Helium as a Signature of Double Detonations in Type Ia Supernovae

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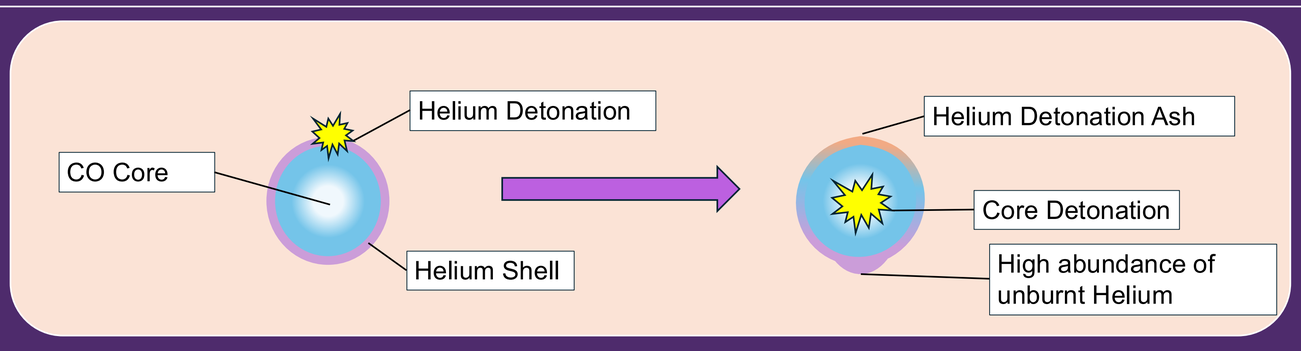
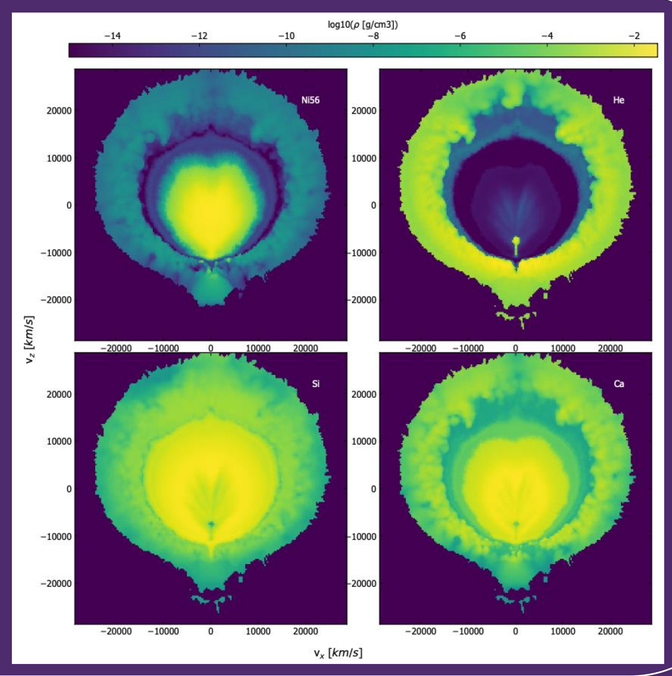
Double Detonation – a sub-Chandrasekhar Mass type Ia Supernova Model





Detonation of a **sub-Chandrasekhar Mass (<1.4M$_\odot$)** Carbon-Oxygen White Dwarf ignited by shockwave from He shell detonation.

Large abundance of unburnt helium in the ejecta – strongest line expected to be He I 10830Å.

Aim: To compare a suite of 3D Double Detonation models (Gronow+ 2021) to observations to see if they can replicate spectra of type Ia supernovae.

Method

Radiative Transfer:

1. **Model**
2. **Luminosity**
3. **Time since Explosion**
4. **Photosphere Velocity**

User defined parameters

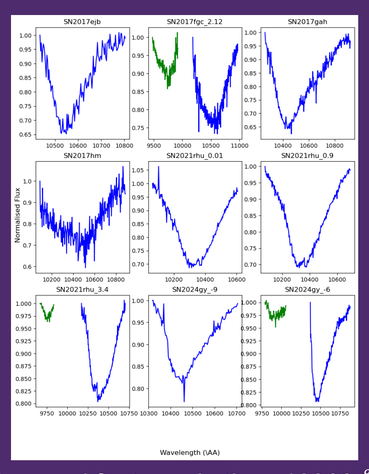
+ TARDIS ! Exploring supernovae made easy

(1D LTE Radiative Transfer Code)

Parameter grids for each observed spectrum → 500 – 1000 synthetic spectra

Observed Sample

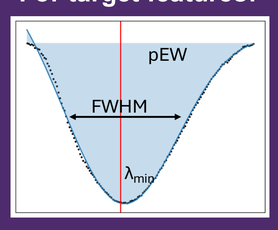
- 31 Spectra from type Ia supernovae
- Spectra from X-Shooter on the VLT
  - Simultaneous optical and near-infrared observations
- Mostly normal type Ia supernovae.
- Mostly within 5d of peak brightness.



Range of observed features in the ~10000Å region.
- *Not all spectra show a feature!*
- *Some show both a strong feature (blue) and a weaker feature to the blue side (green)*

Sort synthetic spectra by quality-of-fit score – no by-eye estimation!
(adapted from Ogawa + 2023)

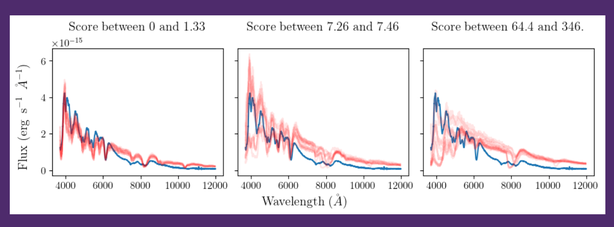
For target features:



The metrics used for determining quality-of-fit as compared to observed.

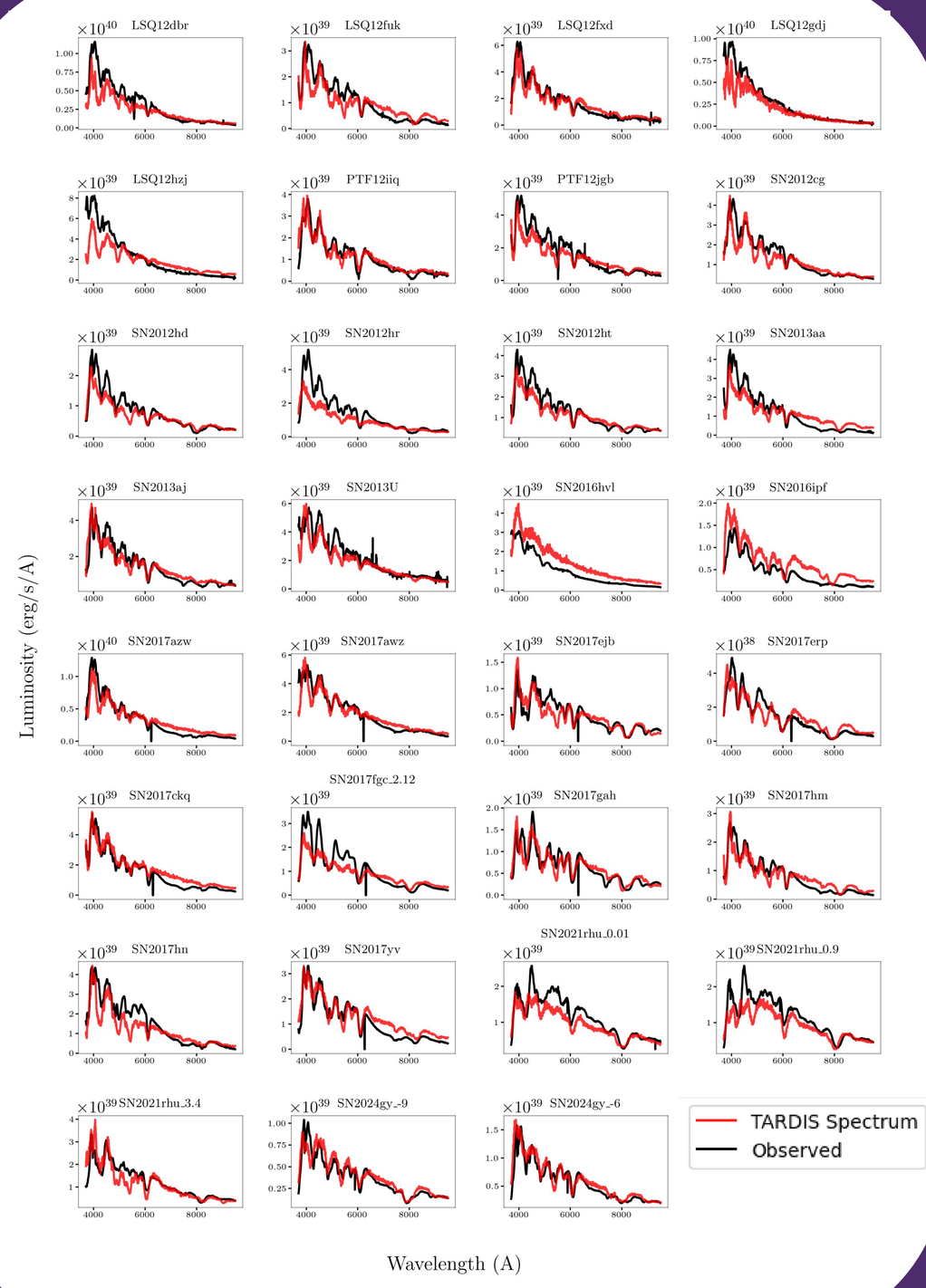
For overall spectrum:

- Spectrum colour
- Total Flux
- Maximum Flux



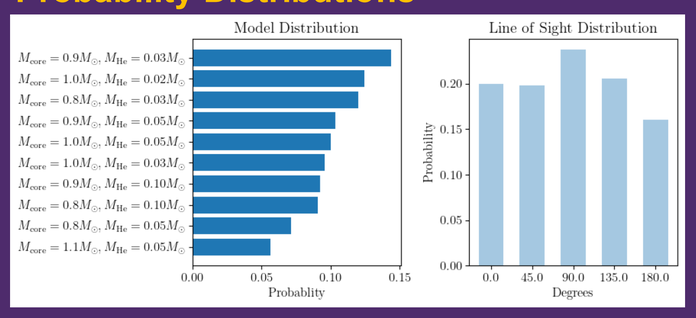
The scoring system in action – a few of the best, median and worst spectra from a parameter grid.

Observed Spectra compared to Best Match Synthetic Spectra



Results & Conclusions

Probability Distributions



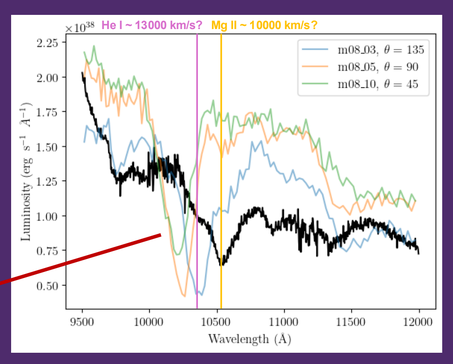
Probability distributions across the whole sample.
Models with smallest He shells are preferred.
Line of sight distribution broadly aligns with expected

$$w_i = \exp(-\beta s_i)$$

$$P_{\text{model}} = \frac{\sum_{i=1}^{m} w_i}{\sum_{i=1}^{N} w_i}$$

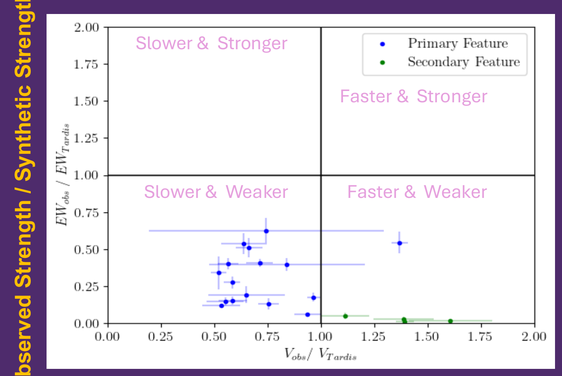
Calculating probabilities from quality of fit scores

Analysis of Absorption Features



Synthetic He features

Synthetic He features from best fitting models are much too strong and at too high a velocity



Key Takeaways :

Double Detonations can replicate a range of observed spectra
- With and without He features!

Models with smaller He shells seemingly preferred
- Smallest He shell available for each core mass is preferred by more spectra.

Observed He features not well replicated
- Too strong and at too high a velocity.
- He shells are too massive?

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