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Constraining SNe Ia explosion mechanisms and identifying early bumps in the ZTF sample

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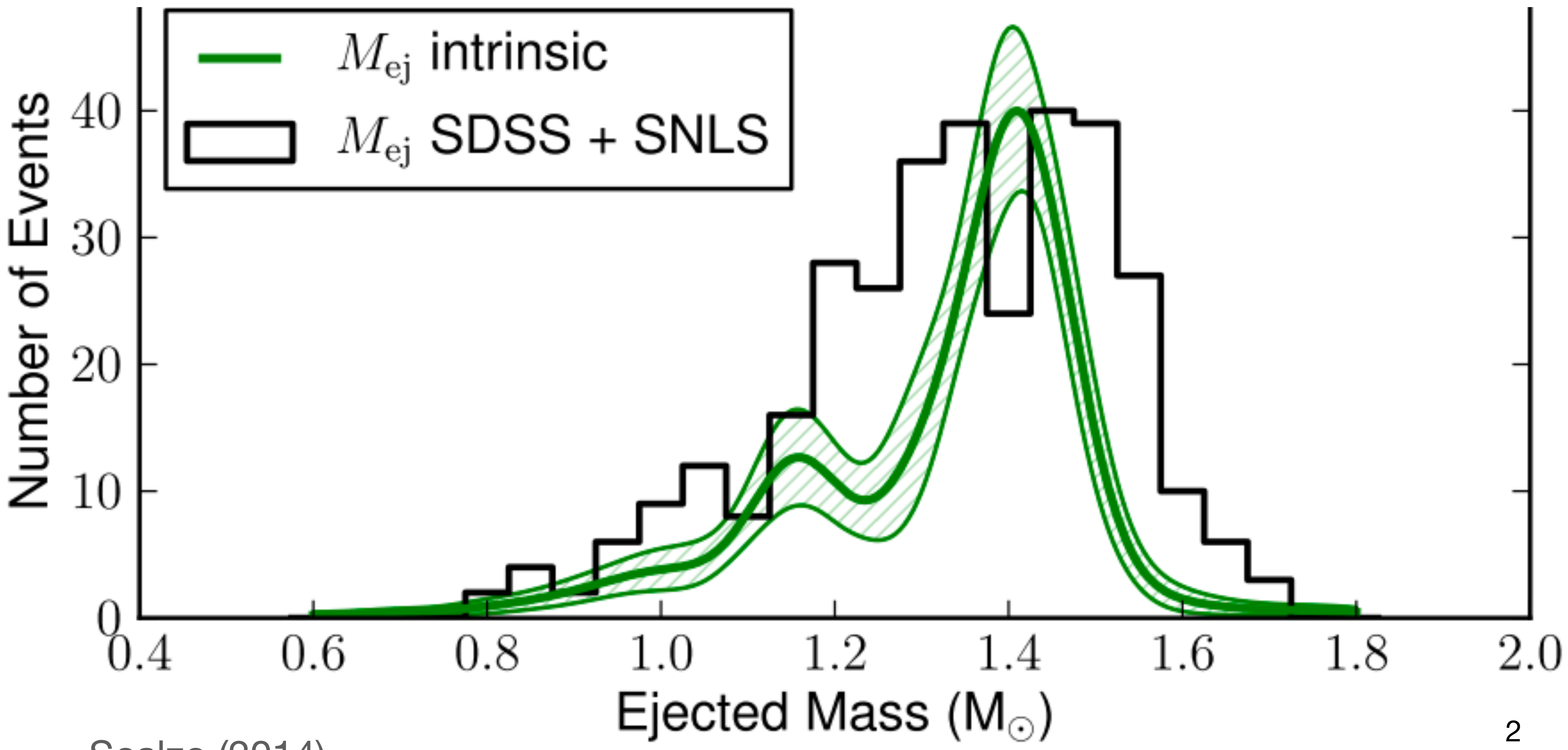
The progenitor problem

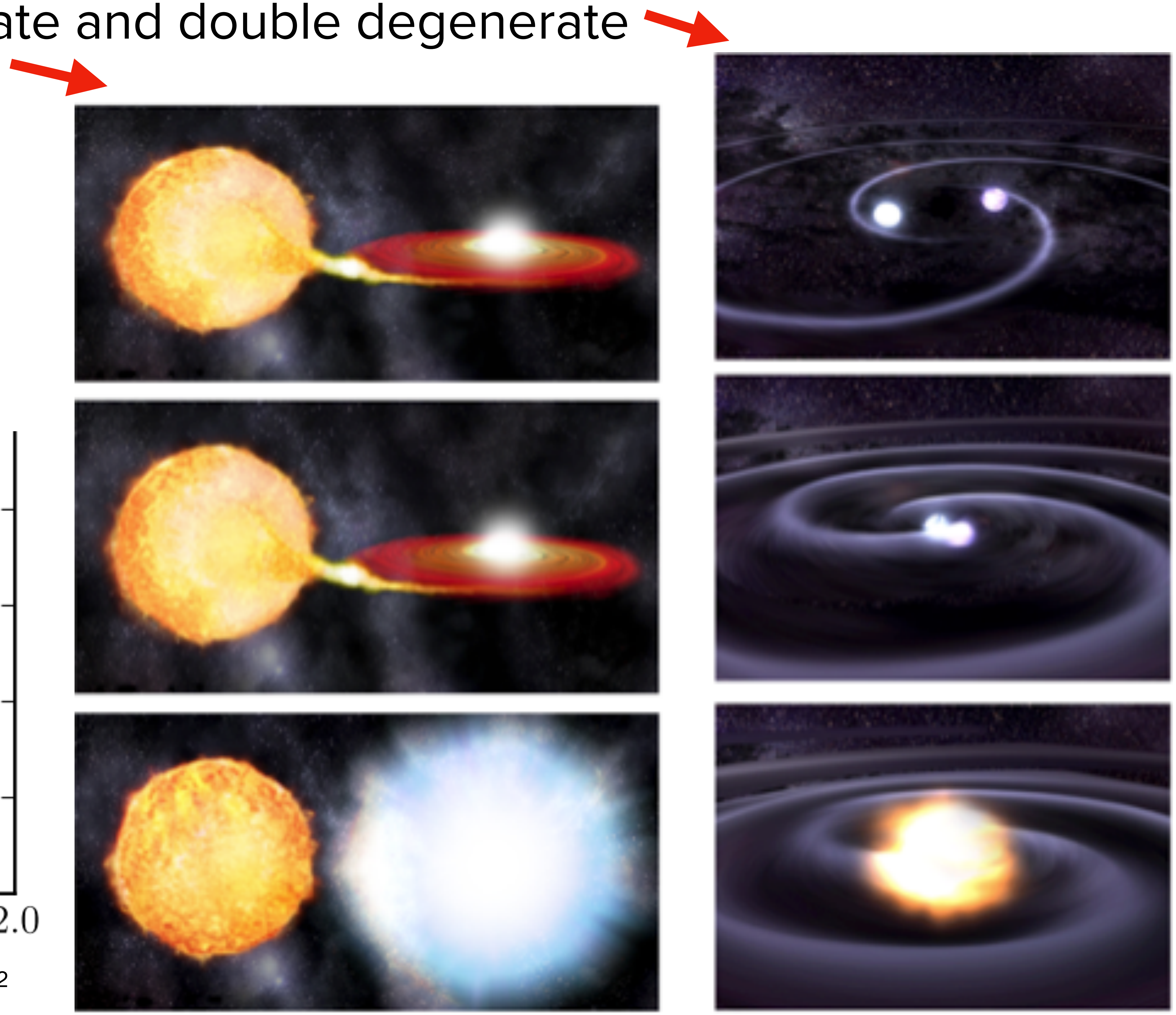
- Despite their importance in cosmology, details of their progenitor systems and their explosion mechanisms are still unknown

- Two main progenitor channels: single degenerate and double degenerate

- Also separated by mass at explosion: sub-Chandrasekhar or Chandrasekhar

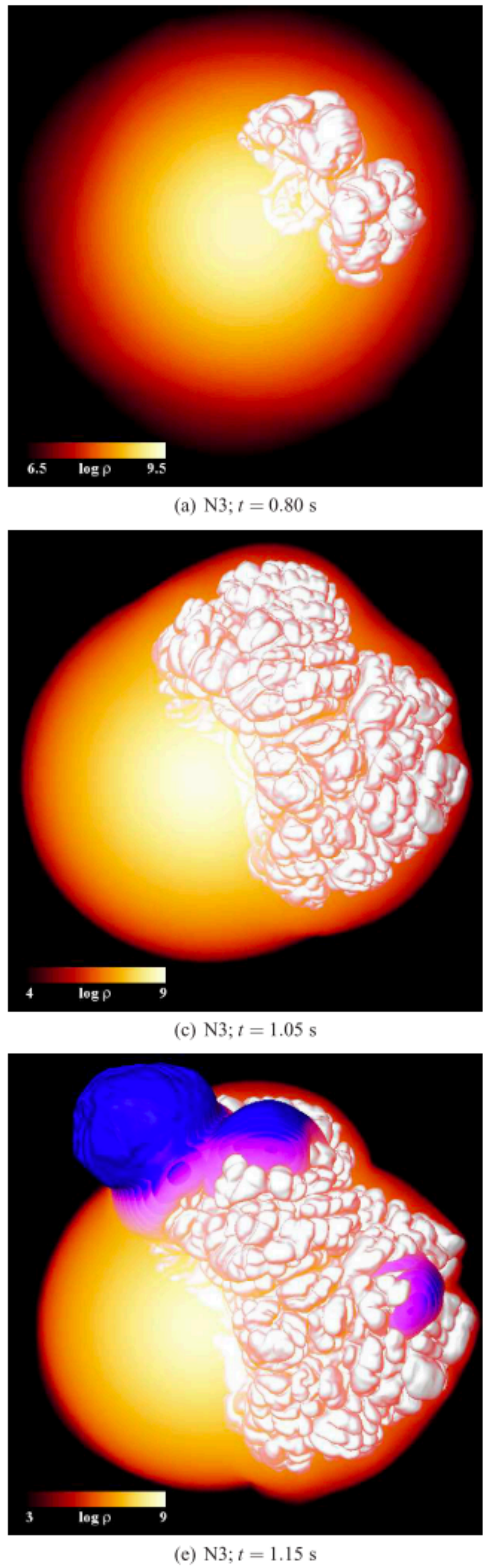


Scalzo (2014)



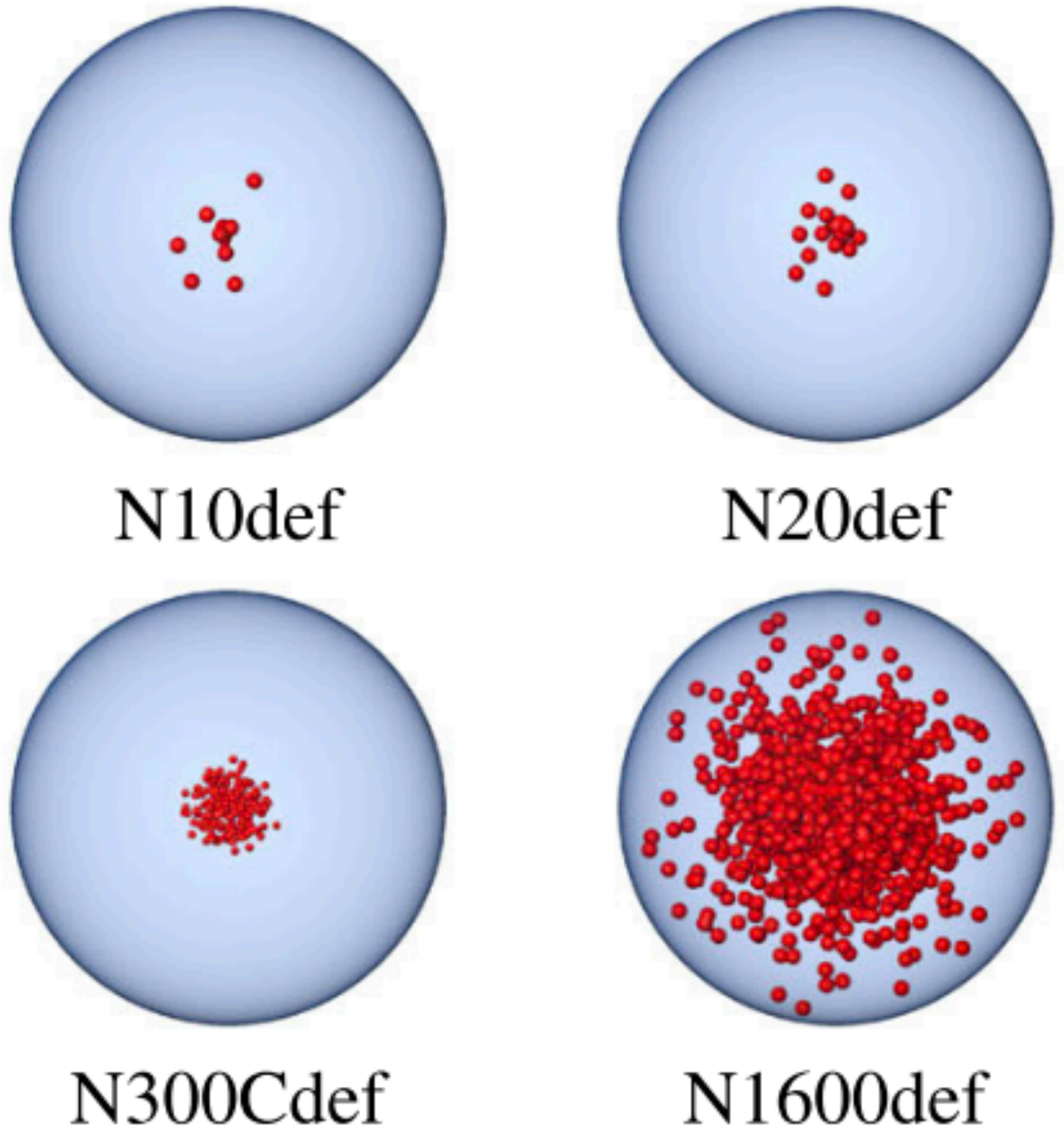
Explosion Mechanisms

- Delayed Detonation (ddt)



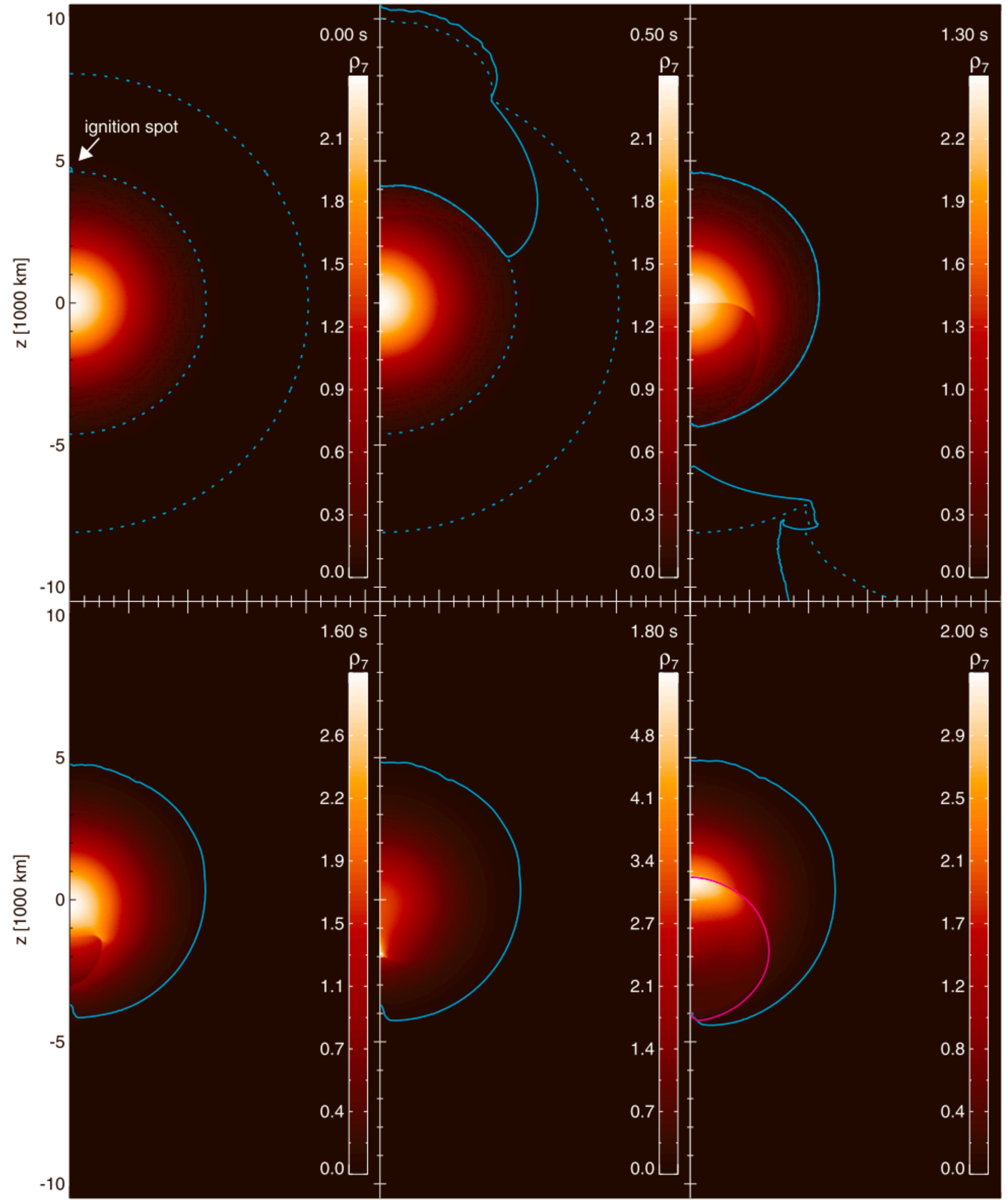
Seitenzahl (2012)

- Deflagration (def)



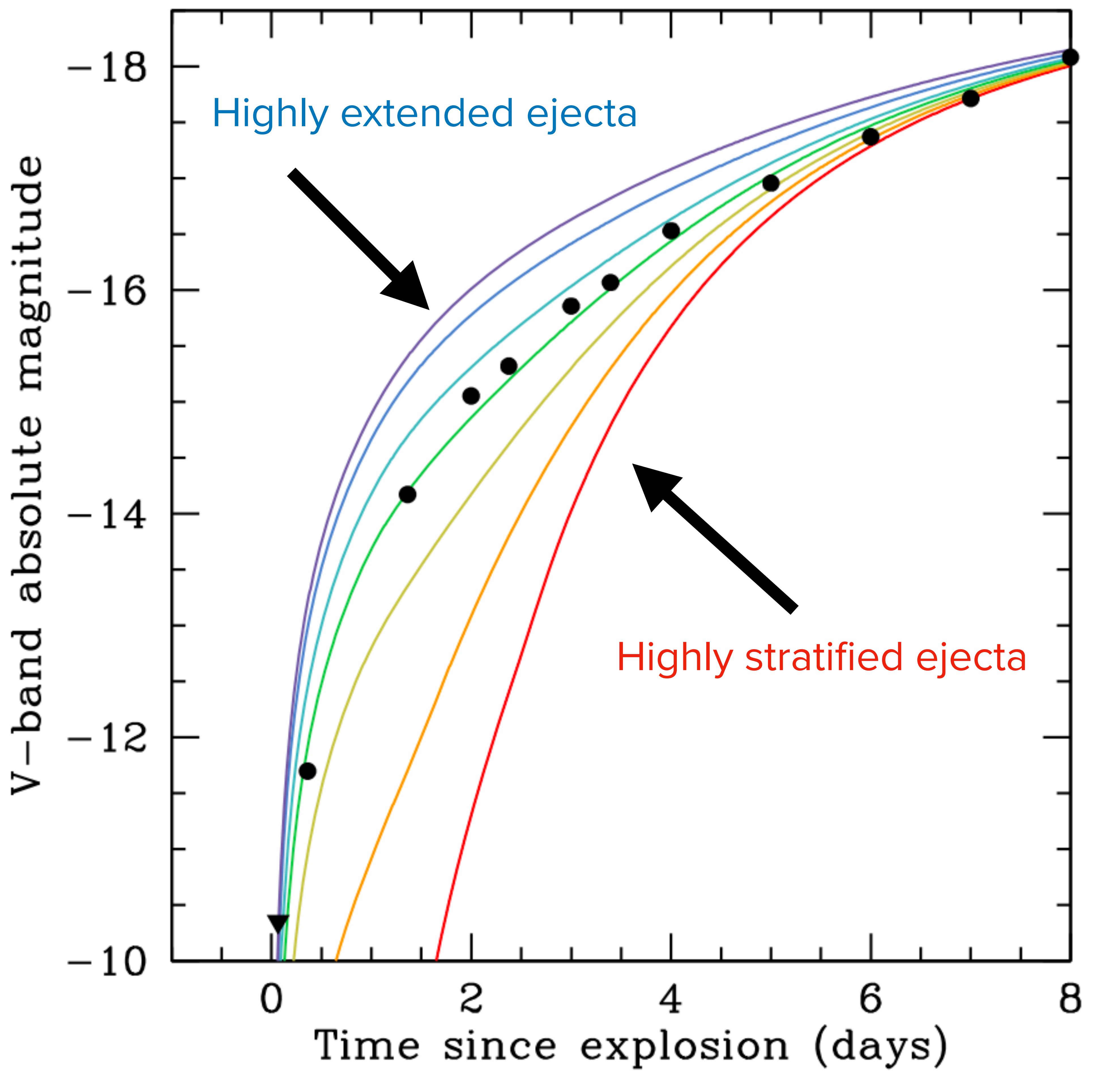
Fink (2014)

- Double Detonation (ddet)



Fink (2010)

Early Light Curves

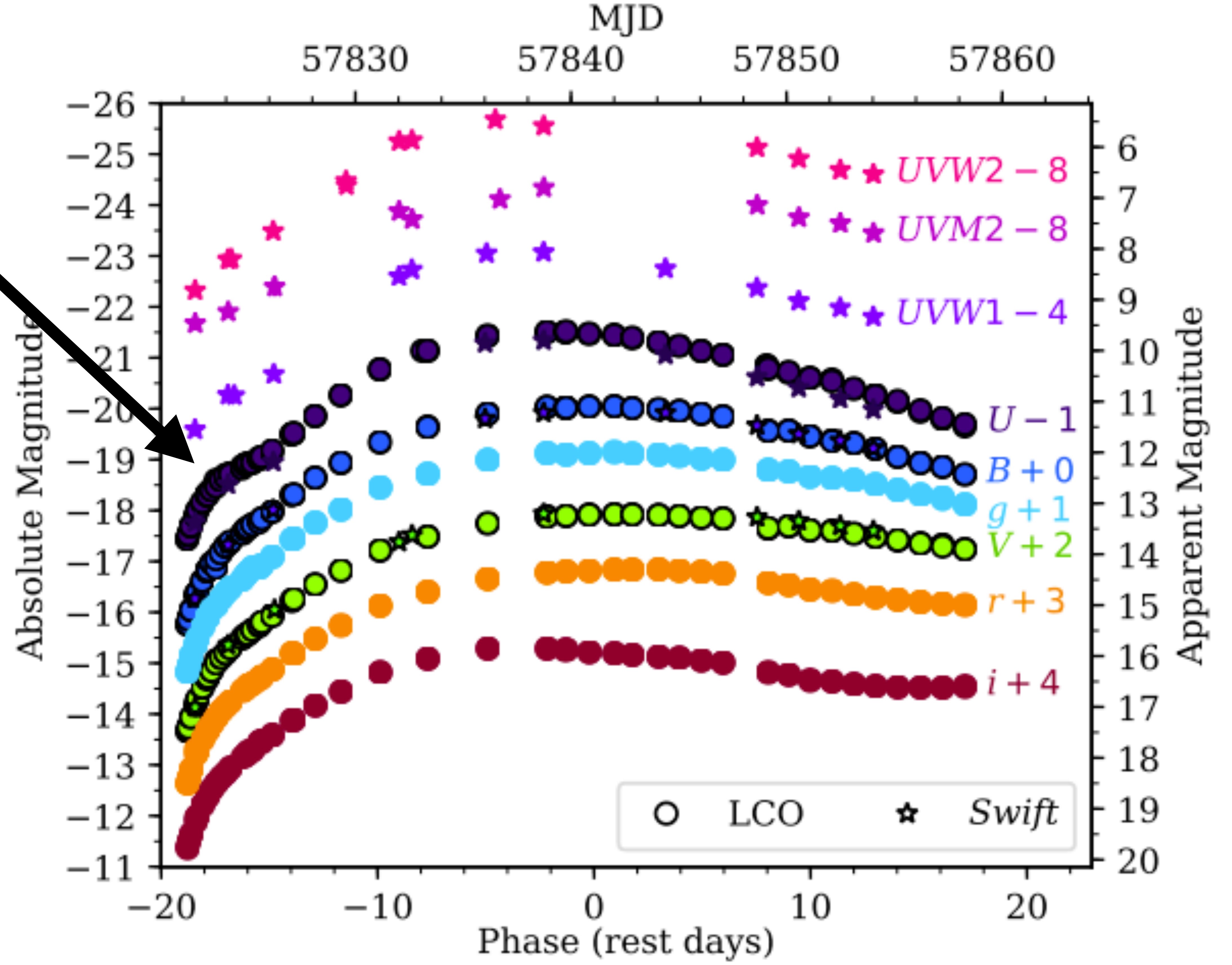


Piro (2016)

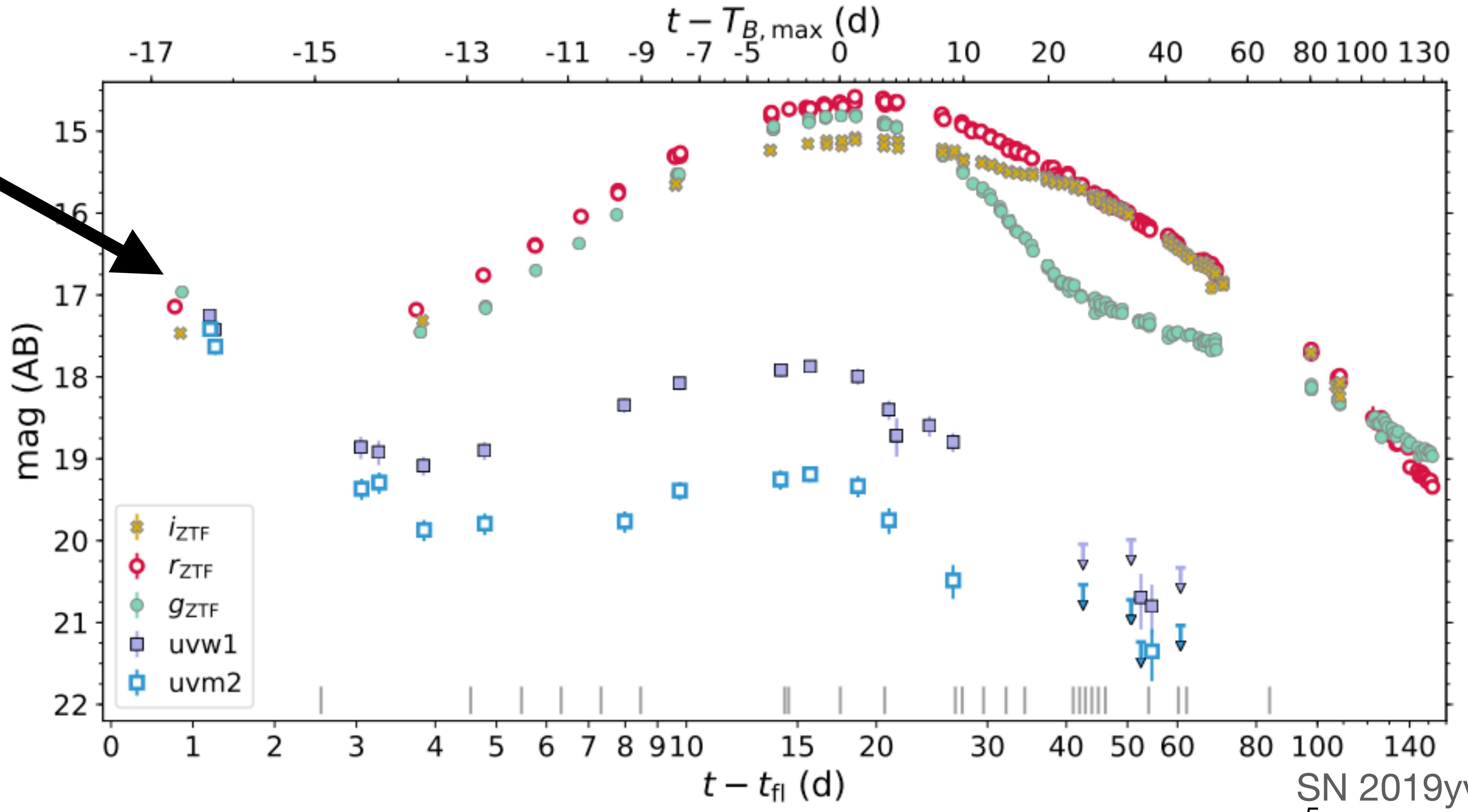
- Early light curves can show significant variation in:
  - Dark phase
  - Shape of rise
- This informs us about the distribution of Ni-56 in the ejecta

Bumps

- In some extreme cases we might detect a “bump” or flux excess in early LC
- Flux excess in early light curves can indicate companion/CSM interaction, Helium shell detonation or Nickel clumps



SN 2017cbv, Hosseinzadeh (2017)



SN 2019yvq / ZTF19adcecwu., Miller (2020)

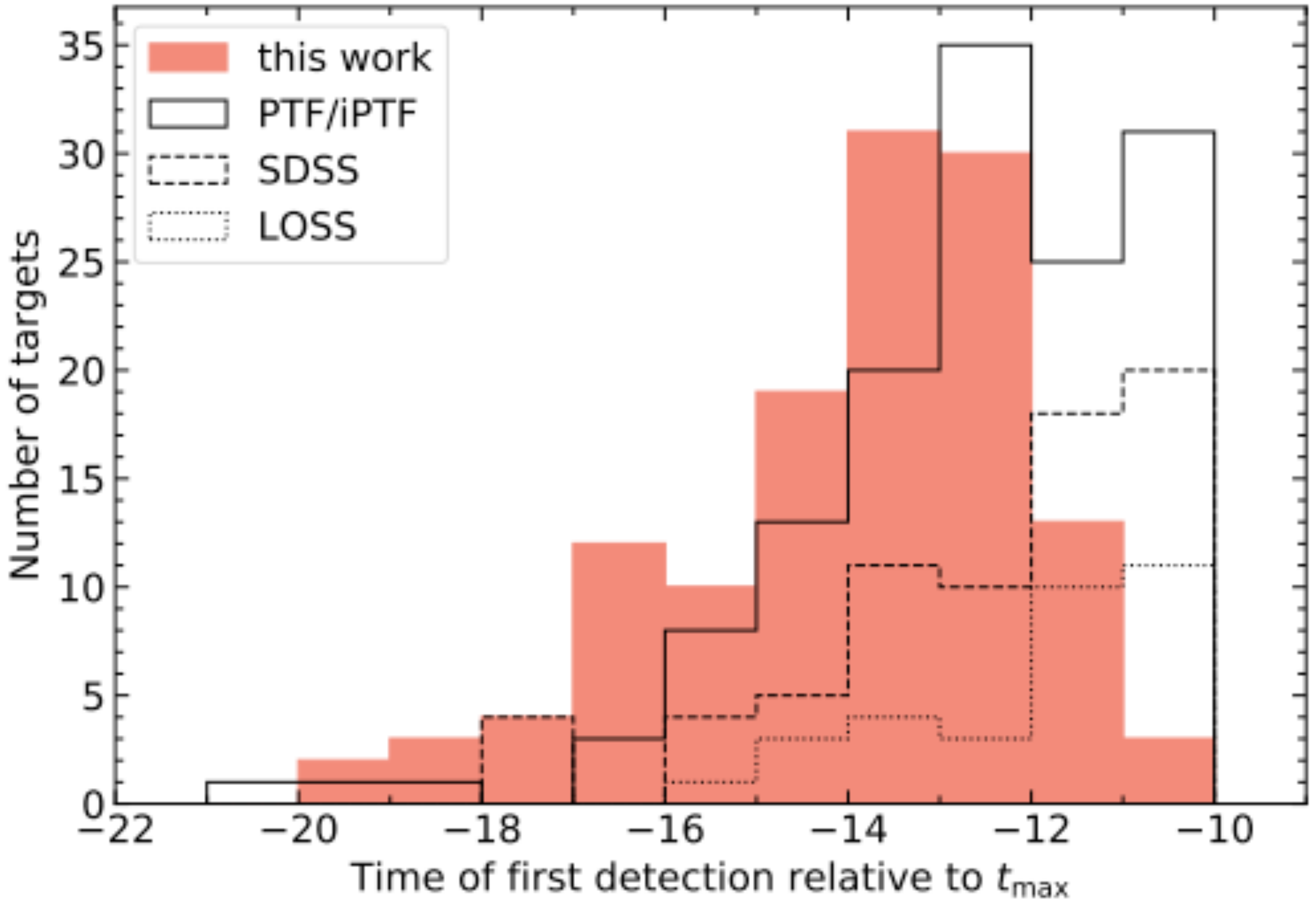
Questions we want to answer

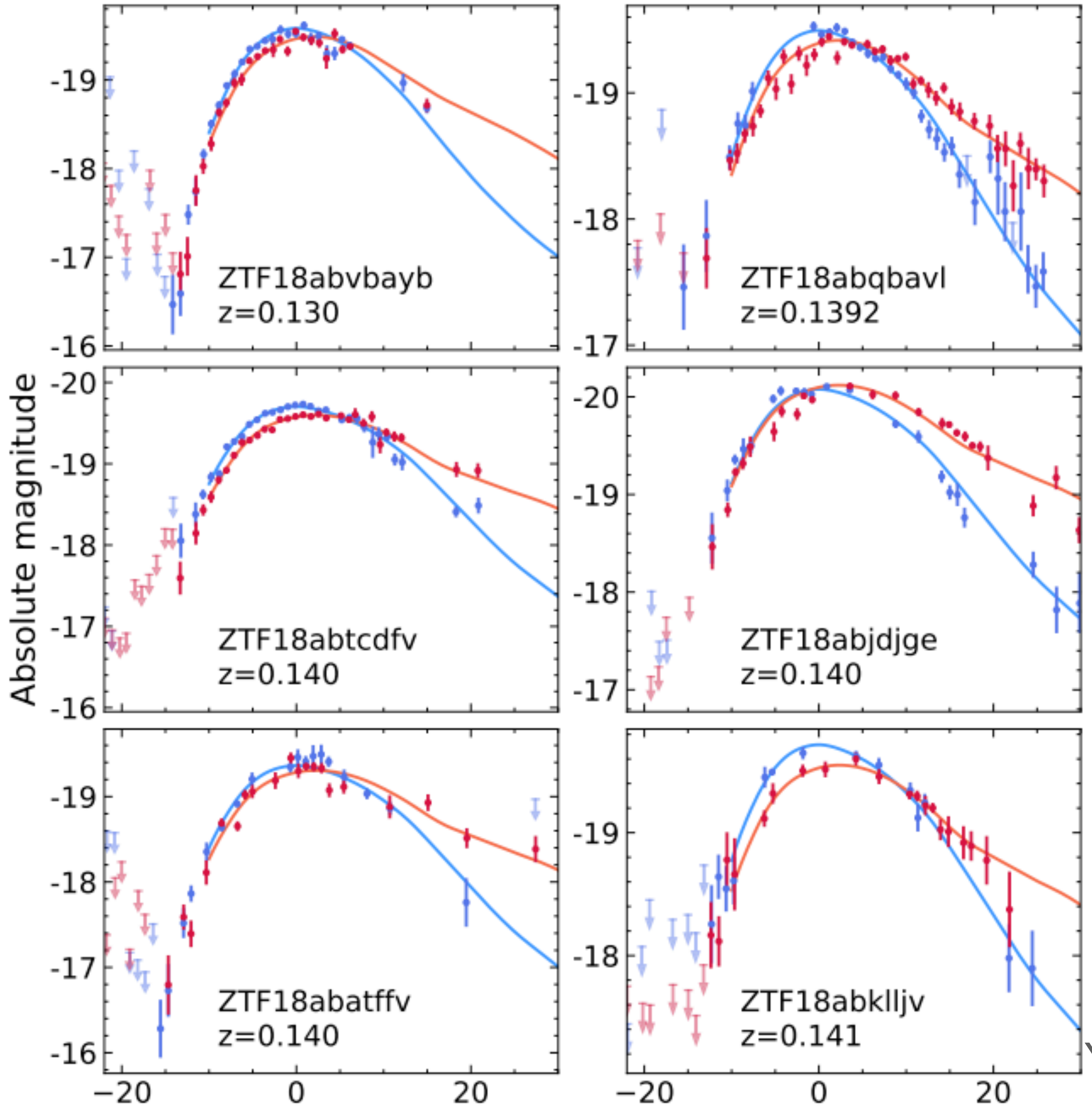
- How many objects in ZTF 2018 sample can be fit by Chandrasekhar mass explosions?
- How is the Ni-56 distributed through the ejecta of these objects?
- Which explosion mechanism best reproduces these light curves?
- What fraction of objects show a flux excess?

Zwicky Transient Facility

2018 SNe Ia Sample

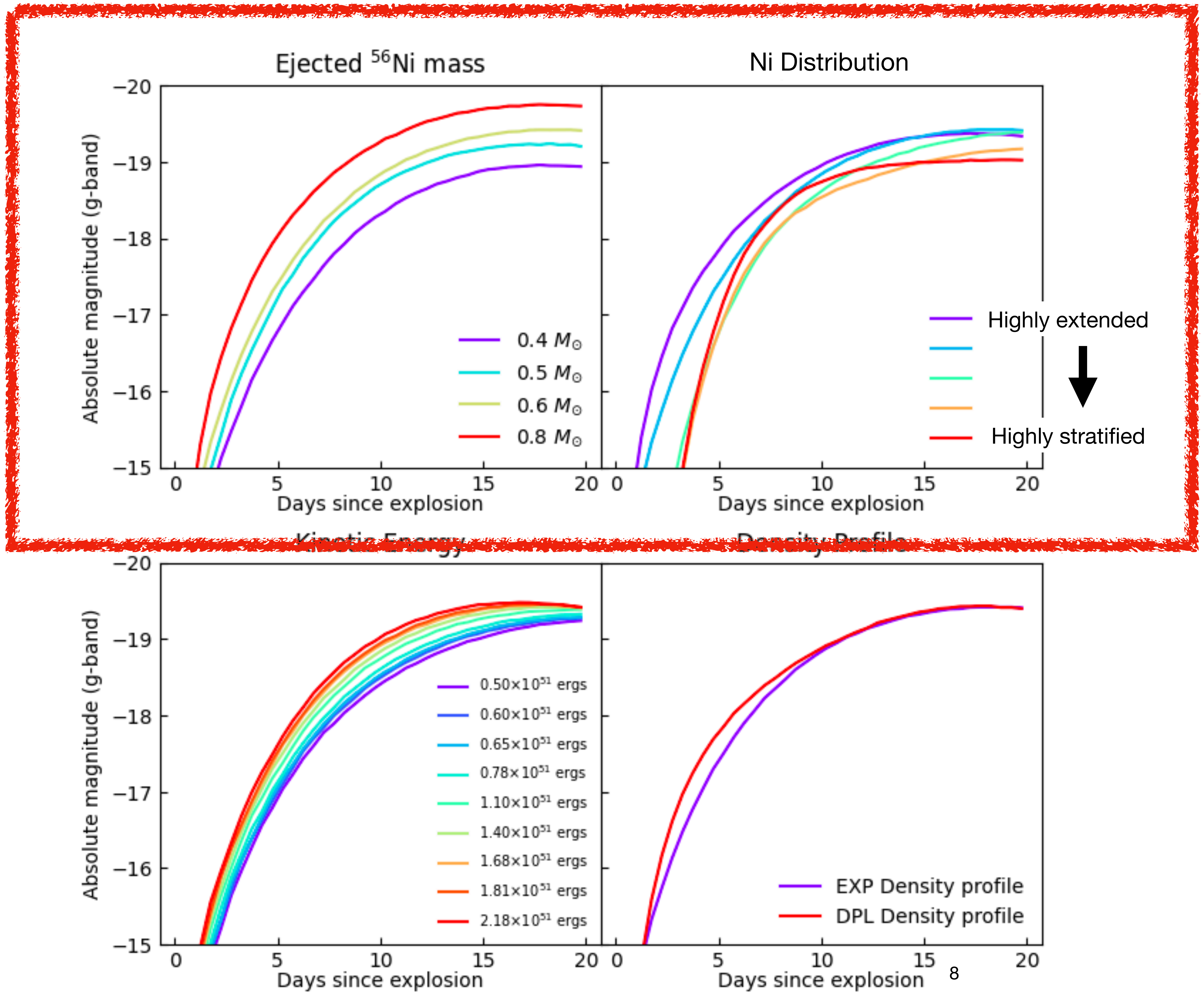
- 127 spectroscopically classified SNe Ia with observations earlier than 10 days before peak in g
- 90 objects in 2018 sample pass cosmological and quality cuts
- **Largest study of Ni-distributions in SNe Ia to date!**





Yao (2019)

The Model Grid- TURTLS (Magee 2018)

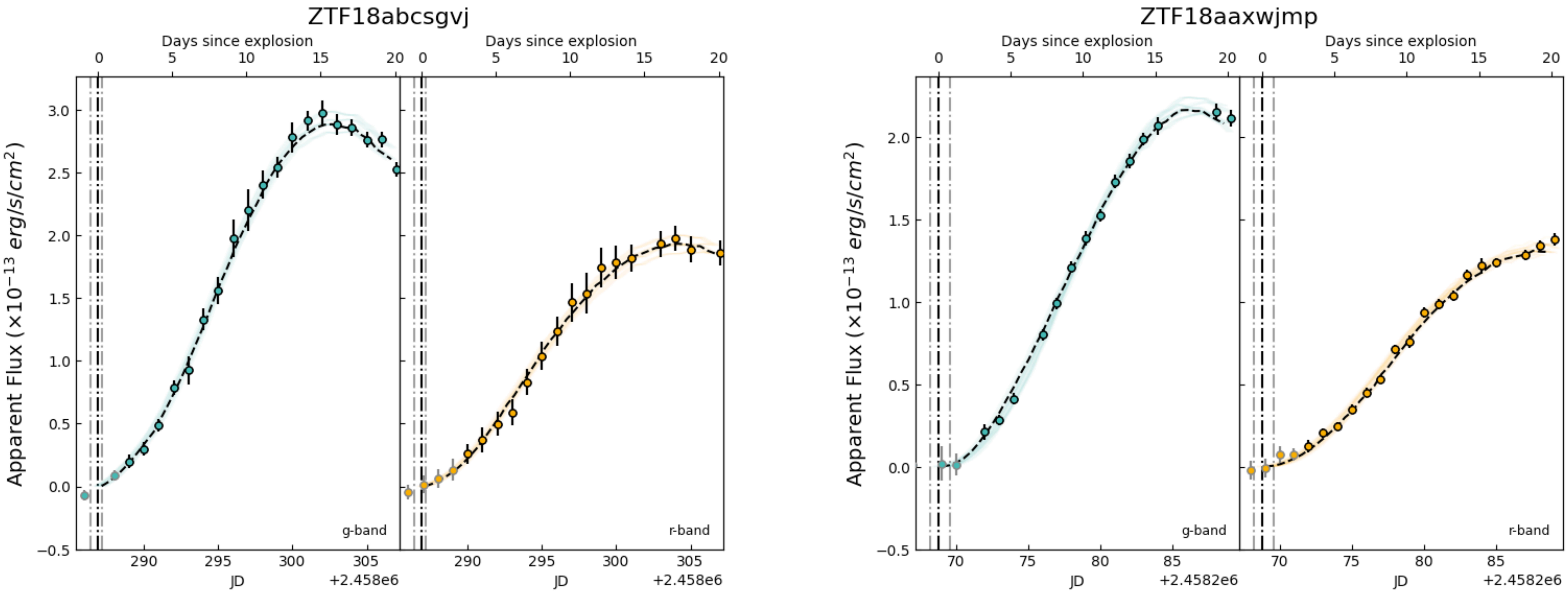


300 models of Chandrasekhar mass explosions with varying:

- Ejected Ni masses
- Ni distributions
- Kinetic Energies
- Density profile

Results

- ~75% objects well fit by Chandrasekhar mass explosions

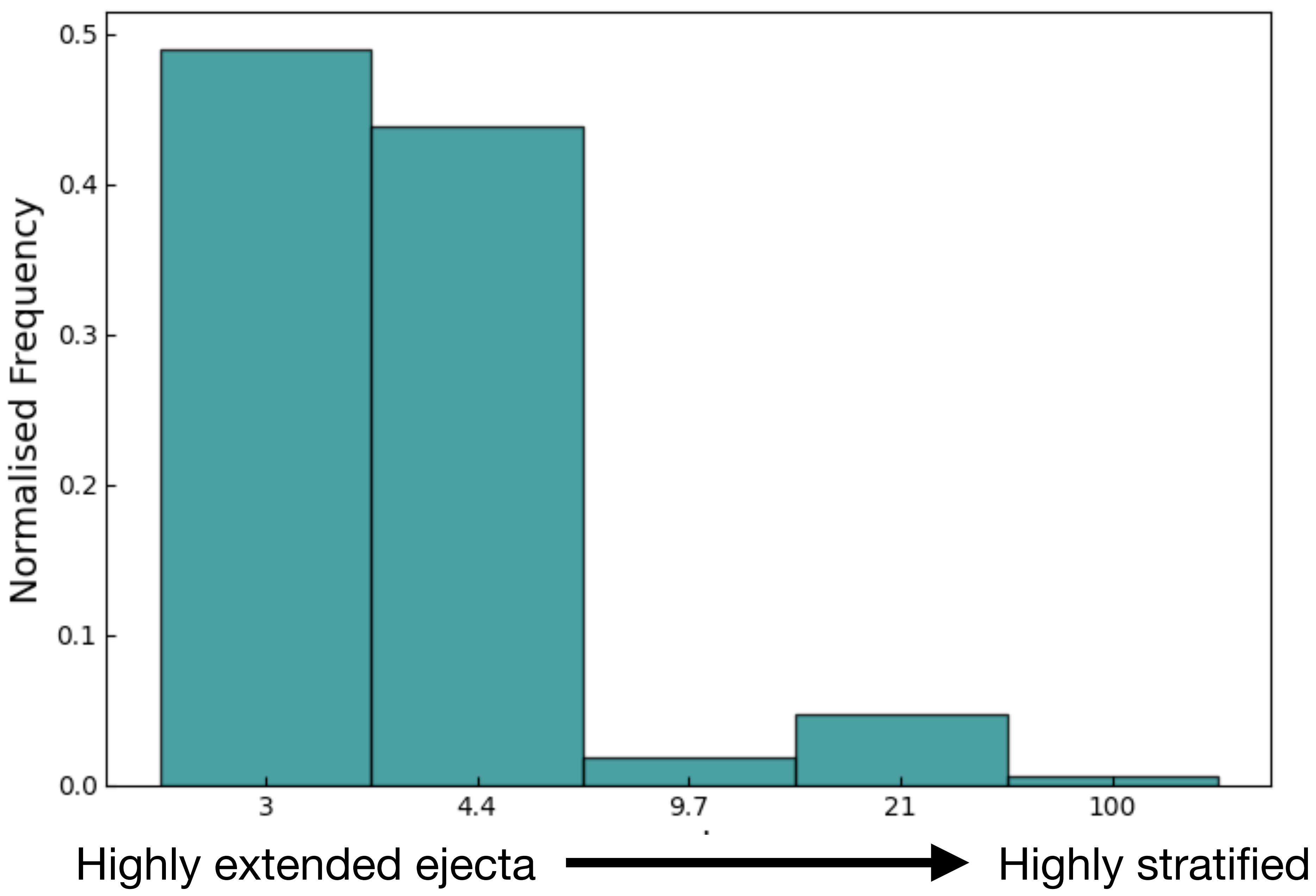


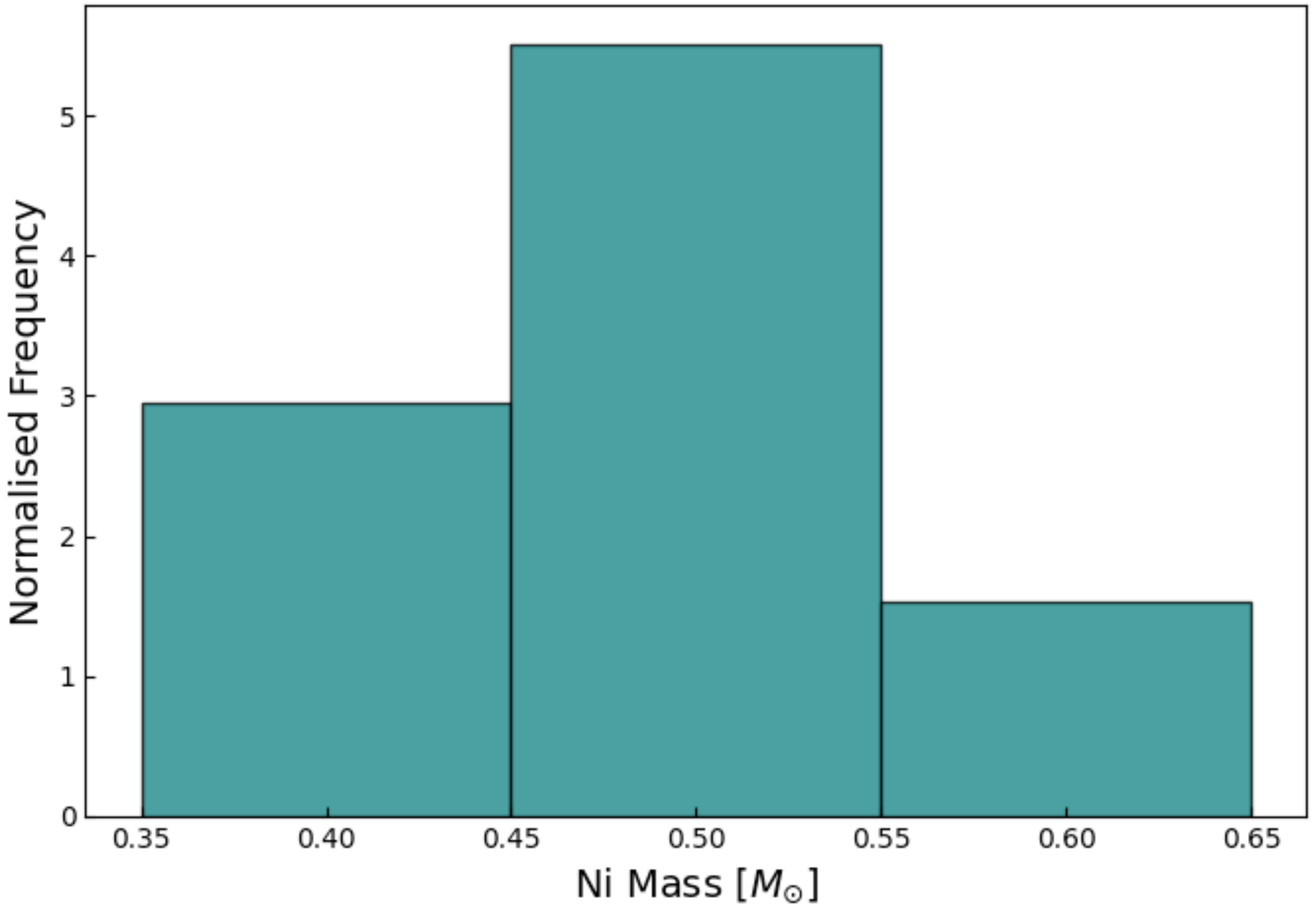
- **Could these objects also be fit by sub-Chandrasekhar mass models?**

Results

Well fit objects

- Models with highly extended Ni ejecta dominate sample - agreeing with previous results (e.g. Magee 2020)
- Ejected Ni mass spread between 0.4-0.6 solar masses





Implications for explosion mechanisms

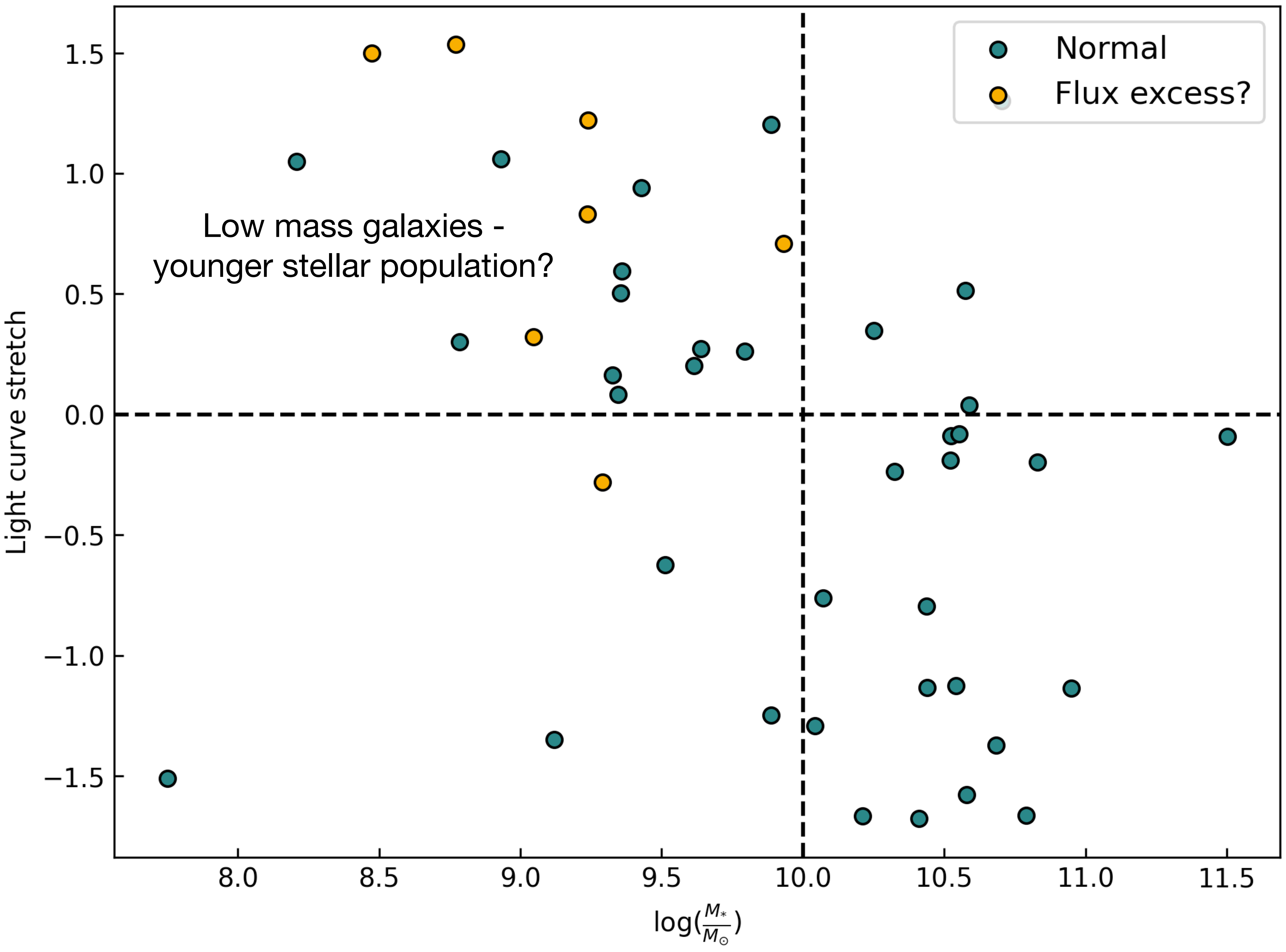
Delayed detonation models

Deflagration models

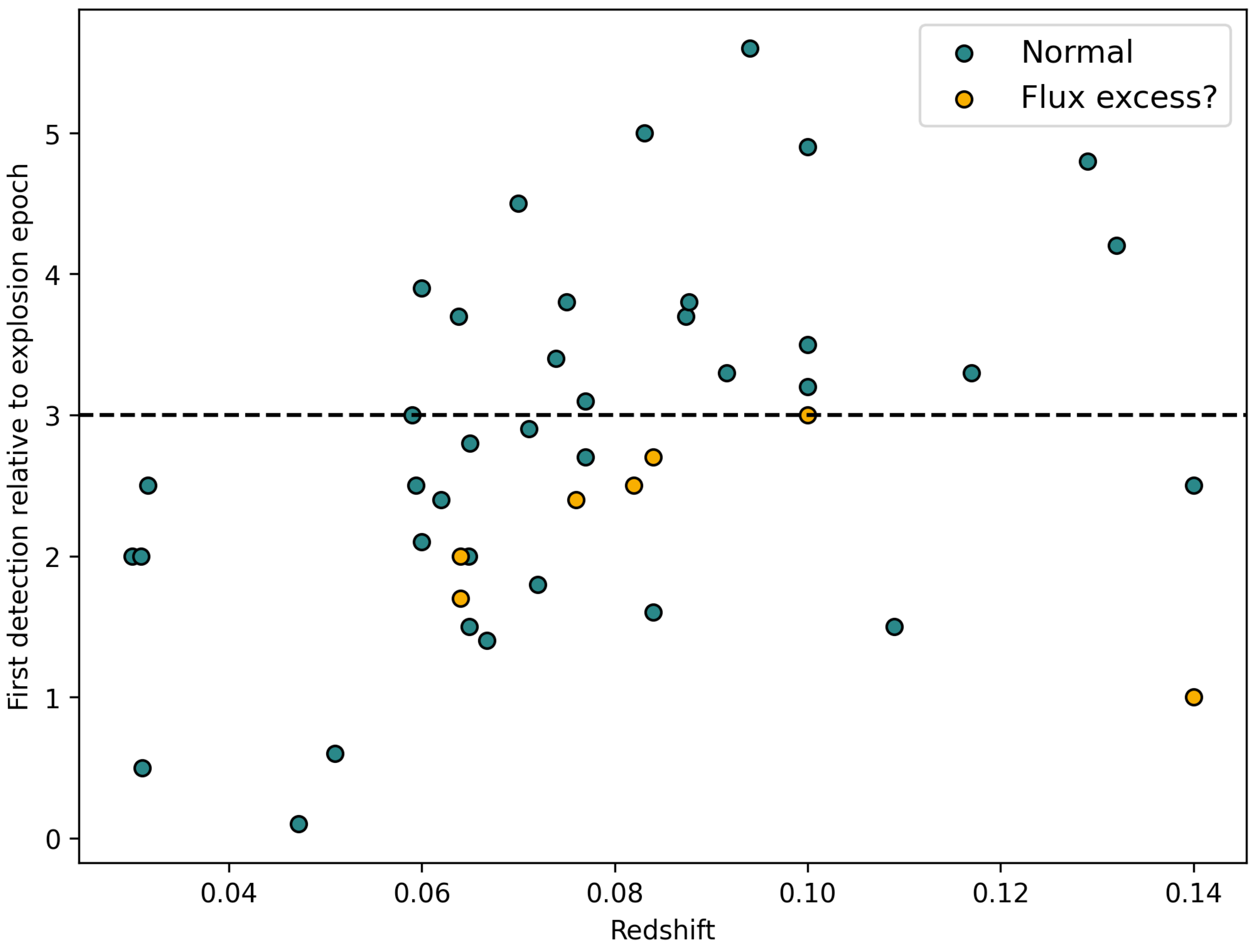
Flux excess (“bumps”)

- We detected a flux excess in 10% of objects based on residual conditions

Objects with flux excess



- The objects with flux excess all had a first detection within 3 days of explosion
- We could be missing many bumpy objects by discovering them too late



Conclusions

- 75% of objects in the ZTF 2018 sample can be modelled with Chandrasekhar mass explosions
- The TURTLS models are most comparable to delayed detonation explosions
- Only 3 normal SN Ia clearly can not be matched with Chandrasekhar mass explosions - these were all at the fainter end of the sample
- 10% objects showed a “bump” or shoulder in the light curve - these are found in predominantly low mass galaxies

Future work

- Refine the flux excess detecting routine - perhaps implement machine learning methods. Detecting bumps in real time could allow us to trigger rapid spectroscopic follow up, necessary for constraining the causes for the flux excess
- Apply this work to the ZTF 2019 sample

Thanks for listening!

Any questions?

Results

- 21 objects were not matched by any models from our grid
- Some due to lack of data or large scatter in data
- Some with early flux excess
- But: **Only 3 objects with a shape that could not be matched! (All faint and narrow)**