SNe Ia: Can Chandrasekhar Mass Explosions Reproduce the Observed Zoo?

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Collaborators

- Gerry Brown
- Hans Bethe
- Jerry Cooperstein
- Sid Kahana
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- David Branch
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- Mark Phillips
- Eric Hsiao
- Kevin Krisiunas
- Lifan Wang
- Nick Suntzeff
- Alexei Khokhlov

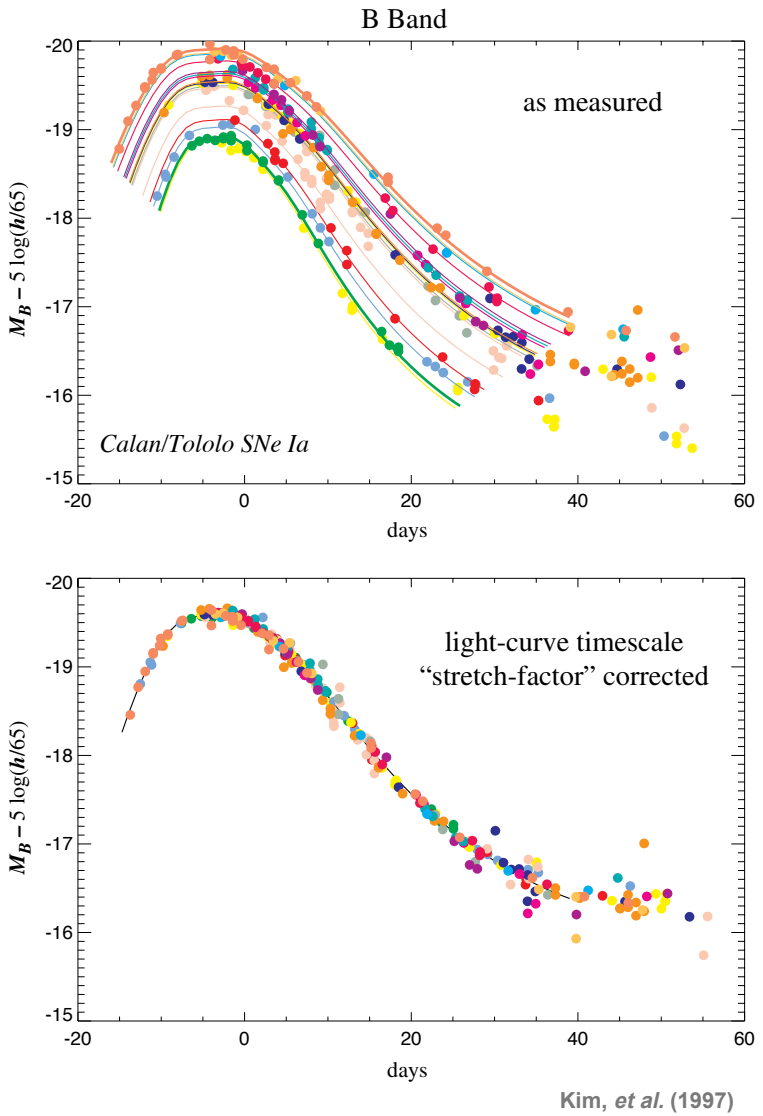
Gerry, Hans, & Me

Gerry and me

- I was a problem child
- I failed the first tests with flying colors
- After that I continued to get into trouble
- At the crises Gerry supported me
- Gerry's sense of fair play

Light Curve Shape

Type Ia Supernovae are “Correctable Candles”



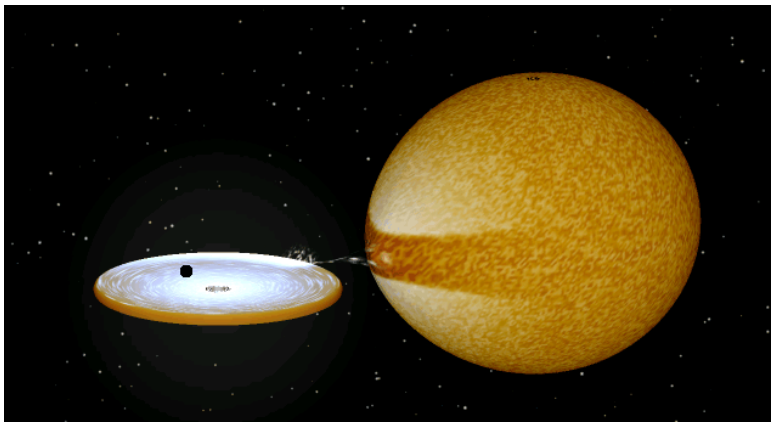
Kim, *et al.* (1997)

Homogeneity

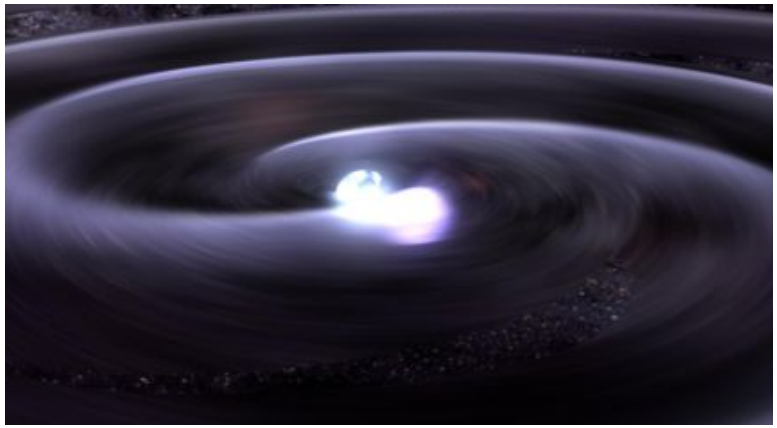
- Homogeneity derives from Chandrasekhar mass explosion of C+O white dwarf
- Phillips relation variation is due to differing amounts of $^{56}\mathrm{Ni}$ produced

Progenitor Systems

Single Degenerate



Double Degenerate



Hydro Models of SNe Ia

- WD Initial Conditions Unknown
- 100 years before ignition: “smouldering phase”, turbulent convection $\longrightarrow$ flame could start at center *or* in convective plumes
- Flame Starts out as subsonic deflagration
- Pure detonation doesn’t reproduce observations: Just $^{4}\mathrm{He}$ + $^{56}\mathrm{Ni}$

Deflagration Models

- W7
  Parameterized Deflagration Model, Flamespeed altered to produce desired nucleosynthesis.

W7 Composition Structure

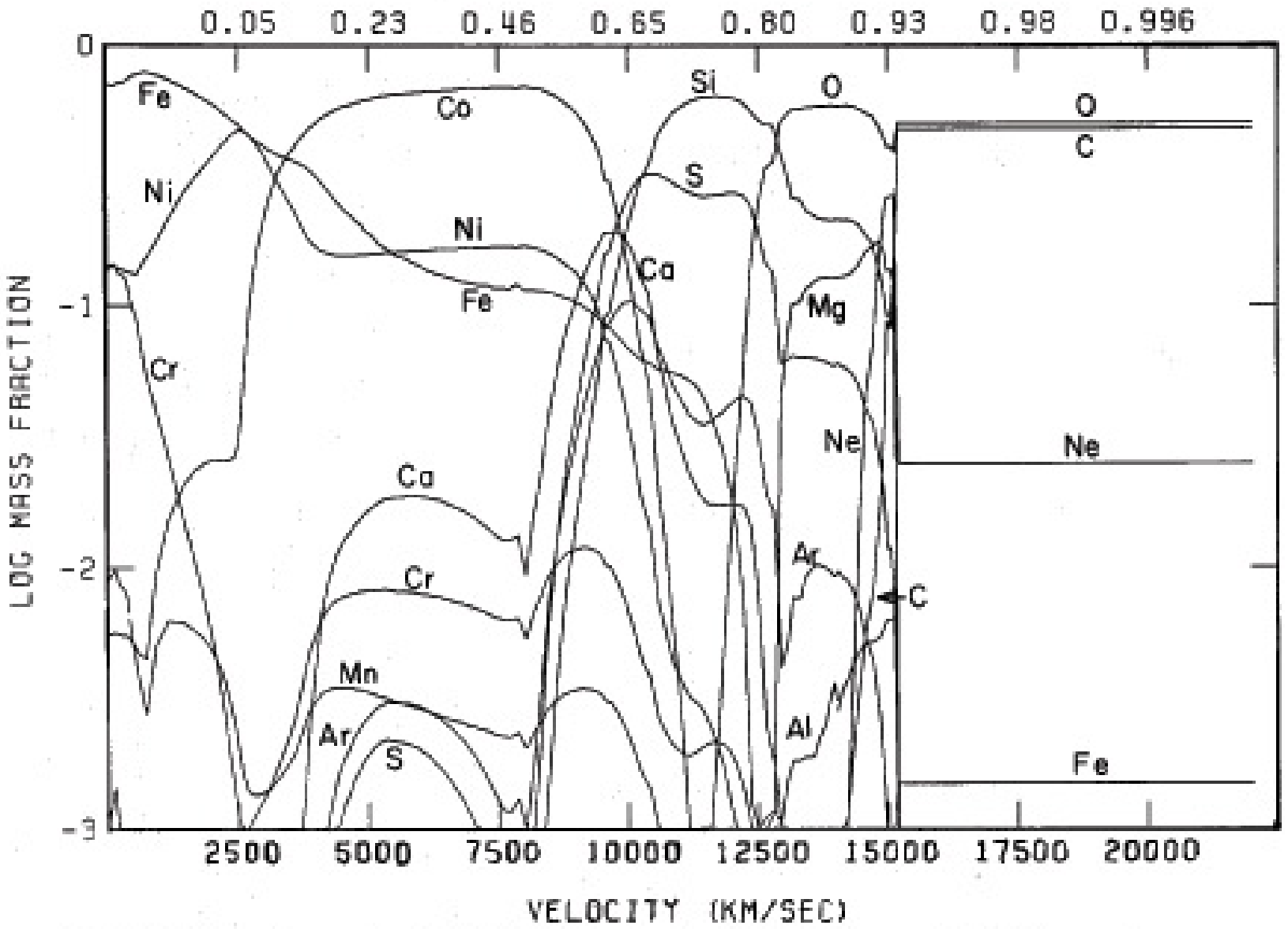
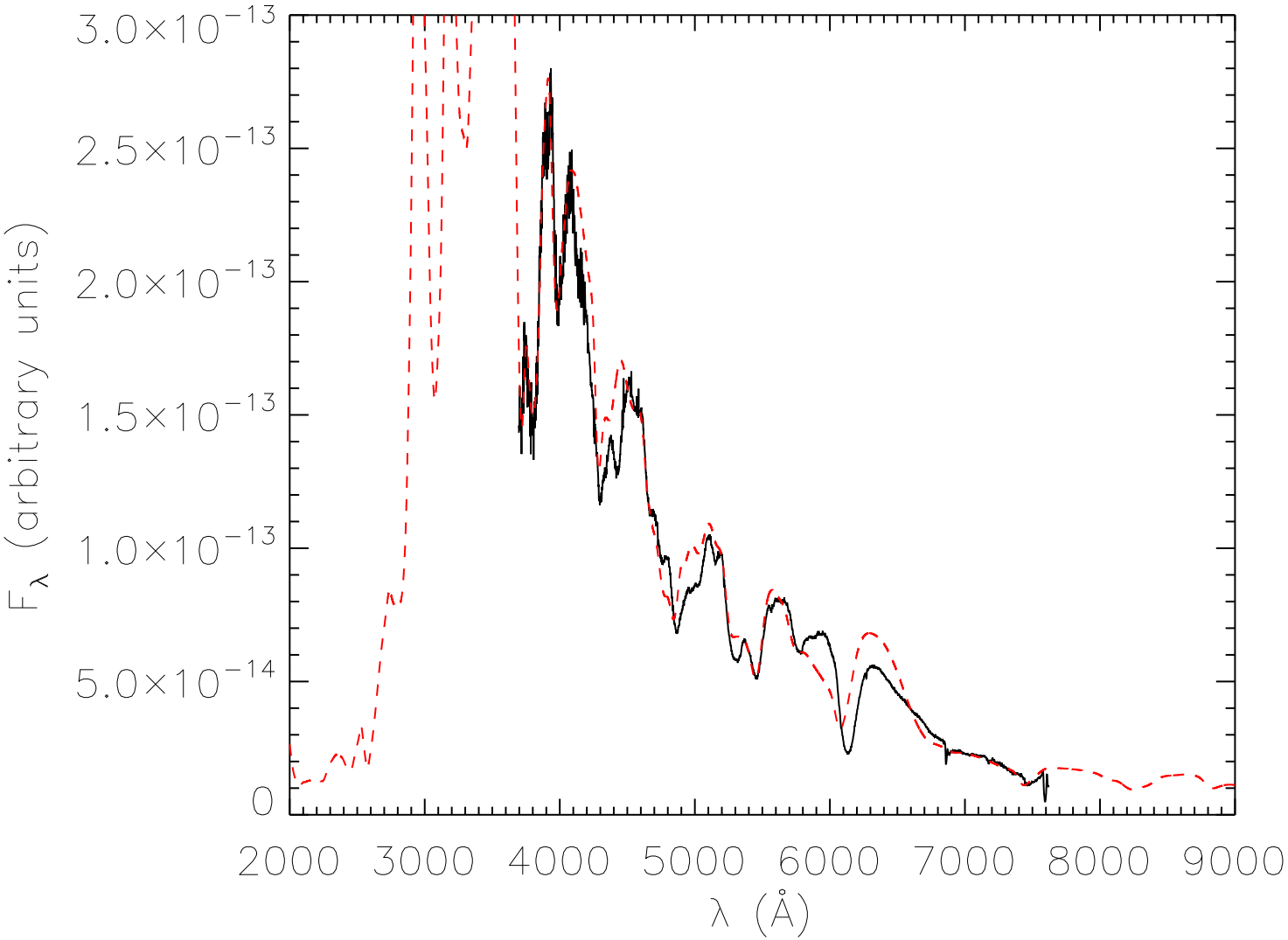


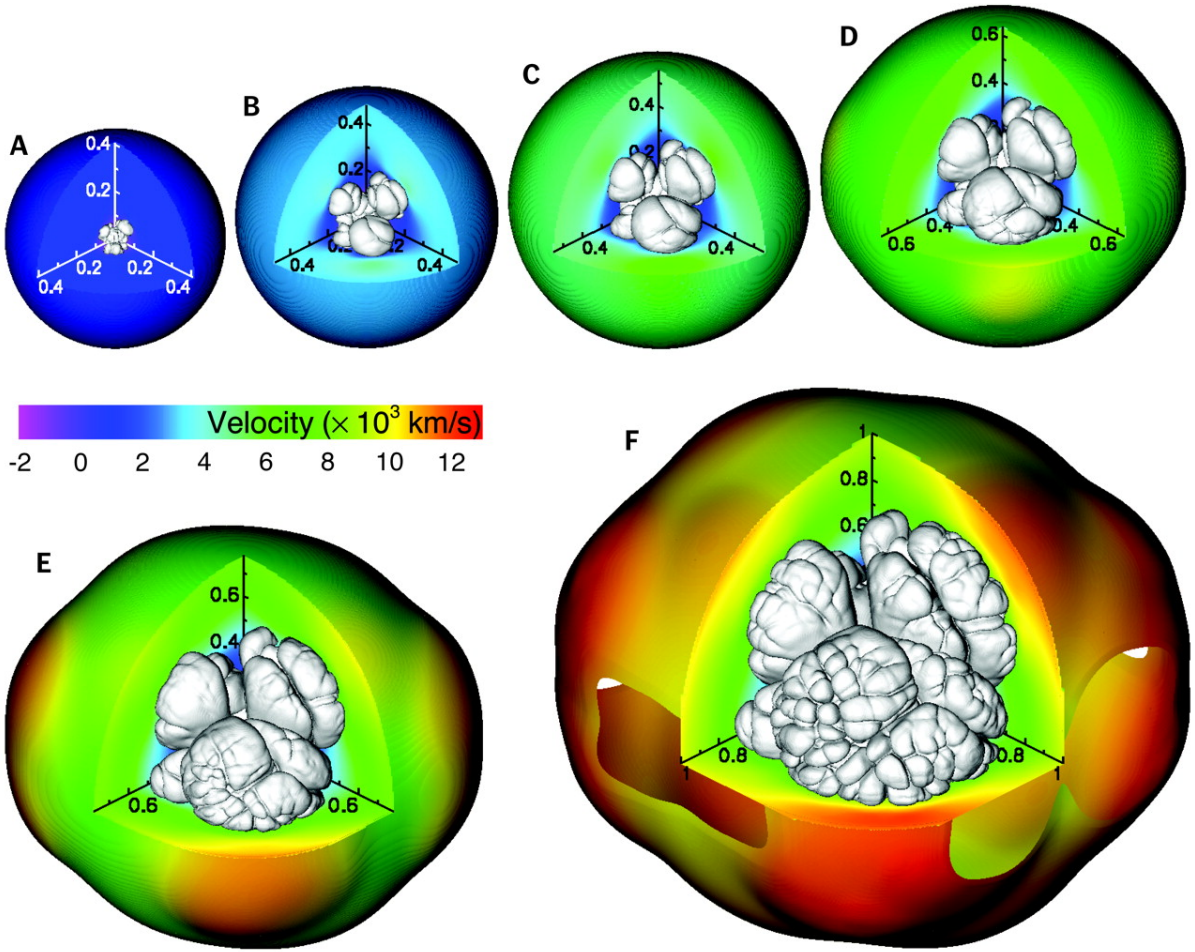
FIG. 2.—The elemental composition of model W7 15 days after the explosion. Interior mass fraction is shown at the top.

W7 NLTE 1994D March 21



3-D Models: Deflagration

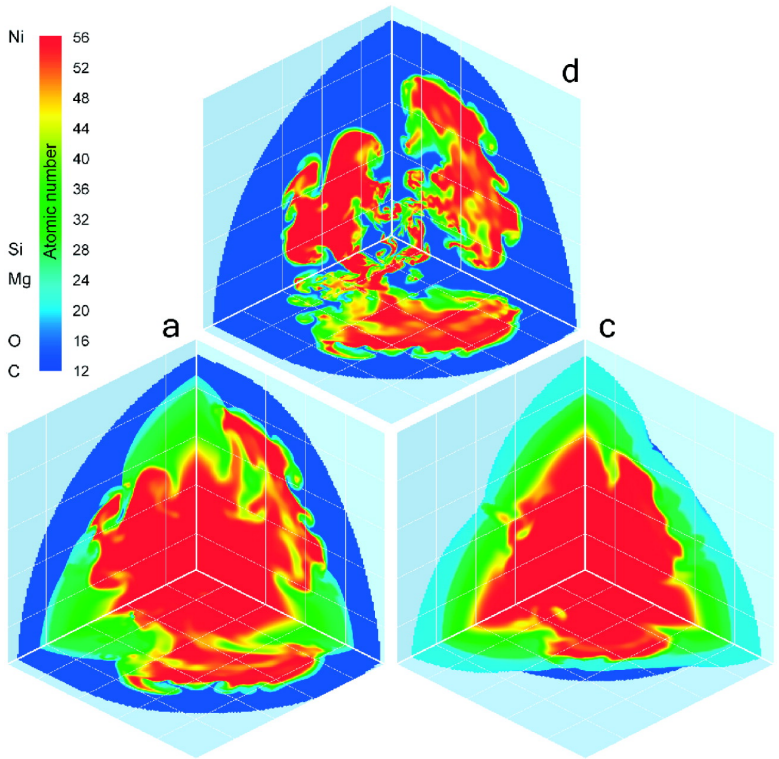
low energy, lots of clumps of unburned material particularly near center (SN Iax?)



3-D Models: Delayed Detonation

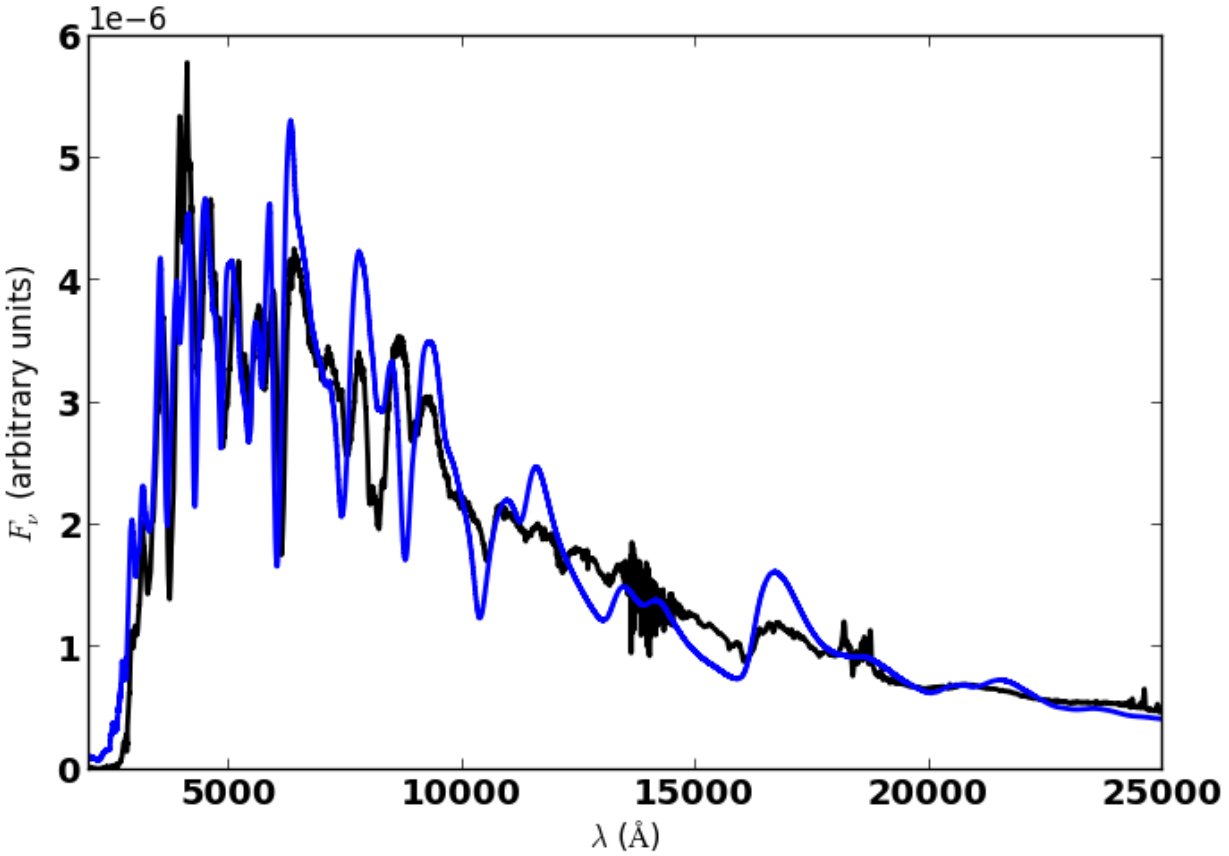
Gamezo et al.

Allows star to pre-expand. “Sphericizes” deflagration. Does it happen in unconfined WD? No carbon left?



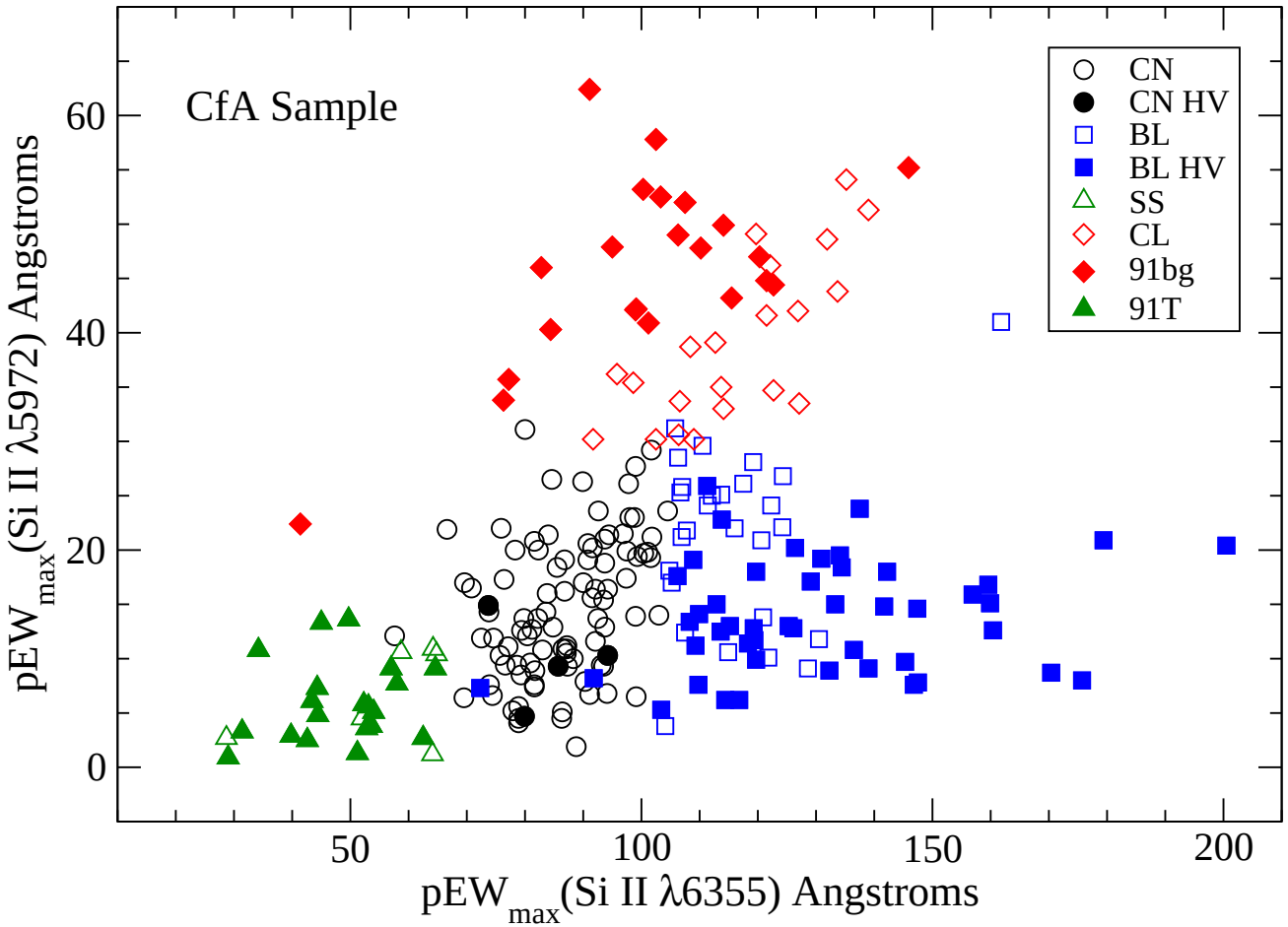
SN 2011fe

Detailed NLTE Spectrum of Delayed Detonation Model



W vs W Diagram

Branch et al. diagram of the Si II pseudo equivalent widths

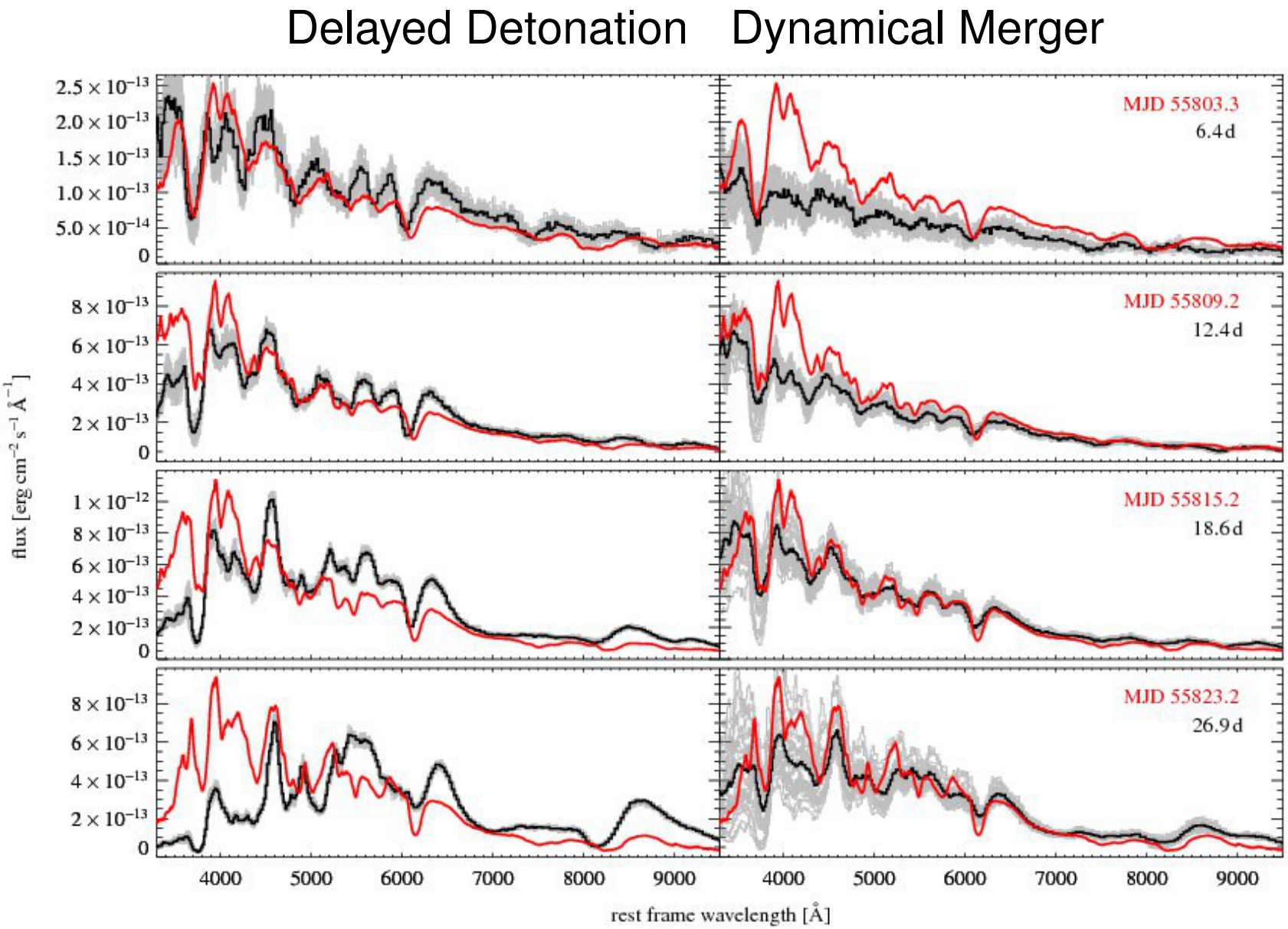


Diversity

2000cx	rare, don't follow the Phillips relation, standard rise, very slow decline, high photospheric temperature
2006bt	Broad light curves like a hot, luminous event spectra at maximum similar to those of low-luminosity SNe Ia.
2001ay	a BL-HVG event with an extremely slow decline rate but with an apparently modest ^{56}Ni yield of 0.6 solar masses.
2002cx	very narrow lines, low luminosities for the decline rates, but hotter photospheres
2002ic	SNe Ia-like events with a strong CSM interaction
Super-Chandra	2003fg, 2006gz, 2007if, 2009dc on basis of brightness and light curve shape

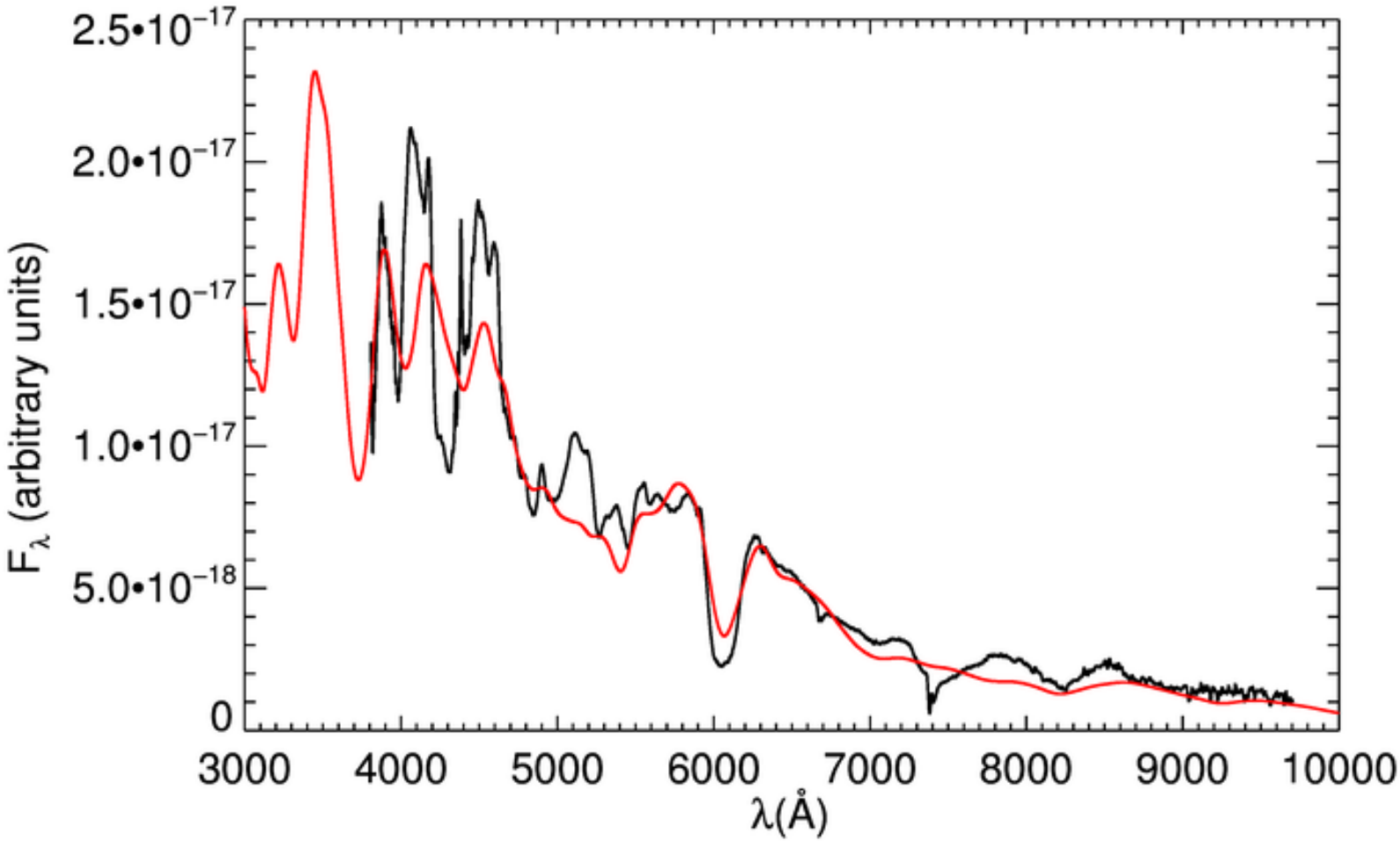
SN 2011fe

Röpke et al. 2012



Pulsating Delayed Detonation

SN 2001ay, Max Light, M_V = -19.07 mag



Summary

- Phillips relation implies strong homogeneity
- Chandra mass + Nuclear Physics gives good homogeneity
- How much diversity can fit into the Chandra mass paradigm?

Gerry and Hans