5- σ detection limit	
	Type Ia SNe	Core Collapse
14	14.3	11.7
15	35.7	34.4
16	44.9	95.6
17	56.5	120.3

Summary

- Kepler Telescope amazing for SN light curves and other transients
- SN Ia
 - SN 2018oh shows excess flux!
 - Sample of ~ 10-15 more SN Ia
- SN IIP
 - Early light curves show interaction with stellar wind and shock break-out!
- SN IIb
 - Shock break-out constrains radius of progenitor!
- Exotic transients:
 - KSN 2015K: Fast transient.
 - AT 2018qb & AT 2018dzv: nuclear transients. TDE? Changing Look QSO?
- More to Come!!