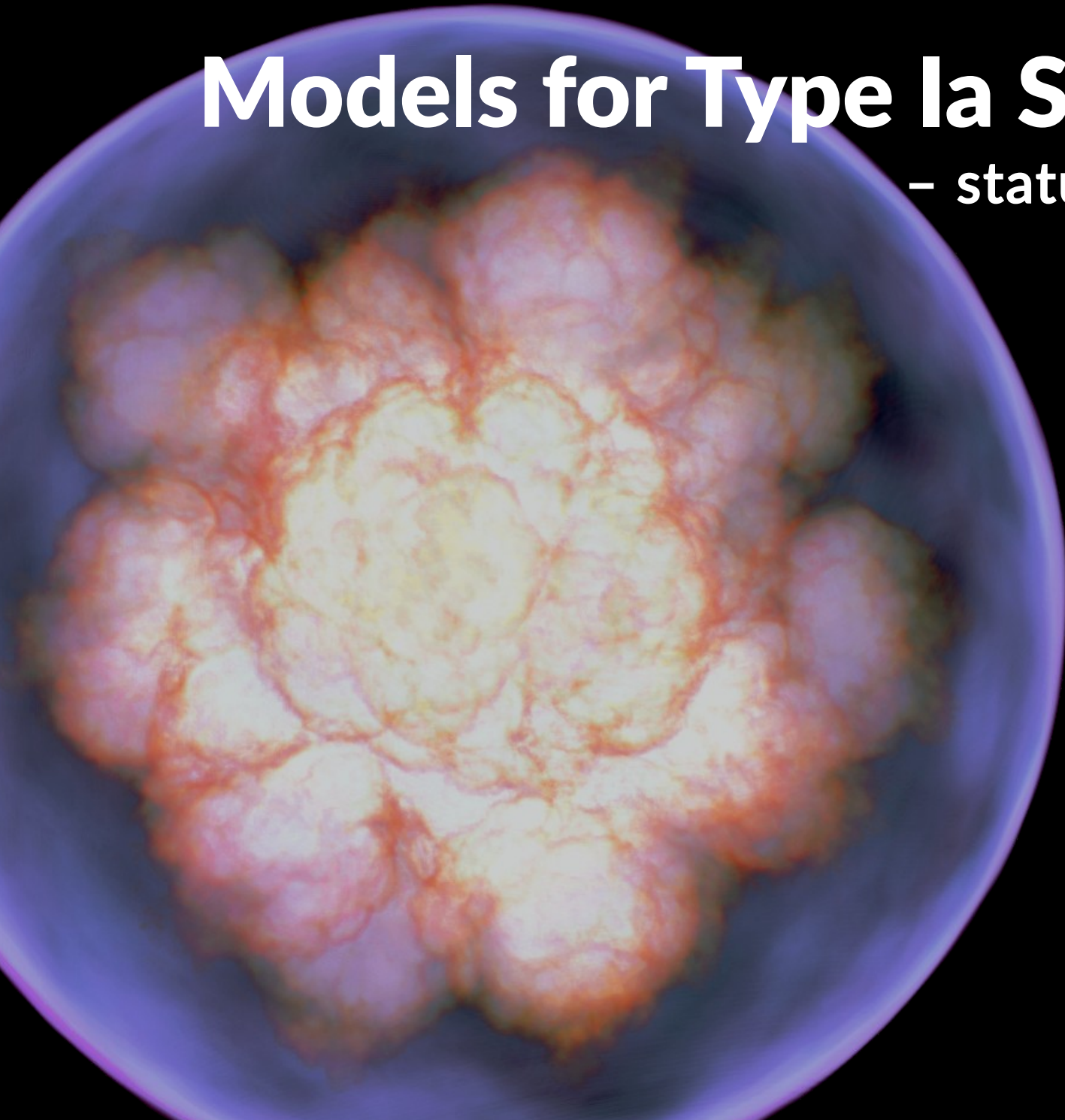


Models for Type Ia Supernovae

– status and challenges

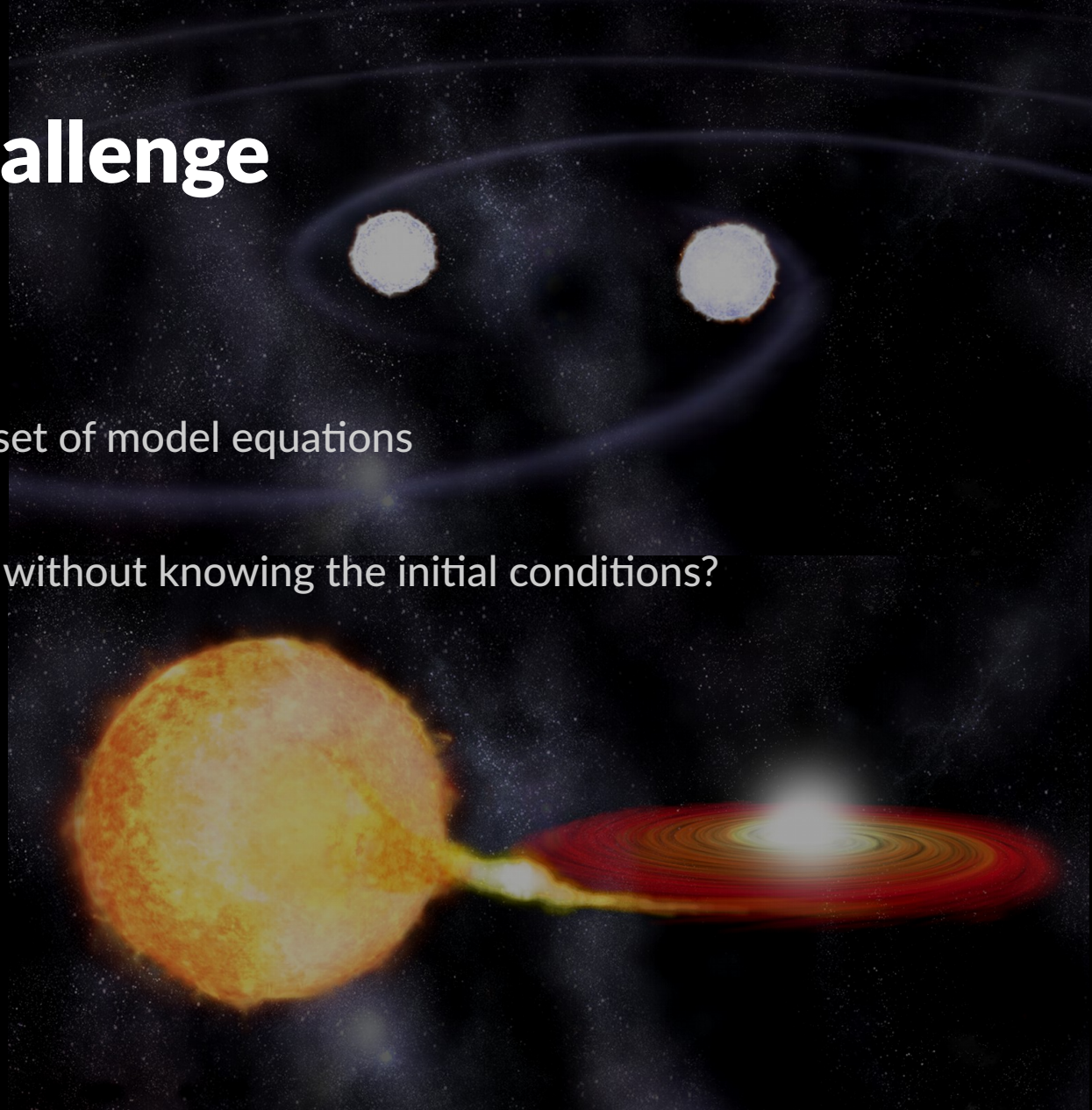


Friedrich Röpke



The progenitor challenge

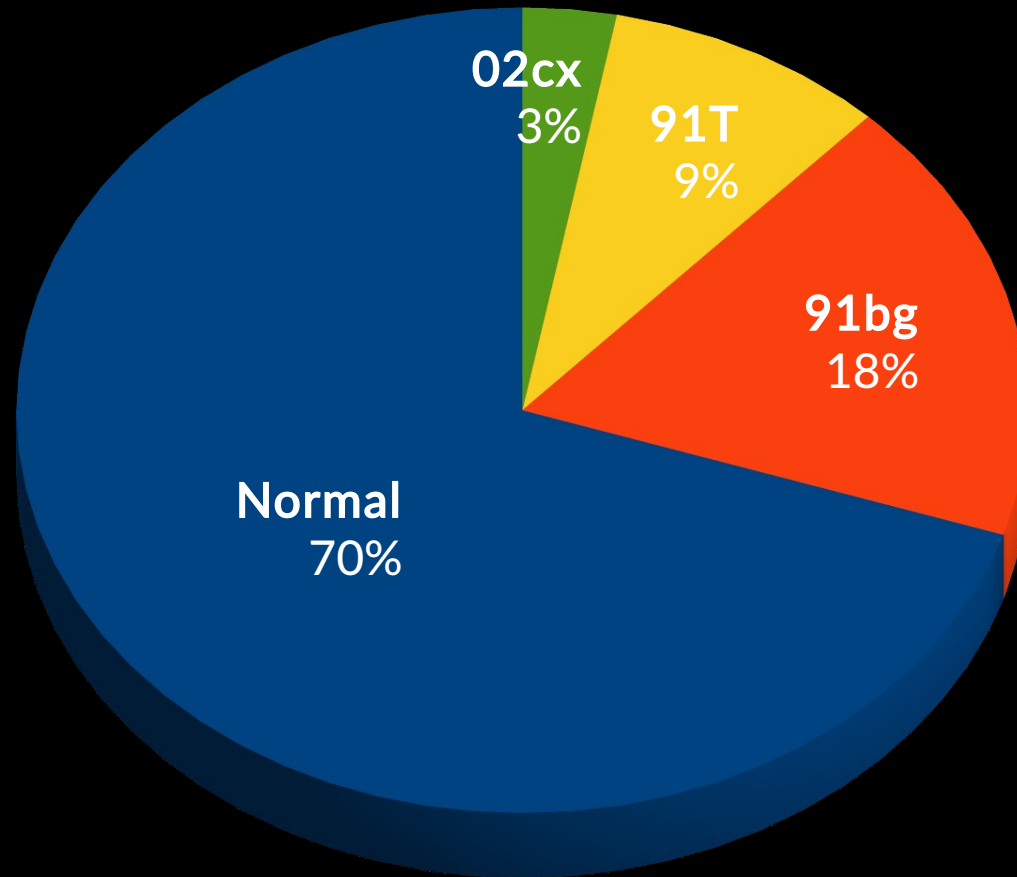
- ▶ Initial conditions for hyperbolic set of model equations
- ▶ Can we make useful statements without knowing the initial conditions?
- ▶ What can we test?



(Illustrations: NASA/CXC/M.Weiss)

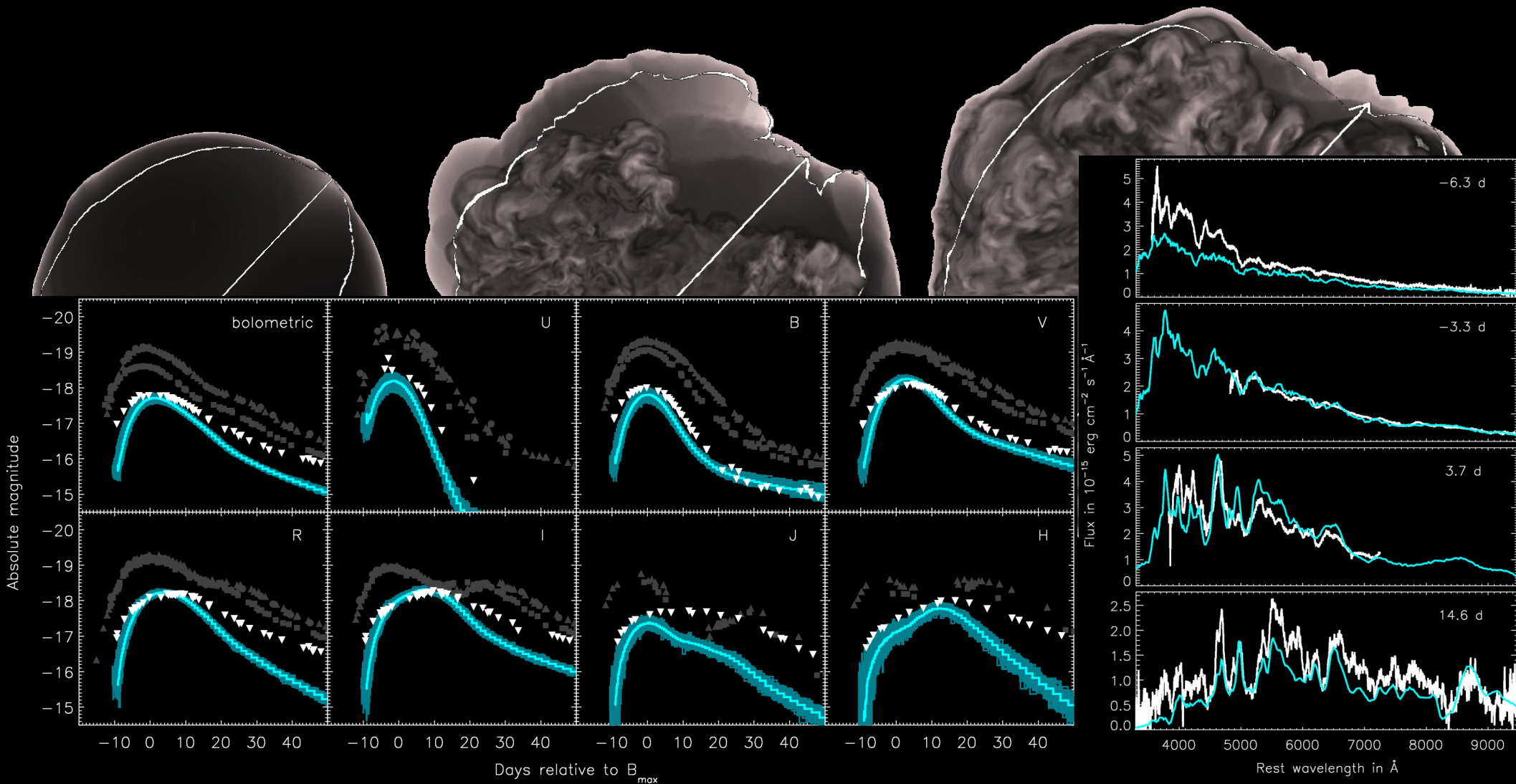
Lessons from observations

- ▶ SN Ia diversity (e.g. Li + 2010)



Chandrasekhar-mass model

- ▶ Can reproduce some (peculiar) events and perhaps some sub-classes well → pure deflagrations



Chandrasekhar-mass model

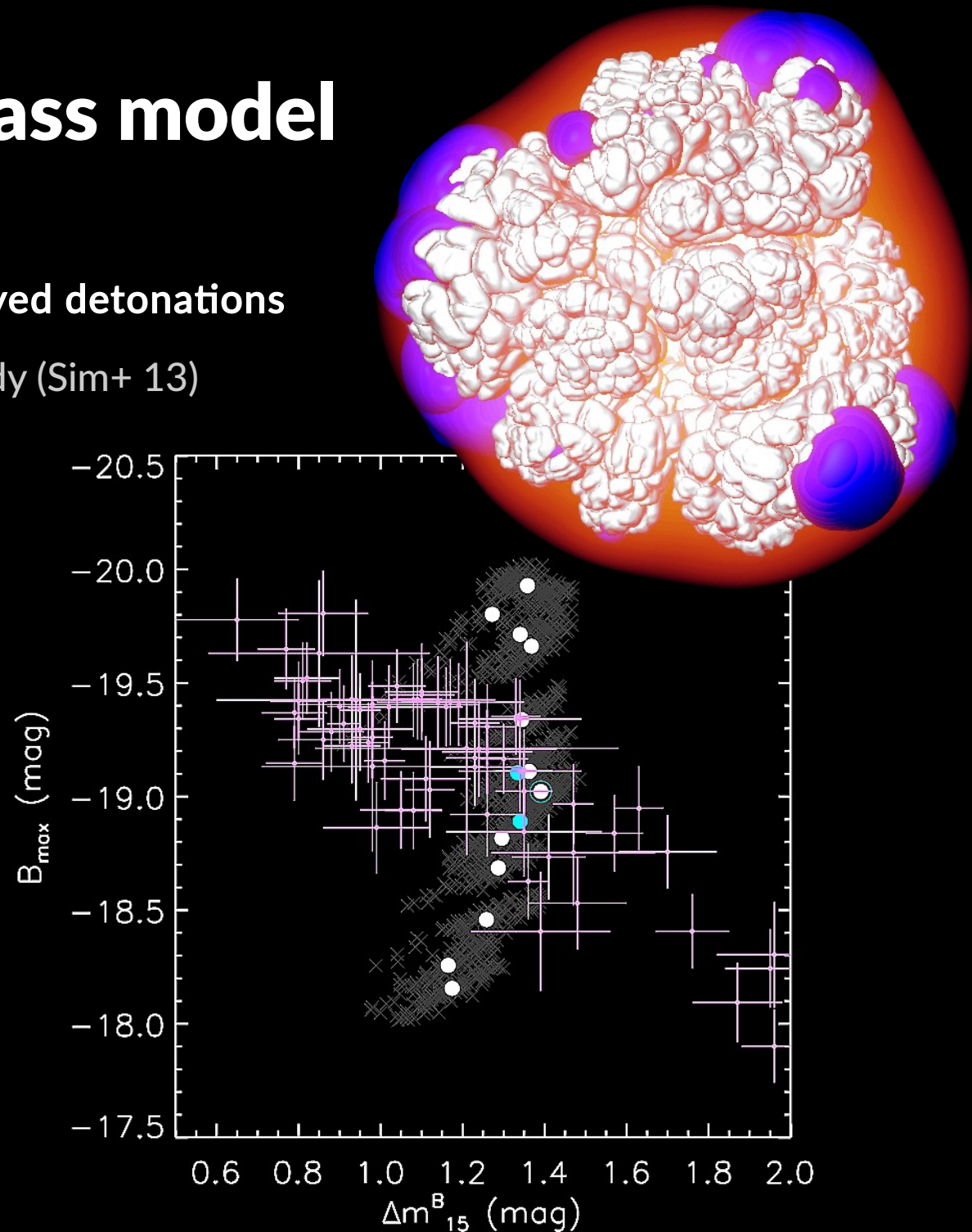
- ▶ Model for normal SN Ia? → **delayed detonations**
- ▶ 2D study (Kasen+ 09) vs. 3D study (Sim+ 13)

- ▶ **Main problems:**

- ▶ M_{Ch} WD in hydrostatic equilibrium
- ▶ Fixed mass → not enough fidelity for reproducing range of observables (?)
- ▶ Problems even (and especially) with trends

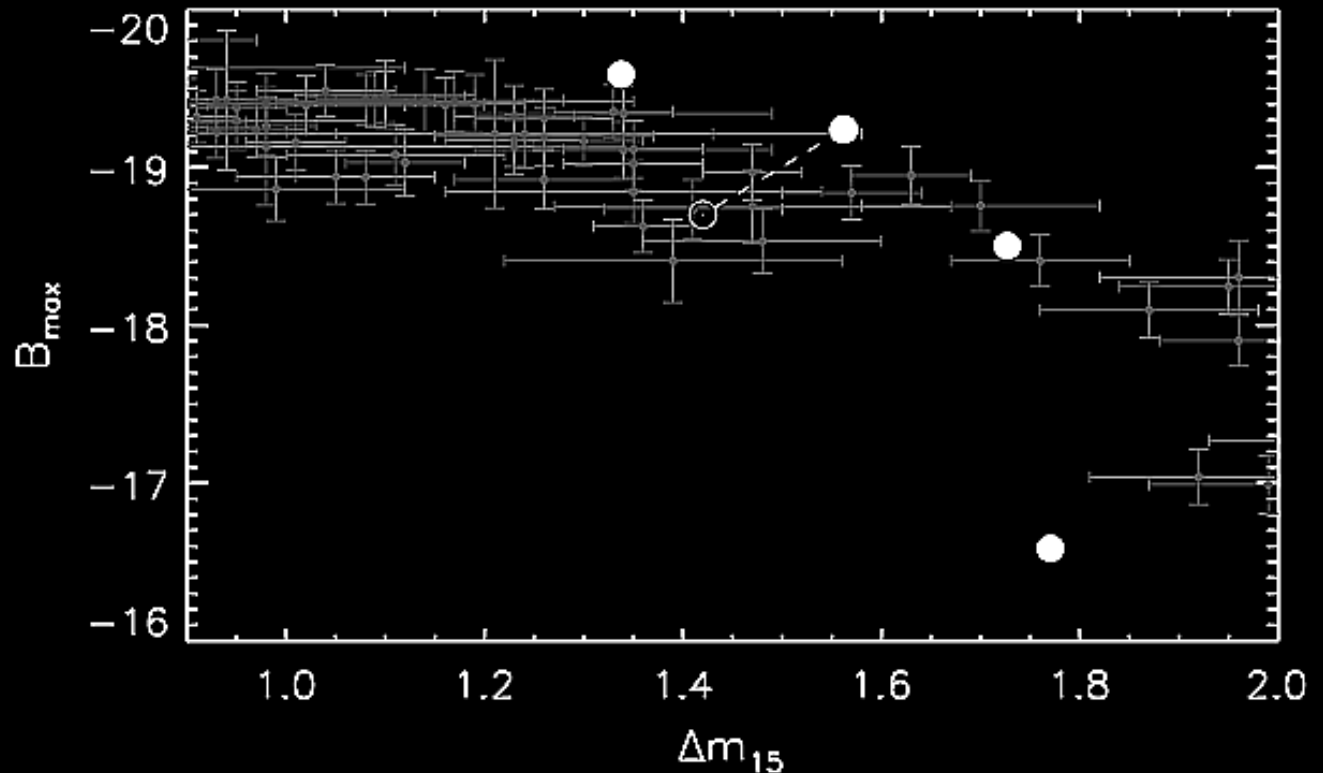
- ▶ **Other models?**

GCD? Detonations triggered in pulsational phases?



Detonations in sub- M_{Ch} WDs

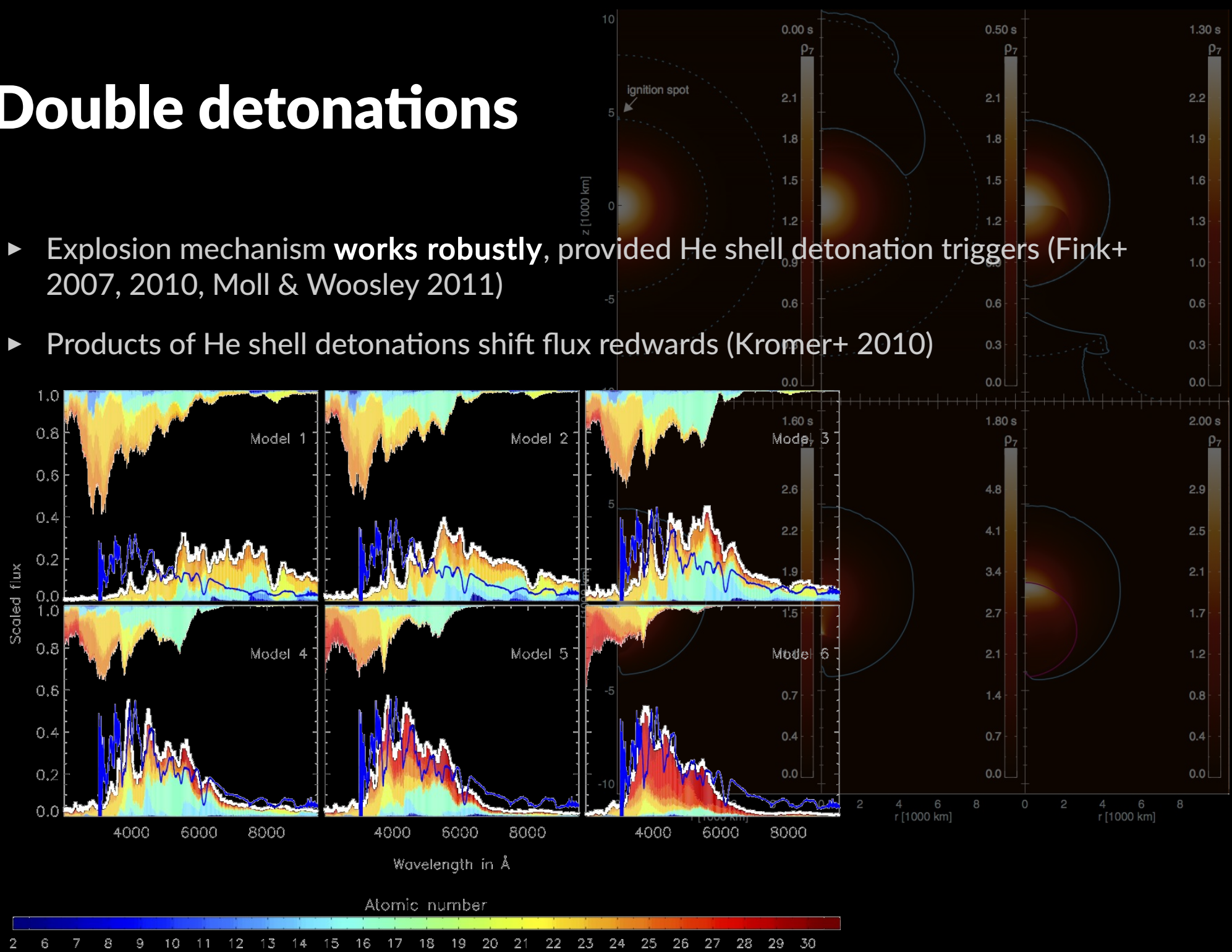
- ▶ Promising scenario (Sim+ 2010)



- ▶ Primary parameter driving trends: mass of exploding WD (see Pinto & Eastman 2000)
- ▶ How to trigger detonation?

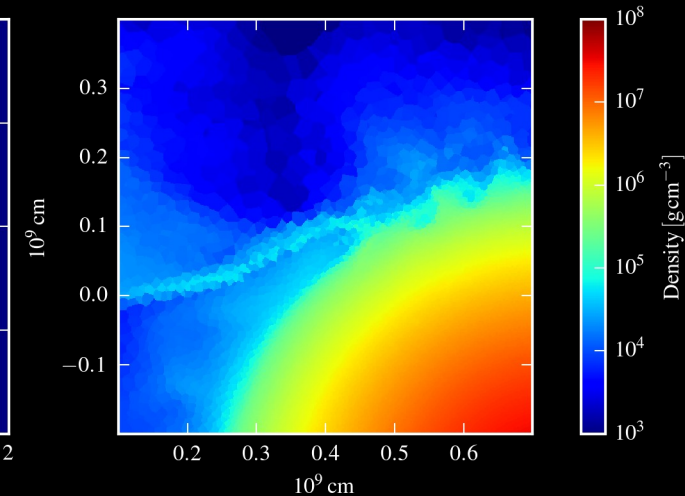
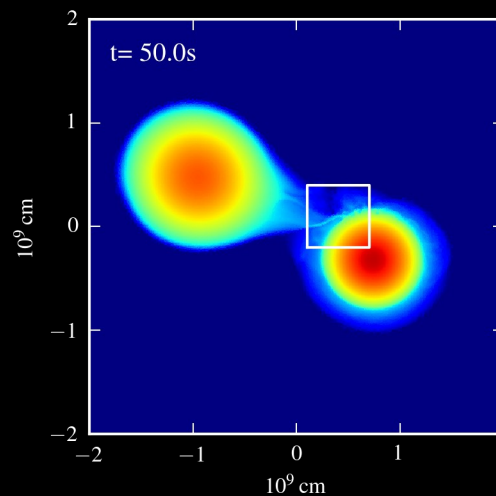
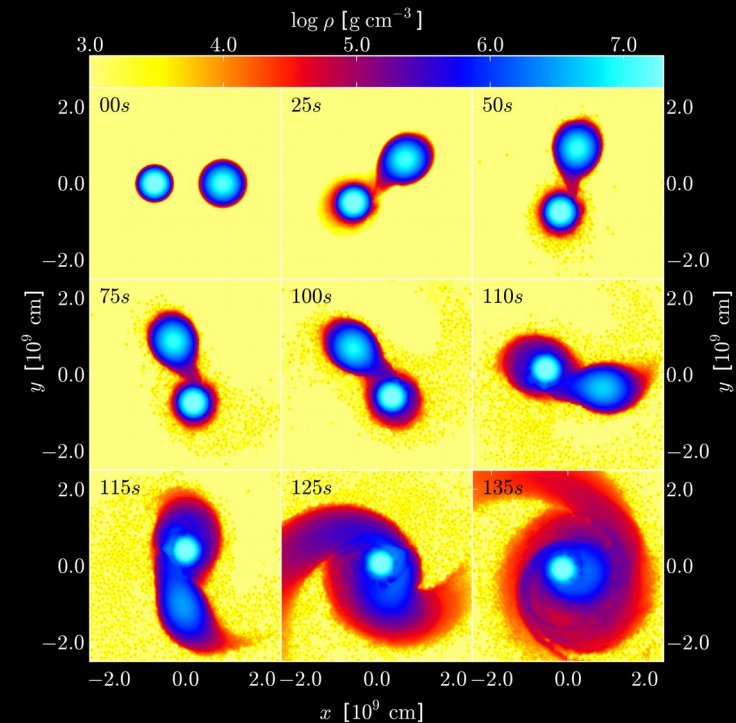
Double detonations

- ▶ Explosion mechanism **works robustly**, provided He shell detonation triggers (Fink+ 2007, 2010, Moll & Woosley 2011)
- ▶ Products of He shell detonations shift flux redwards (Kromer+ 2010)



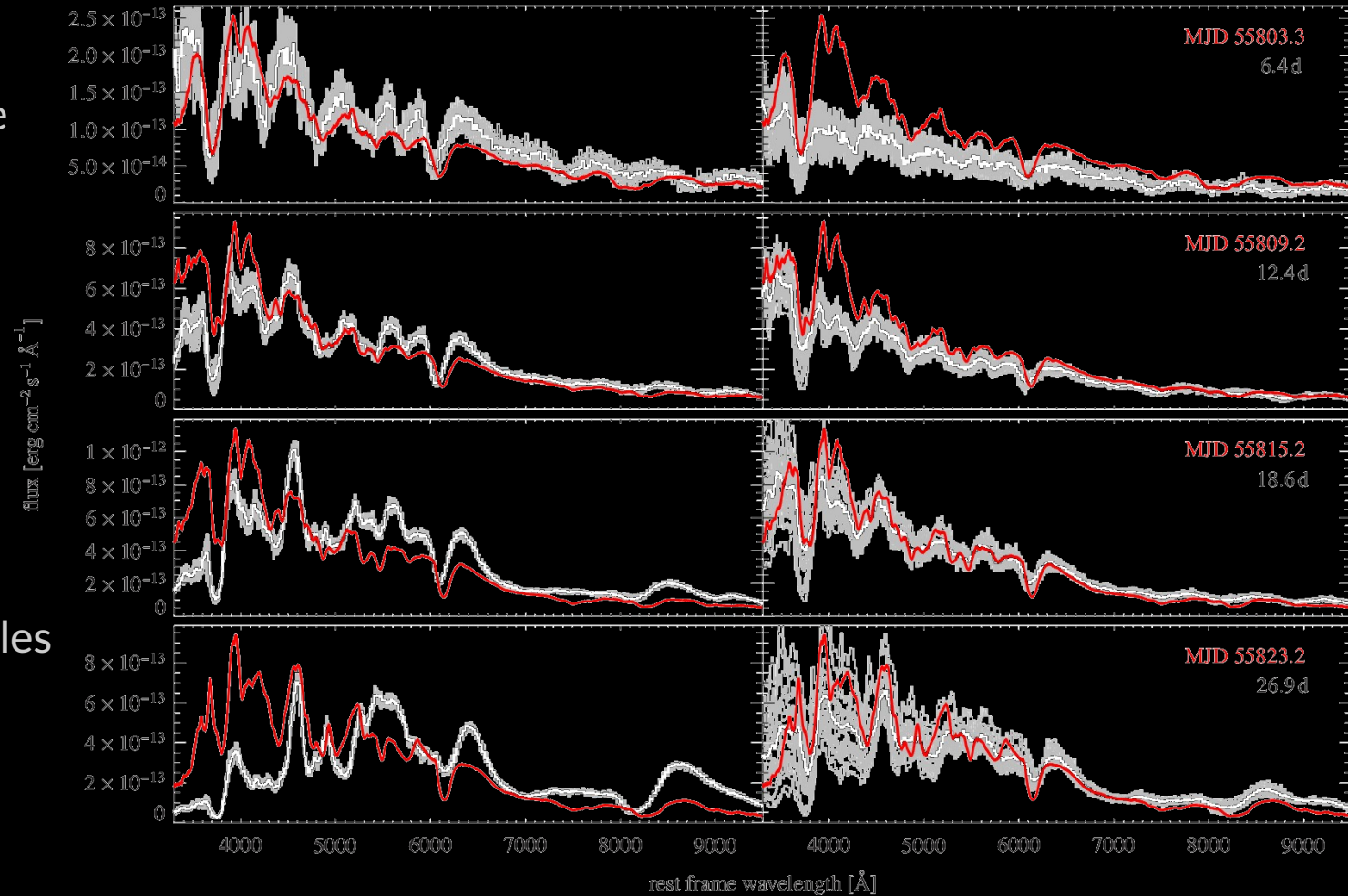
WD mergers

- ▶ Most promising model (?): **violent merger**
(Pakmor+ 2010,2011,2012)
- ▶ possibly **He-ignited** (Pakmor+ 2013)
- ▶ **Variant of sub- M_{Ch} detonation model**
- ▶ May reproduce observed brightness distribution of SNe Ia
(Ruiter+ 2013)
- ▶ Parameter space not fully explored



Predicted observable signatures

- ▶ Not much difference in optical
- ▶ Or not precise enough?
- ▶ Hope: late observables
- ▶ Nucleosynthesis
- ▶ Spectrapolarimetry
- (Bulla+, 2015,2016)
- ▶ Nebular spectra
- ▶ Gamma ray observables



Current status:

- ▶ We can explain some sub-classes (O2cx, 10lp, Kromer+ 2013a,b)
- ▶ There are suggestions for explaining normal SNe Ia, but these have to be tested more rigorously

- ▶ **We are not (yet?) very useful for SN Ia cosmology...**

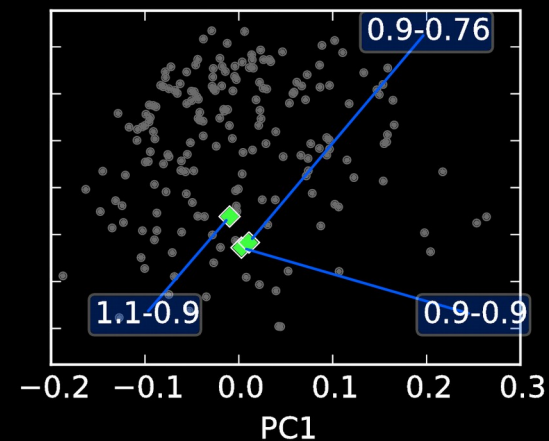
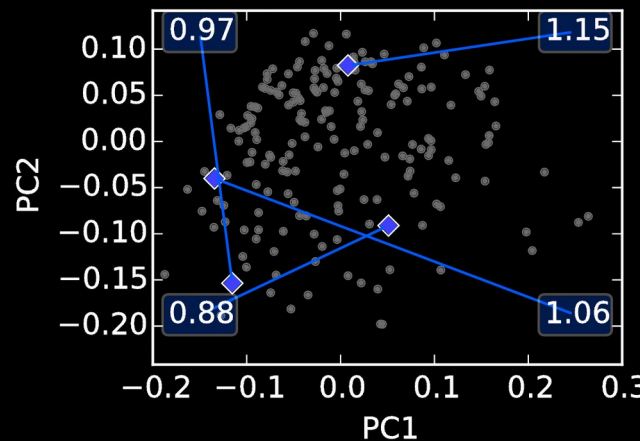
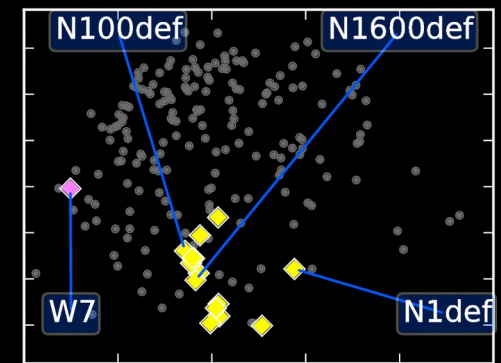
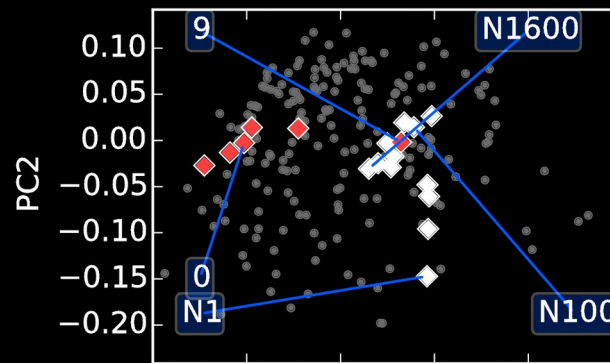
How to proceed?

- ▶ Observe a nearby SN Ia and identify progenitor system → is this enough?
- ▶ Simulate **model series** and search for **systematic trends**

- ▶ Which trends do we expect from models and observations?
- ▶ How do they relate to physical properties of the models?

→ **systematic analysis of observables**, e.g.

Sasdelli+ 2015, 2016 subm.



Expectations & discussion

- ▶ What exactly are the questions cosmologists want to have answered from modeling?
→ your ideas ?...