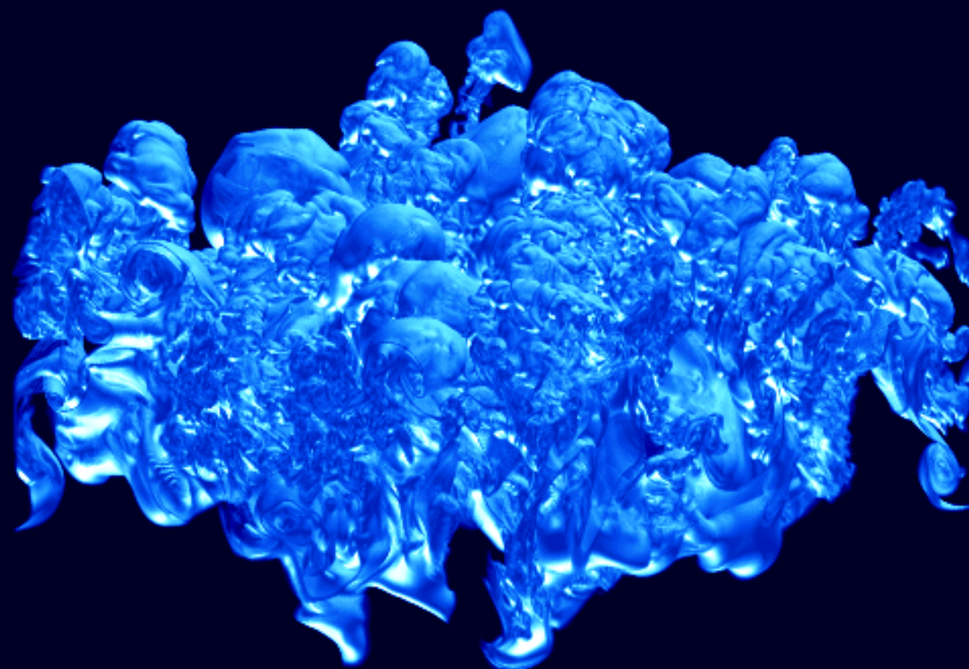
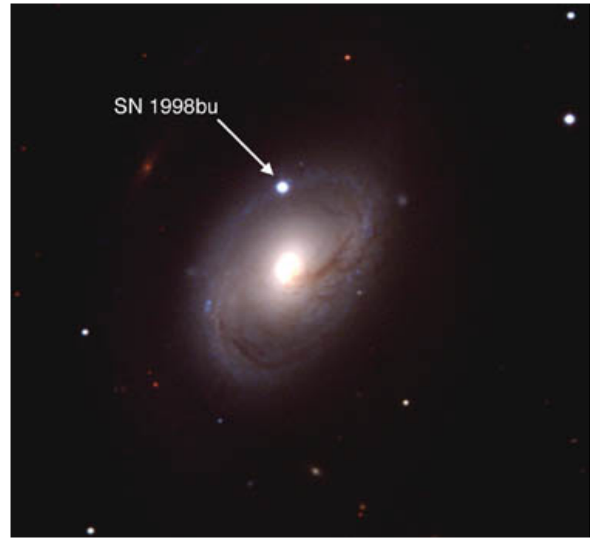


Type Ia
Supernovae

SN 1998aq

SN 1998dh



SN 1998bu

SN 1994D

Type Ia supernovae are the biggest thermonuclear explosions in the modern universe.

Twenty billion, billion, billion megatons ($\sim 10^{51}$ erg).

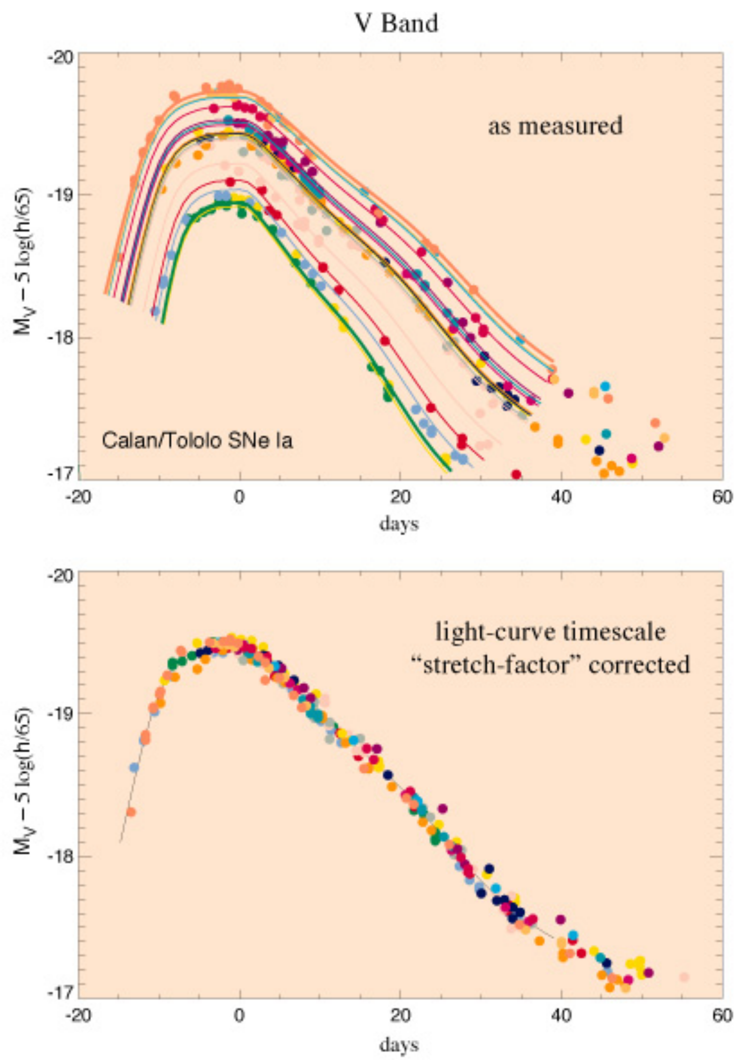
For several weeks their luminosity rivals that of a large galaxy.

Observational Facts

SN 1994D

- Very bright, regular events, peak $L \sim 10^{43}$ erg s^{-1}
- Associated with an old stellar population (found in ellipticals, no clear association with spiral arms)
- No hydrogen in spectra; strong lines of Si, Ca, Fe
- Not strong radio sources
- Total kinetic energy $\sim 10^{51}$ erg (no compact remnant)
- Higher speed, shorter duration and less frequent than Type II

Low Redshift Type Ia
Template Lightcurves

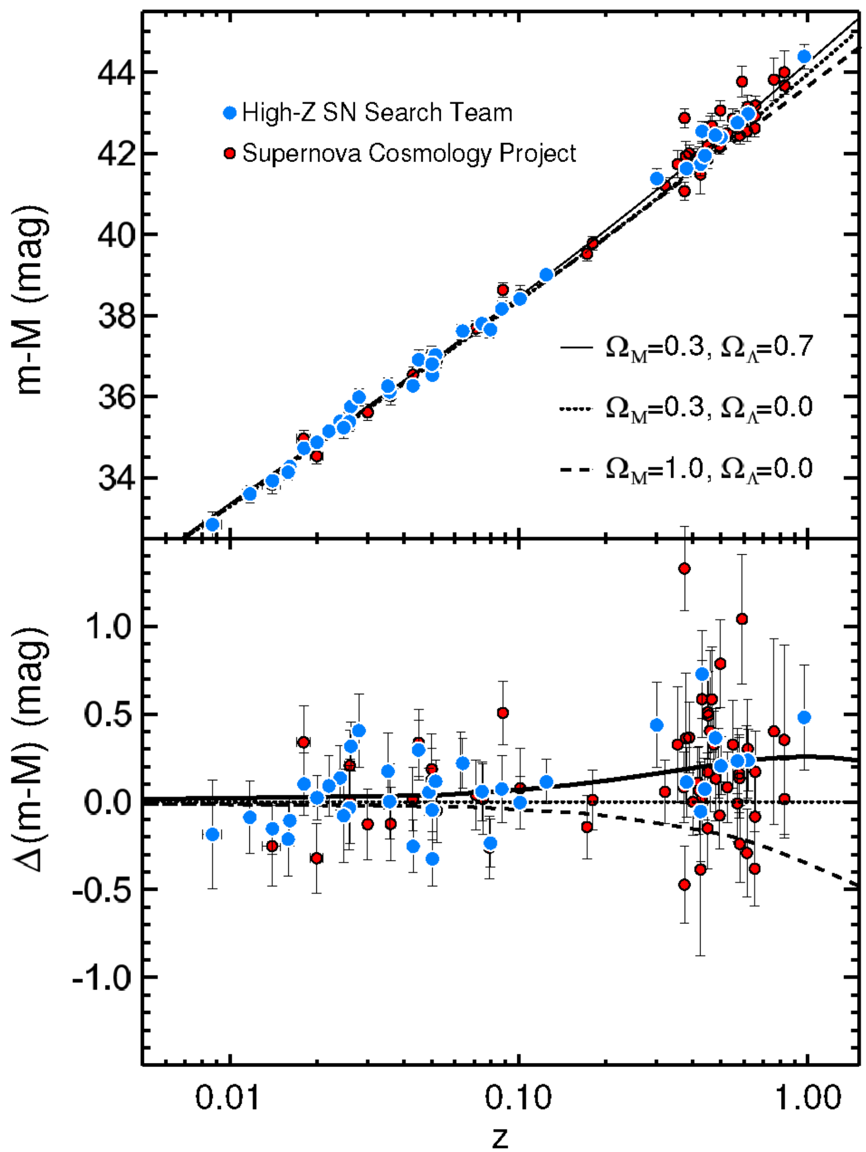


<u>The Phillips Relation</u>
(post 1993)

Broader = Brighter

Can be used to compensate for the variation in observed SN Ia light curves to give a "calibrated standard candle".

Note that this makes the supernova luminosity at peak a function of a single parameter – e.g., the width.



Type Ia supernovae at large distances seem to be fainter, for their observed red shift, than what would be expected in any cosmology without a cosmological constant.

Bottom panel shows difference between the distance modulus and that expected for a universe with no cosmological constant and Omega matter = 0.3

Models that have been Suggested

All are based upon accreting white dwarfs – to explain the association with an old stellar population, the absence of hydrogen, regularity of the light curve, etc. (Hoyle and Fowler 1960)

- *Merging white dwarfs*

  High accretion rate leads to ignition at the edge
  Flame burns stably to center, converts dwarf to NeO
  Collapse to a neutron star. But see also Yoon et al. (2007, MNRAS, 380, 933). Other outcomes possible.

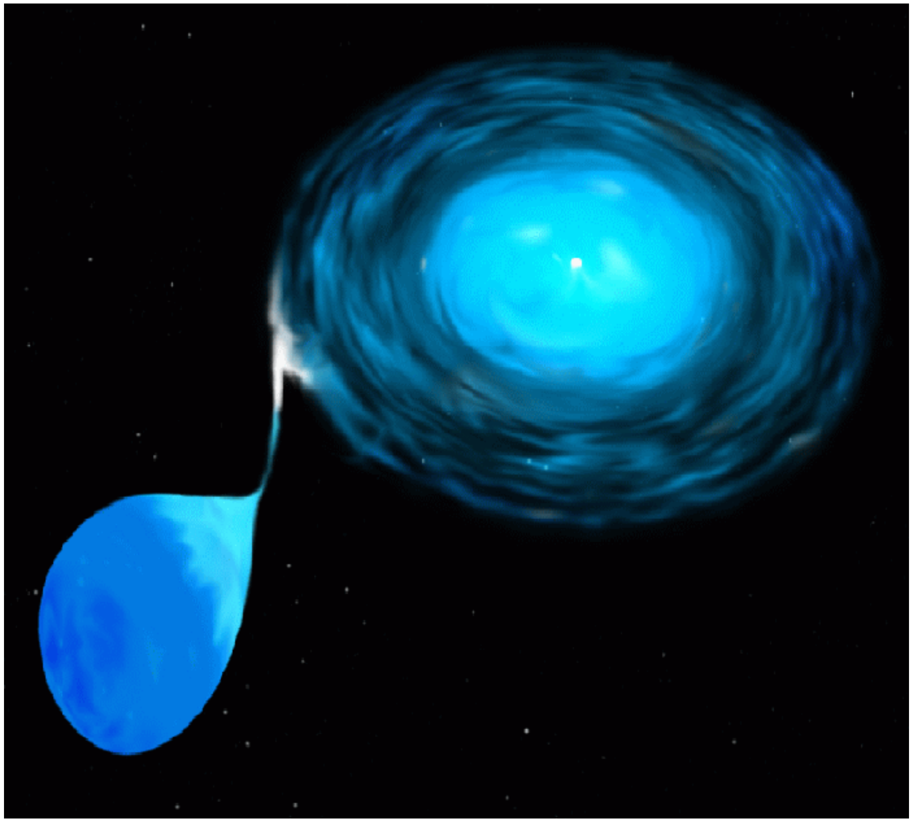
- *``Sub-Chandrasekhar mass models*

  Accretion at about 3 x 10^{-8} solar masses/yr
  Build a thick He layer of about 0.15 to 0.20 solar masses on top of a carbon-oxygen white dwarf of 0.7 – 0.9 solar masses
  He detonation induces a detonation of the CO core?
  Possible problems with spectrum and difficulty detonating CO
  Currently an area of active investigation

THESE WILL BE DISCUSSED LATER IF TIME ALLOWS.

Chandraskhar Mass Model

Accretion and growth to *almost* the Chandrasekhar Mass (1.38 solar masses)
-corrected for Coulomb effects but neglecting general relativistic effects.



In order to avoid the nova instability must accrete at a rate ~10^{-7} solar masses per year.

This must be maintained for millions of years.

Possible observational counterpart – supersoft x-ray sources (controversial)

Also a possible outcome for mergers with higher accretion rates

Ignition

Arnett (1968, 1969)
Nomoto, Sugimoto, & Neo (1976)

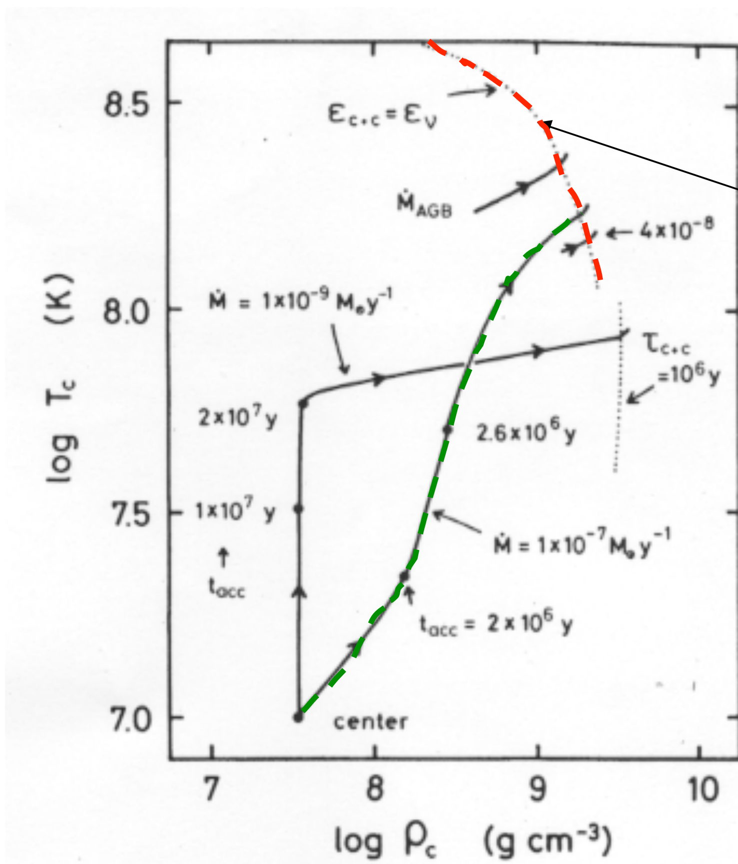
Ignition occurs as the *highly screened* carbon fusion reaction begins to generate energy faster than (plasma) neutrino losses can carry it away.

At a given temperature, the plasma neutrino losses first rise with density and then decline when $\hbar\omega_p > kT$.

$$\text{As } \rho \rightarrow 3\times10^9 \text{ gm cm}^{-3};\ \text{T} \approx 3\ \times 10^8\ \text{K}$$

$$\text{S}_{\text{nuc}}\,(^{12}\text{C} + ^{12}\text{C}) \geq \text{S}_{\nu}\,(\text{plasma}); \qquad \text{M} \approx 1.38\ \text{M}_{\text{sun}}$$

The ignition conditions depend weakly on the accretion rate. For lower accretion rates the ignition density is higher. Because of the difficulty with neutron-rich nucleosynthesis, lower ignition densities (high accretion rates) are favored.



Ignition when nuclear energy generation by (highly screened) carbon fusion balances cooling by neutrino emission.

First Ignition

- *Supernova preceded by 100 years of convection throughout most of its interior. Energy goes into raising the temperature of the white dwarf (not expansion, not radiation).*

- *Last "good convective model" is when the central temperature has risen to $>7.5 \times 10^8$ K*

Pressure scale height: 400 km

Nuclear time scale: ~10 s
(hottest spots)

Convective time scale: ~10 s

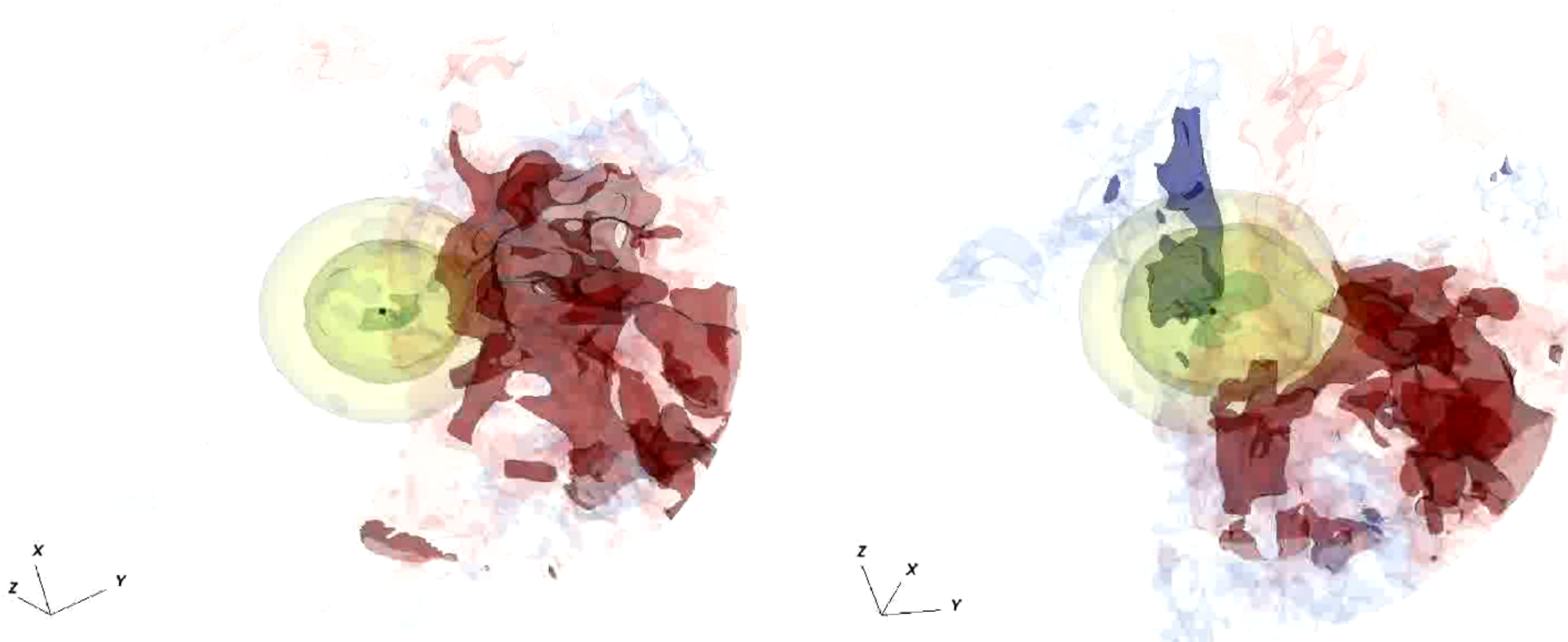
Convective speed: 50 km s^{-1}

Binding energy: 4×10^{50} erg

Density: 2.7×10^9 g cm^{-3}

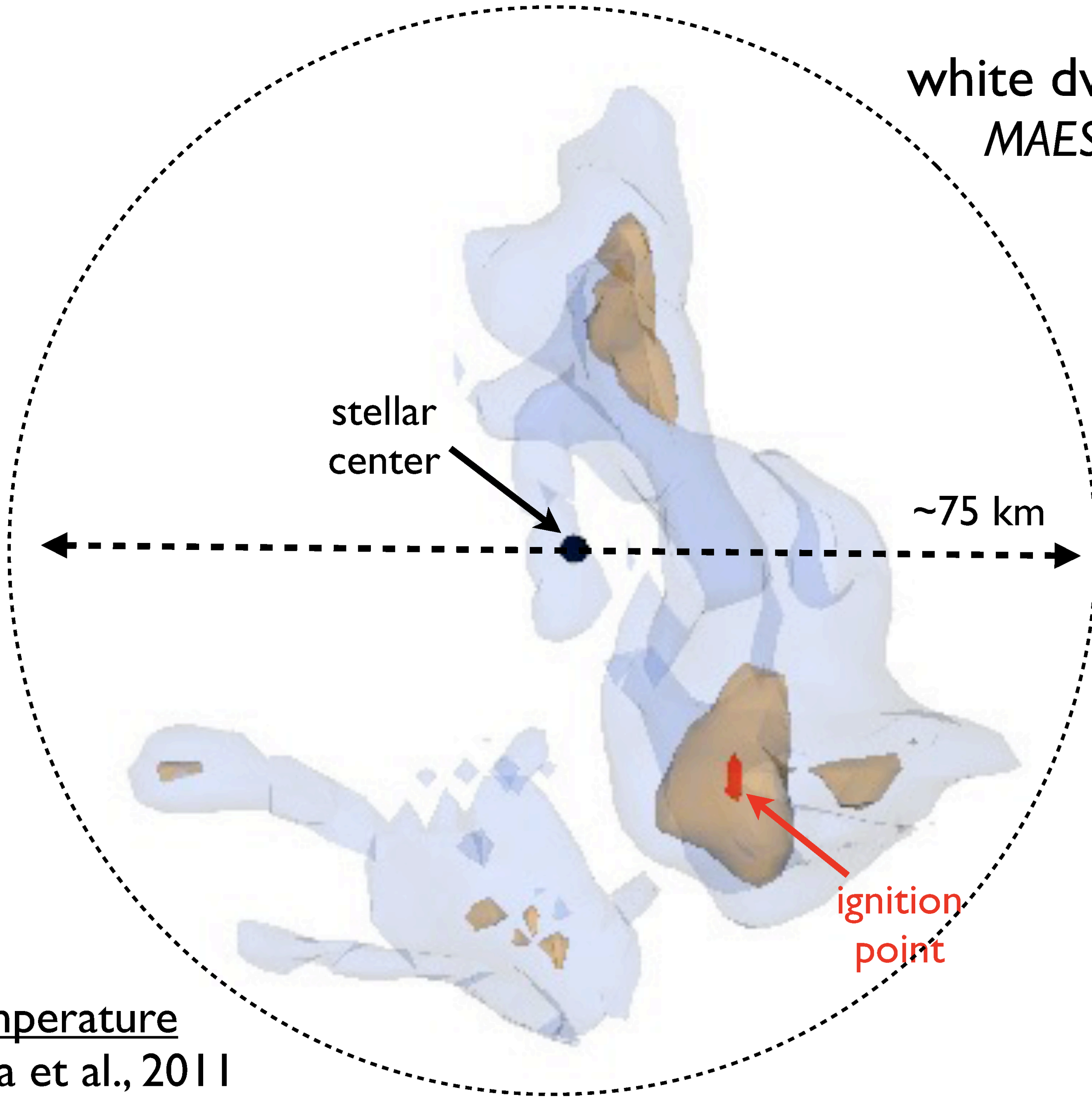
Burning 0.05 solar masses can cause expansion by a factor of three

Nonaka et al (2011) using **MAESTRO**



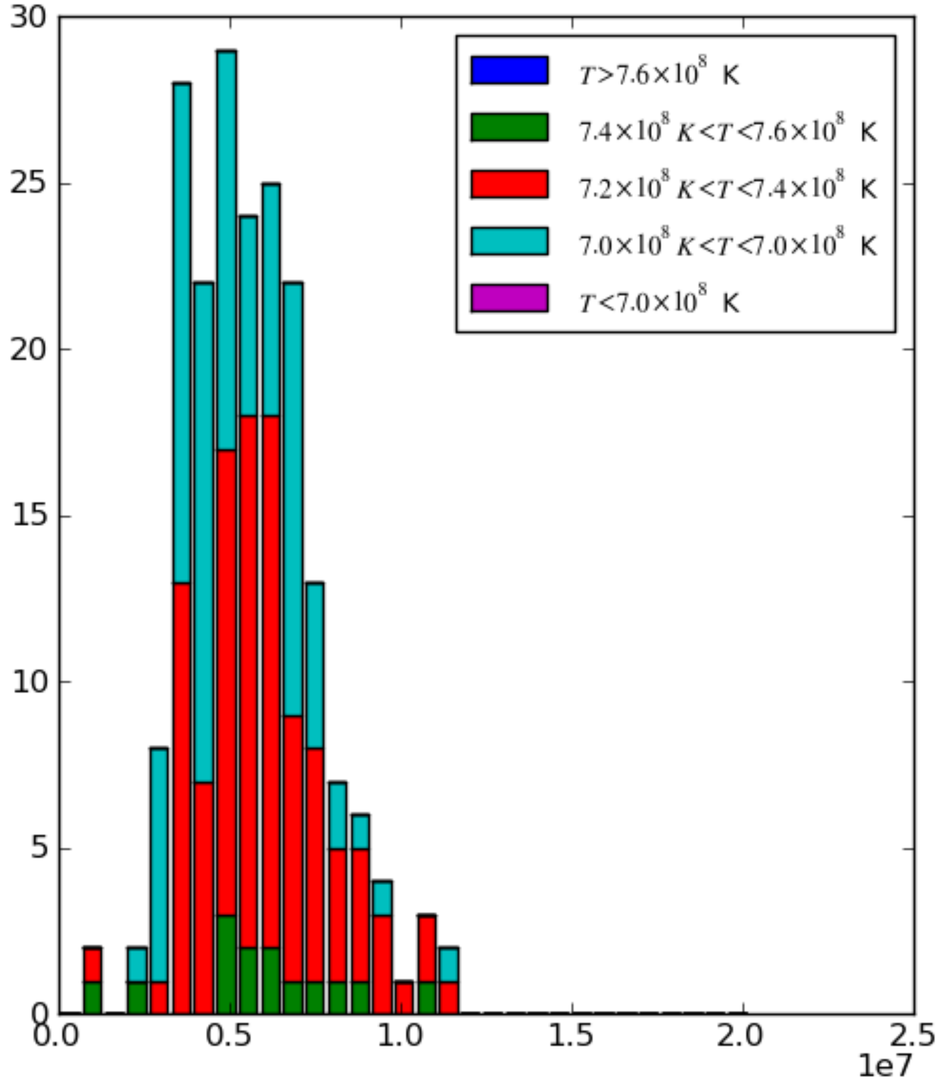
MAESTRO simulations of convection in a non-rotating white dwarf (left) and a 1.5% Keplerian rotating white dwarf (right) preceding a Type Ia supernova. Each simulation uses adaptive mesh refinement with an effective 768^3 zones (8.5 km spatial resolution) white dwarf ignition

MAESTRO code



<u>temperature</u>

nonaka et al., 2011



Zingale et al (2011)

This figure shows the distribution with radius of the hottest spot in the 3D simulation during the last few minutes leading up to ignition.

The Typical SN Ia will ignite a runaway at around 60 km off center but there will be a distribution of ignition points ranging all the way from central ignition to 120 km off center.

This chaotic ignition is probably the underlying cause of the SN Ia diversity and, indirectly, the width-luminosity relation.

Dependence on Rotation

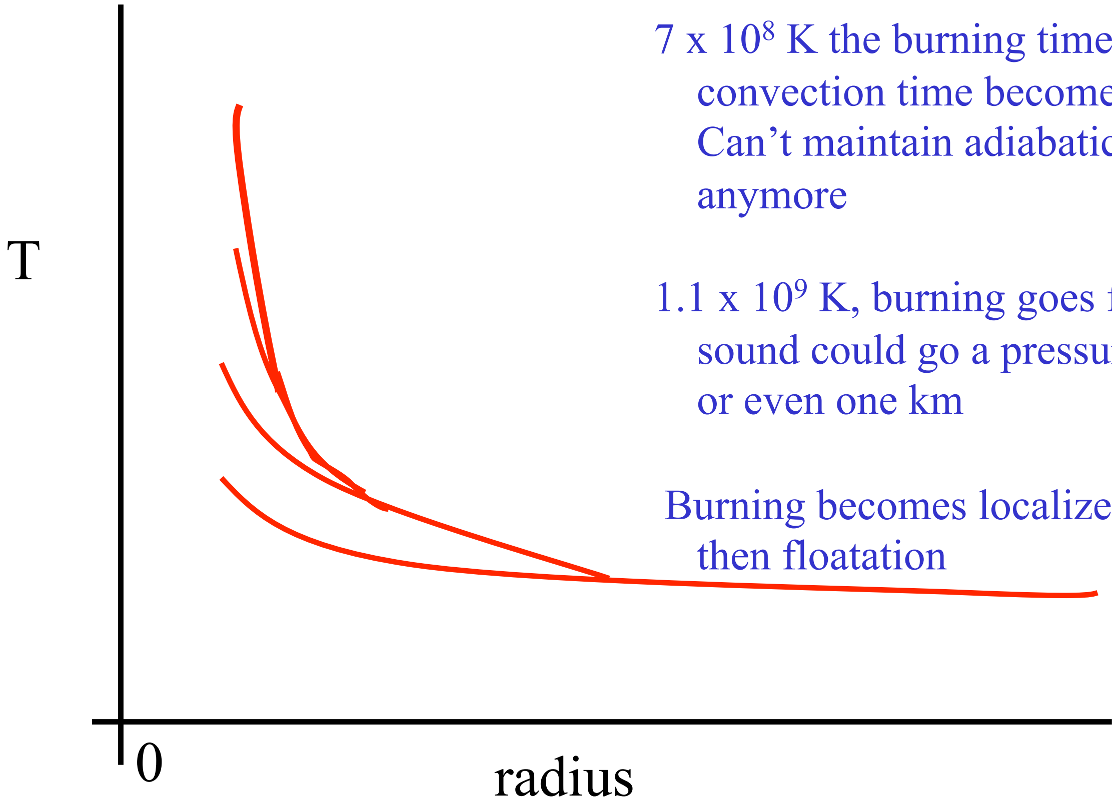
(Ma et al., in preparation)

Ω (rad/s)	Ignition radius (km)
0	120
0.167	80
0.84	35
2.52	45

If ignition farther off center correlates with greater Ni production in the detonation, as seems likely, then the brightness of a SN Ia might correlate inversely with its rotation rate.

Convection for 100 years, then in the last second, the formation of a thin flame sheet and the first burning, floating bubble.

Note that at:



7 x 10^8 K the burning time and convection time become equal. Can't maintain adiabatic gradient anymore

1.1 x 10^9 K, burning goes faster than sound could go a pressure scale height or even one km

Burning becomes localized. First laminar burning then floatation

$$S_{nuc} \propto T^{26}$$

$$\tau_{diffusion} \approx \tau_{nuc}$$

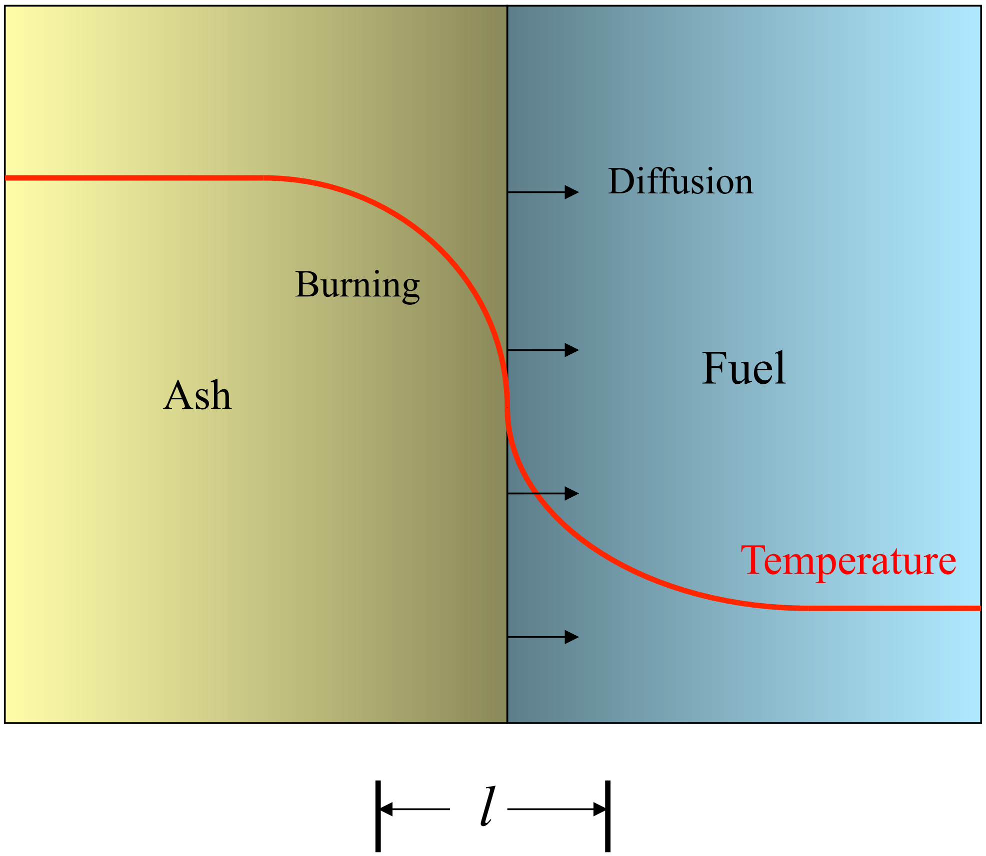
$$\left(\frac{l^2 \kappa \rho}{c}\right) \approx \left(\frac{\varepsilon}{S_{nuc}}\right)$$

ε = internal energy (erg/g)

κ = opacity (cm^2 / g)

S_{nuc} = energy generation (erg/g/s)

ρ = density (g/cm^3)



$$l = \left(\frac{\varepsilon c}{\kappa \rho S_{nuc}}\right)^{1/2}$$

$$v_{cond} = l / \tau$$

This is the conductive
- or sometimes “laminar”
- flame speed.

A *laminar* flame

Laminar Flame Speed

$$v_{cond} \approx \left(\frac{c\, S_{nuc}}{\varepsilon\, \kappa\, \rho} \right)^{1/2} \qquad c_{sound} \approx 10{,}000 \text{ km/s}$$

Carbon-Oxygen Conductive Wave Properties[a]

ρ_9	v_{cond}	Width	$\Delta\rho/\rho$
10.0	187 km/s	1.27 (−5)	0.085
8.0	152	1.65 (−5)	0.090
6.0	115	2.50 (−5)	0.098
4.0	76.3	4.96 (−5)	0.111
2.0	35.3	1.85 (−4)	0.139
1.0	15.1	7.28 (−4)	0.205
0.5	5.46	2.79 (−3)	0.222
0.2	1.09	2.03 (−2)	0.398
0.1	0.415	8.11 (−1)	0.415
0.05	0.113	2.31	0.483
0.01	9.82 (−3)	8.68 cm	0.503

nb. these speeds are comparable to the convective speeds prior to runaway. Shear may affect initial propagation.

Timmes and Woosley, (1992), *ApJ,* **396**, 649

Heat Capacity

$$C_P = \left(\frac{\partial \varepsilon}{\partial T}\right)_{ions} + \left(\frac{\partial \varepsilon}{\partial T}\right)_{electrons} + \left(\frac{\partial \varepsilon}{\partial T}\right)_{radiation}$$

$$\approx 9.1 x 10^{15} + \left(\frac{8.7 x 10^{15}\, T_9}{\rho_9^{1/3}}\right) + \left(\frac{3.0 x 10^{13}\, T_9^3}{\rho_9}\right) \text{erg/(gm}\, 10^9\, \text{K)}$$

Nuclear burning to the iron group gives q_{nuc} = 7 x 10^{17} erg/gm
" " " silicon group " " 5 x 10^{17} erg/gm

Solving $C_P T = q_{nuc}$ for temperature:

At $\rho_9 = 1$	$T_9 \approx 10$	(electrons)
$\rho_9 = 0.02$	$T_9 \approx 4$	(radiation)

Above about 10^7 gm cm^{-3} burning will go to nuclear statistical equilibrium and make only iron group elements

At 10 billion K burning always goes to completion and makes iron. Only below four billion K (few x 10^7 gm cm^{-3}) does one begin to make Si, S, Ar, Ca, Mg, etc. Almost all the initial white dwarf is more dense than that. Prompt carbon detonation will not reproduce observations.

On the other hand, naive flame physics gives us slow extremely subsonic burning to iron. The ash experiences a lot of electron capture, and the star gradually becomes unbound – maybe after several pulses. This too does not give an acceptable SN Ia.

A Successful Model Must:

(Kasen and Woosley 2007;

Mazzai et al. (2007)

(Starting from 1.38 solar masses of carbon and oxygen)

- Explode violently
- Produce approximately 0.8+- 0.1 solar masses of ^{56}Ni *For the light*
- Produce at least 0.2 solar masses of SiSArCa *For the spectrum*
- Not make more than about 0.1 solar masses of ^{54}Fe and ^{58}Ni combined *For the nucleosynthesis*
- Allow for some diversity

It has been known empirically for some time that the way to get around these problems and agree with observations is with a flame that starts slowly, pre-expands the star (so as to avoid too much electron capture) then burns very rapidly when the density is around $10^7 – 10^8$ gm cm^{-3}.

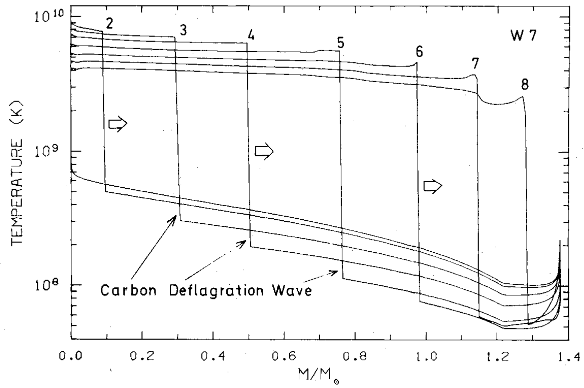


FIG. 4a

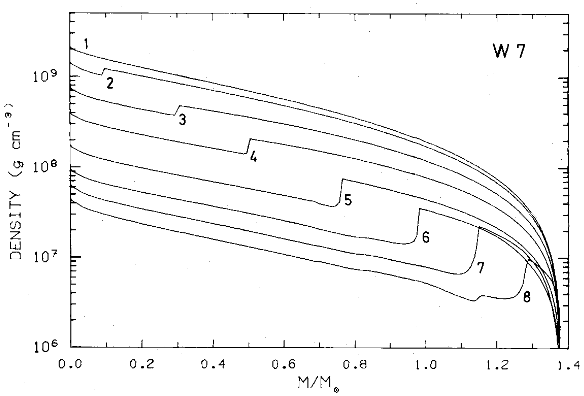
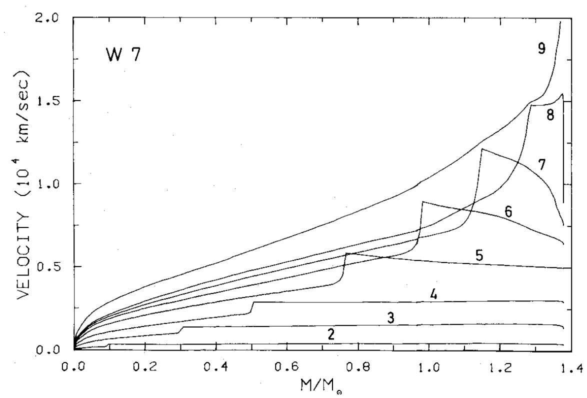


FIG. 4b



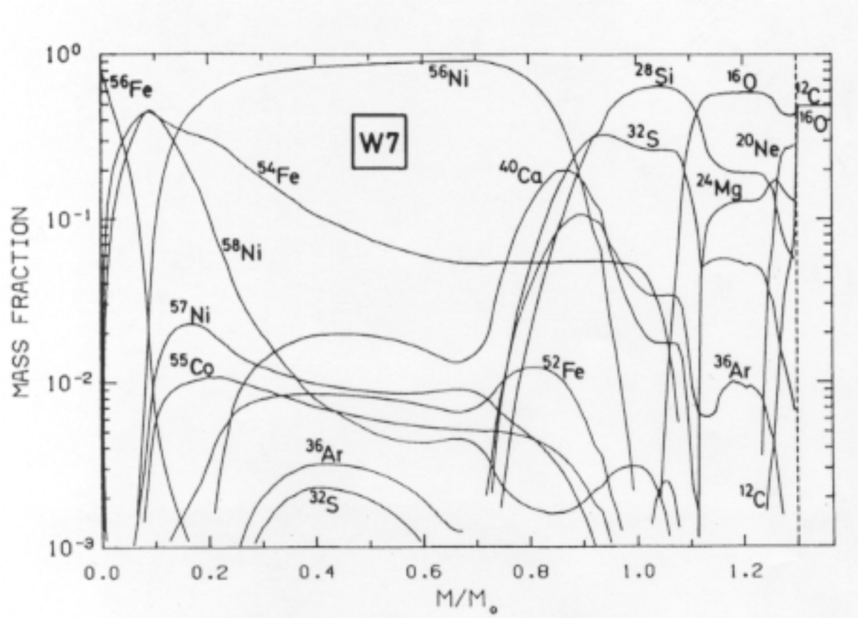
Model W7 – an empirical model that works

Thielemann, Nomoto, and Yokoi (1986), *A&A*, **158**, 17 and (1984), *ApJ,* **286**, 644

1) 0.0 s
2) 0.60 s
3) 0.79 s
4) 1.03 s
5) 1.12 s
6) 1.18 s
7) 1.24 s
8) 3.22 s

Half of the time is spent burning the first 0.1 solar masses.

Note the long time spent at going slow near the center. The flame accelerates to nearly sound speed at the end



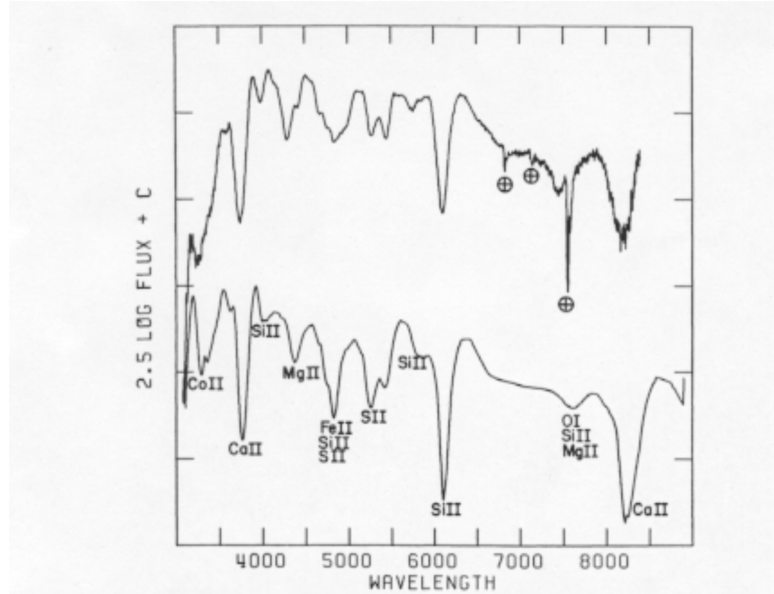
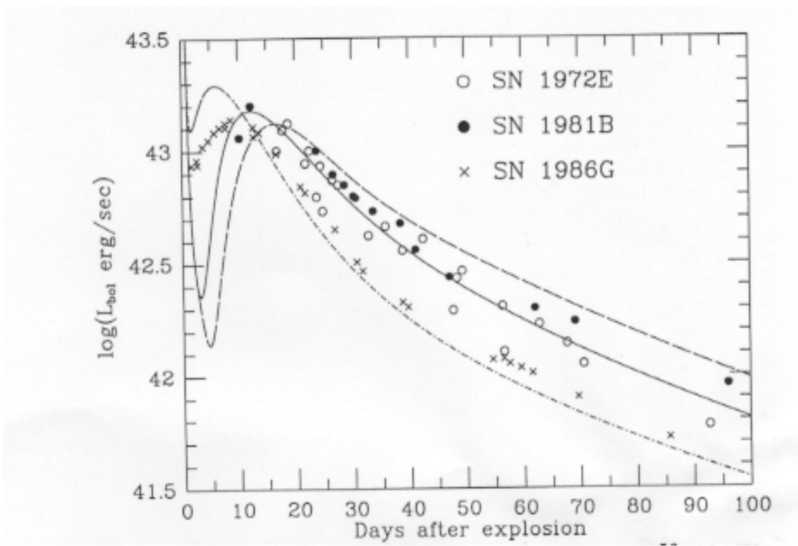


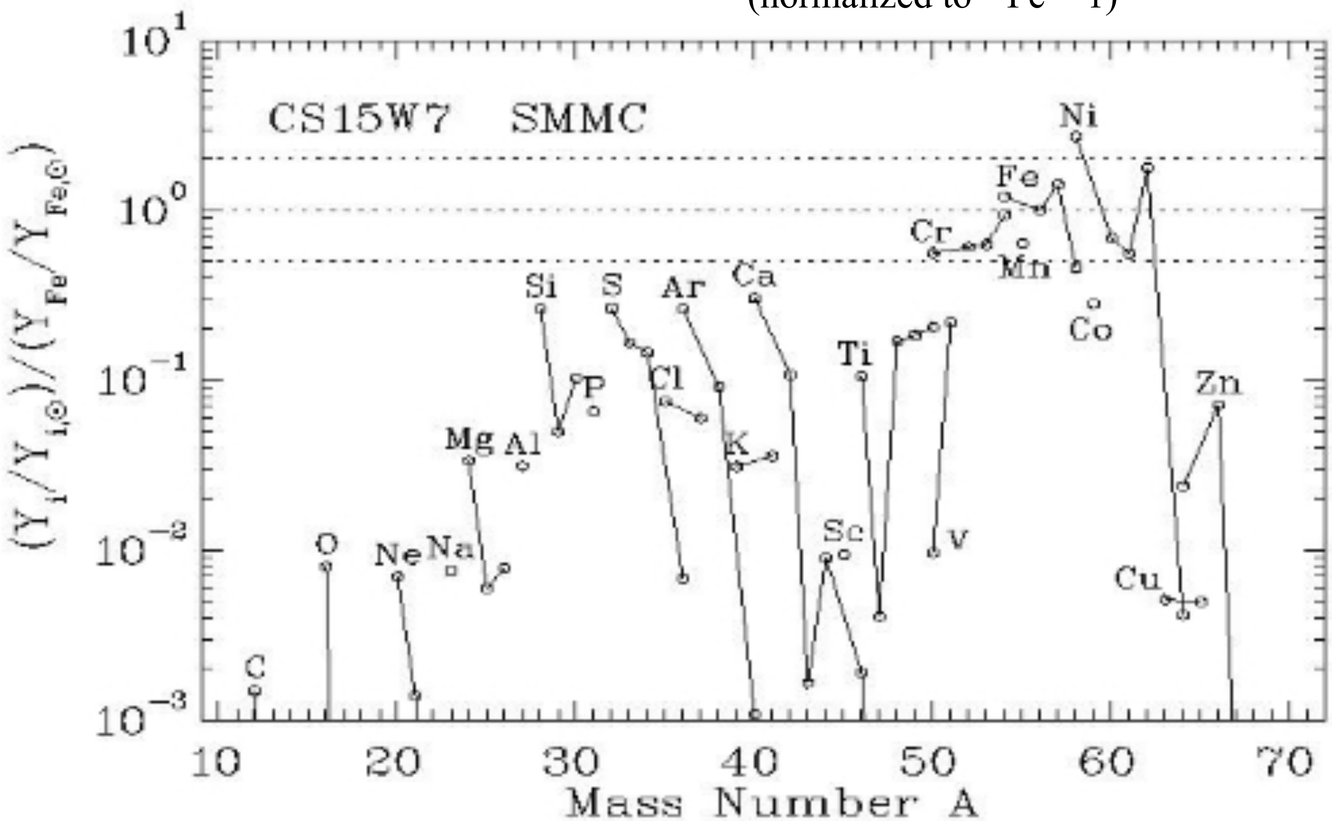
Fig. 4.—Like Fig. 3, but the synthetic spectrum is for the mixed form of model W7



The fact that W7, an empirical parameterized model agrees so well with observations suggests that the correct SN Ia model should have similar properties.

Nucleosynthesis compared to the Sun

(normalized to ^{56}Fe = 1)

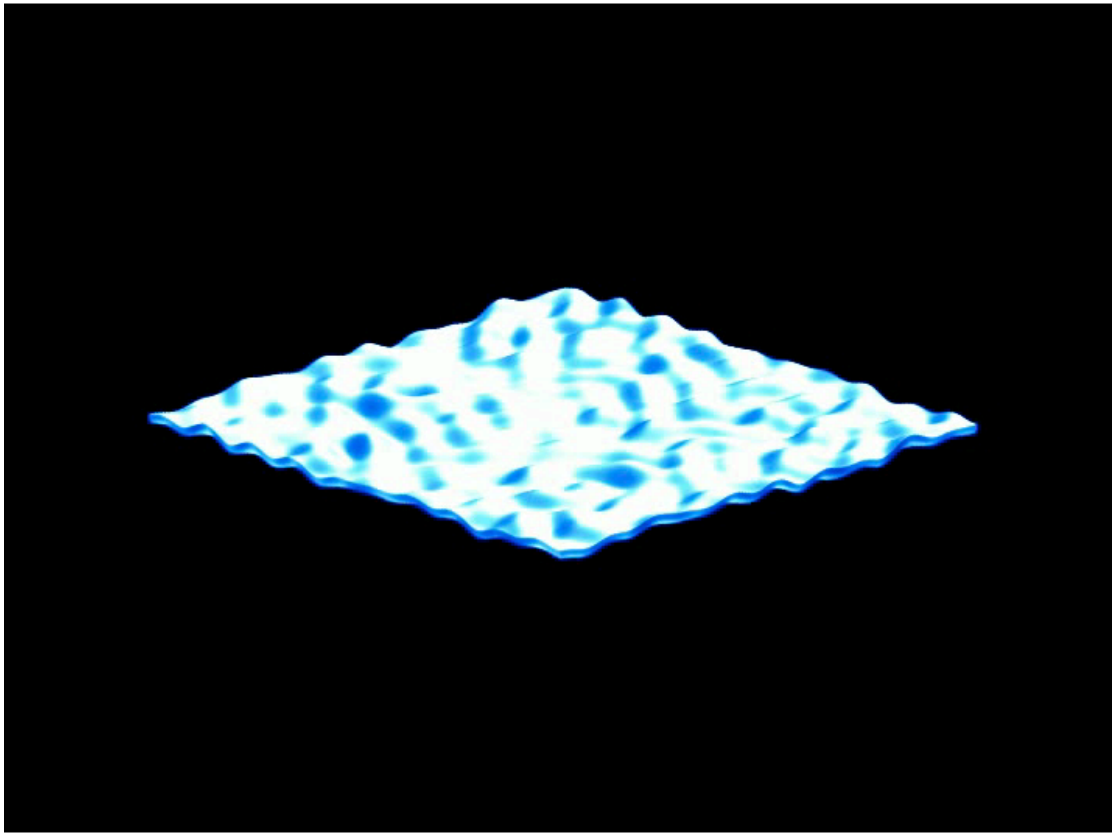


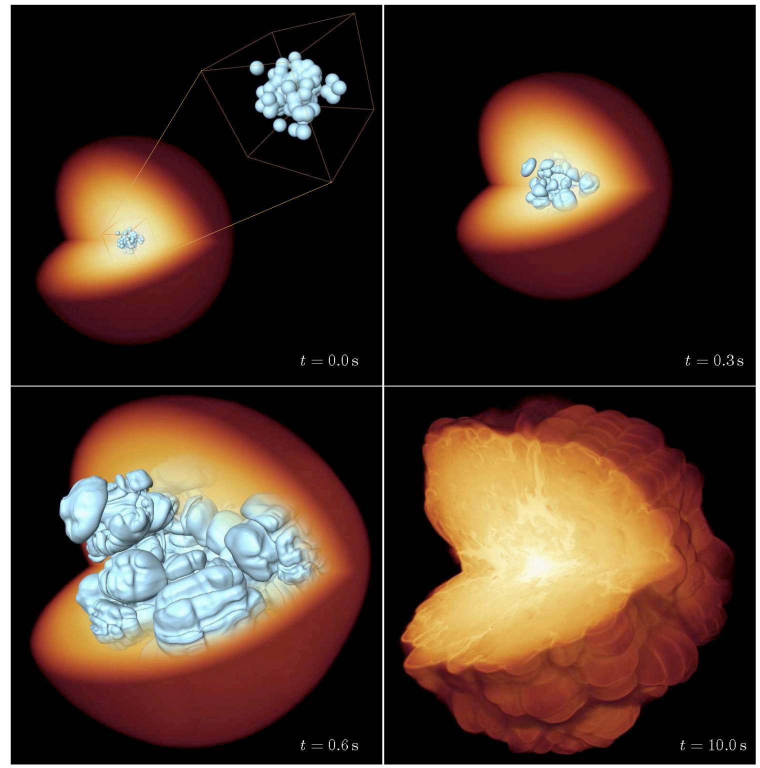
Brachwitz et al. (2000)

some problems with ^{58}Ni indicate too much electron capture in the explosion.

MULTI-D MODELS

Explosion - Burning and Propagation





Some terms:

- *Deflagration* – subsonic burning through a flame mediated by conduction but possibly accelerated by instabilities. Because the burning advances slow that the sound speed, pressure across the burning front is constant. T goes up and r goes down

- *Detonation* – A shock wave in which the burning behind the wave occurs sufficiently rapidly to keep the shock wave (and burning) advancing at a supersonic speed. In a detonation wave, the pressure, T, and r all go up. The increase in pressure raises T and r to the point where the burning happens faster than a sound wave crosses the region.

Computationally, detonation is easy. Deflagration is hard.

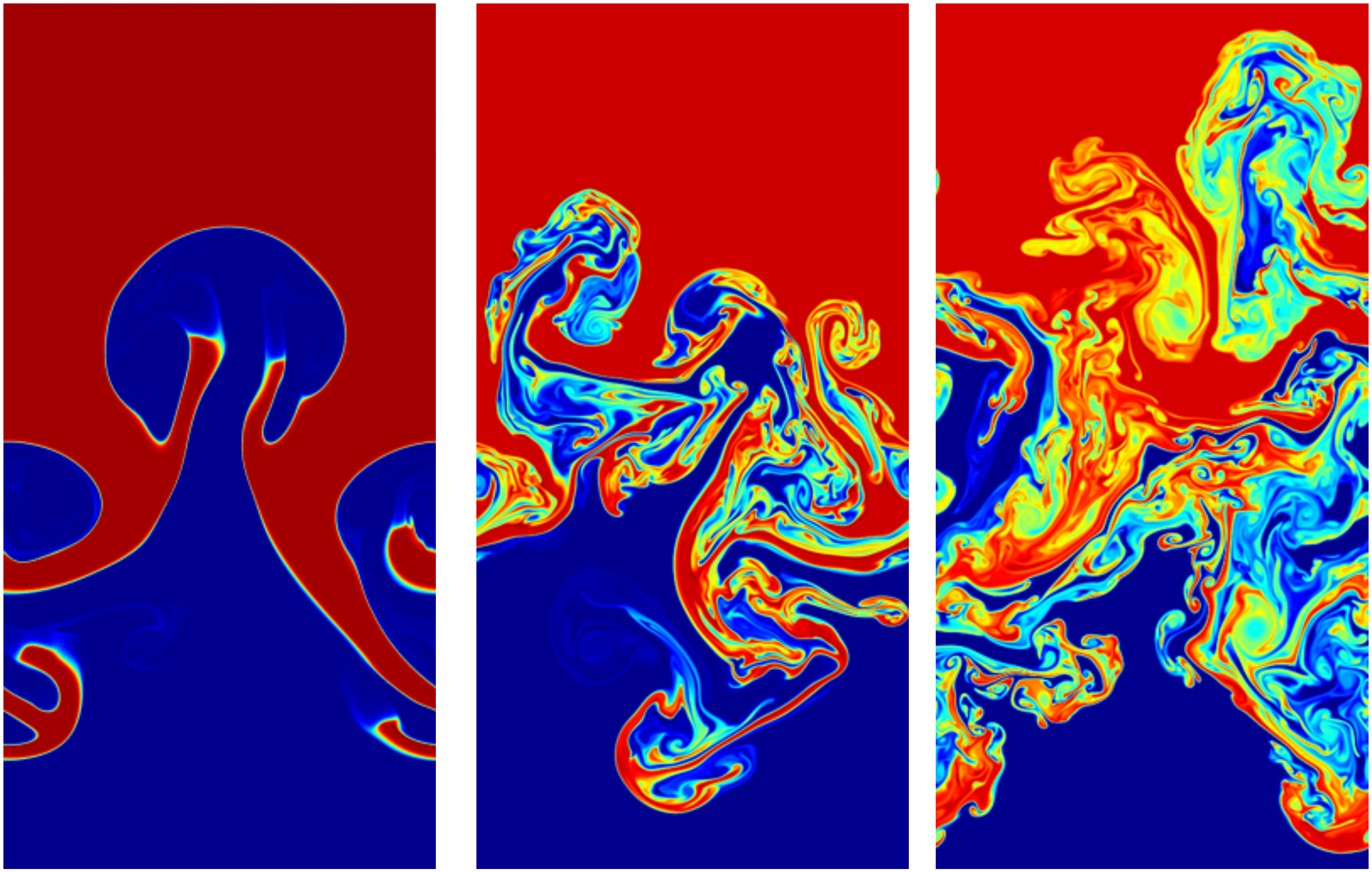
Centrally ignited deflagration

Summary: Central ignition, pure deflagration

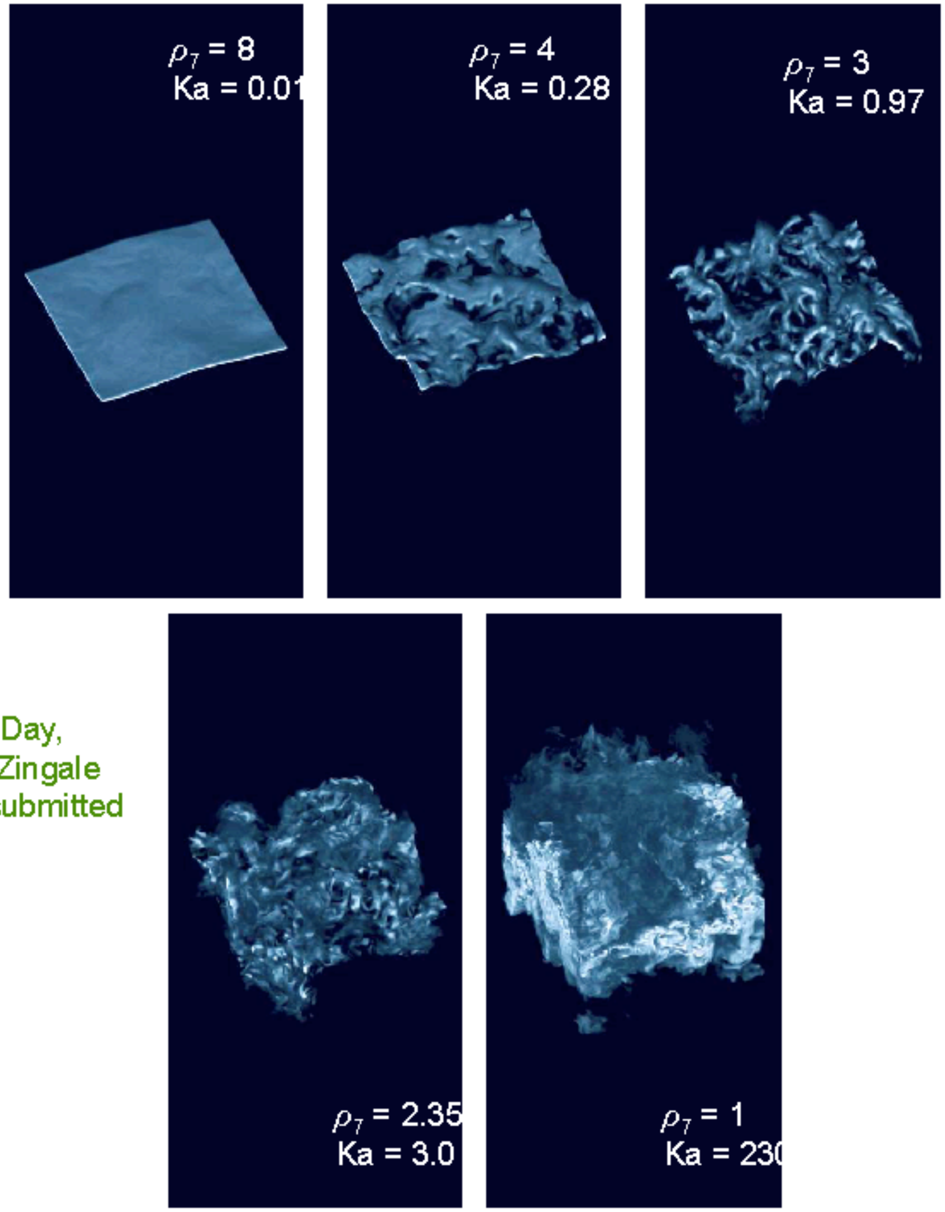
- Can unbind the star. Produces about 0.8 to 1.0 solar masses of iron, ^{56}Ni, and Si-Ca
- Not enough ^{56}Ni to explain any but the faintest of SN Ia
- Residual unburned carbon and oxygen at low velocity is not observed in the spectrum
- Need some sort of late time accelerated burning, i.e., detonation.
- Ignition studies suggest that ignition at the center is unlikely

THIS IS NOT THE COMMON SN Ia

Transition to detonation?



1.5×10^7 1.0×10^7 0.667×10^7



Low Mach Number code "SNe". Adaptive mesh.

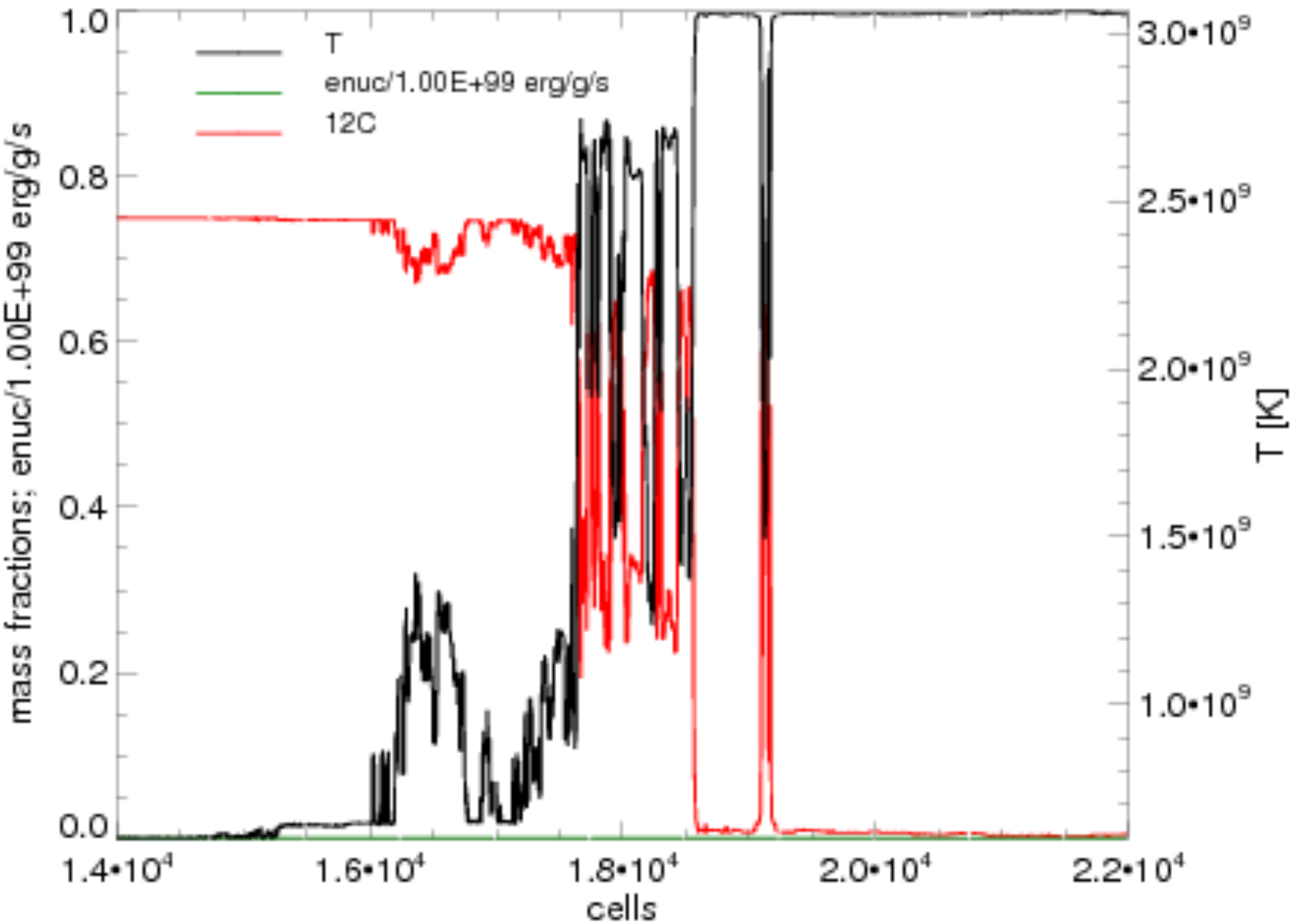
Background Kolmogorov turbulence

$u' = 10^7$ cm s^{-1}
L = 10 km

Aspden, Bell, Day, Woosley and Zingale (2008), ApJ, submitted

3D
1000 x 1000 x 250 zones
~ 2 M hr ATLAS
LLNL

Woosley et al 2009, ApJ, 704, 255 using ODT

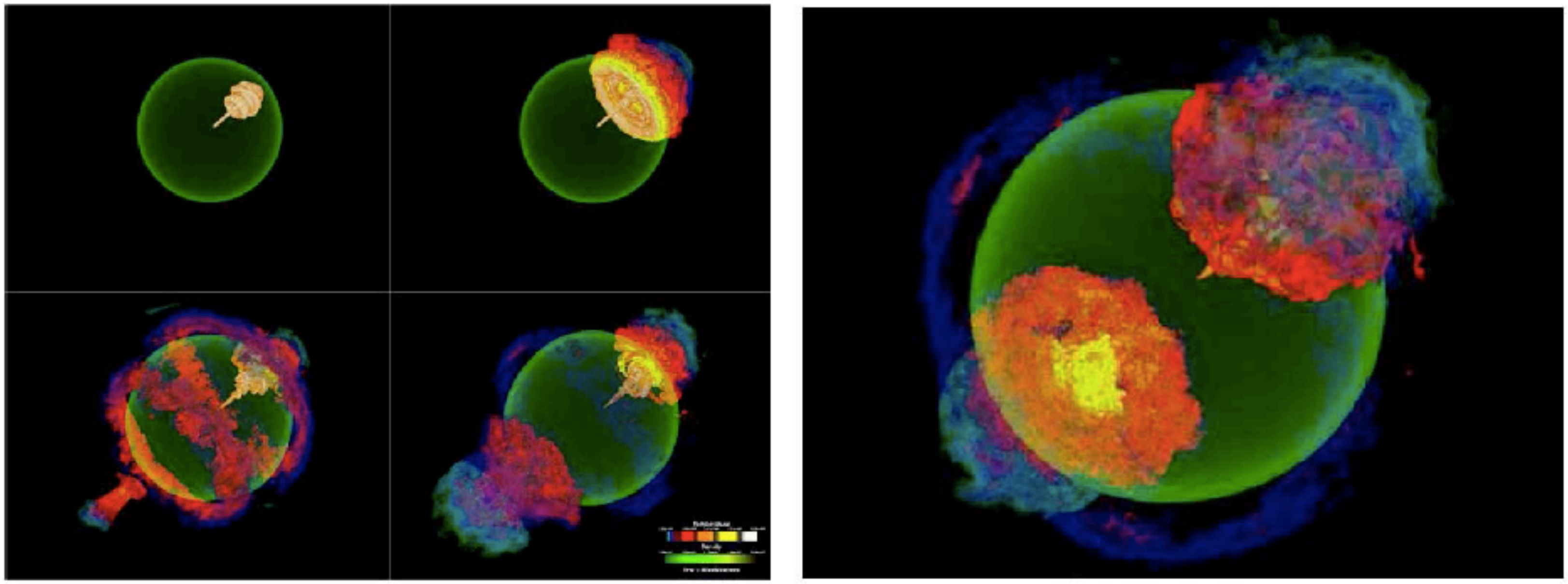


Conclusion:

A transition to detonation can occur if (isotropic Kolmogorov) turbulence exists at the flame-fuel interface at a density of ~10^7 g cm^{-3} with a characteristic speed on the integral scale of greater than 20% sonic (Woosley et al 2009).

Off-Center Ignition (the real thing)

Chicago GCD Model

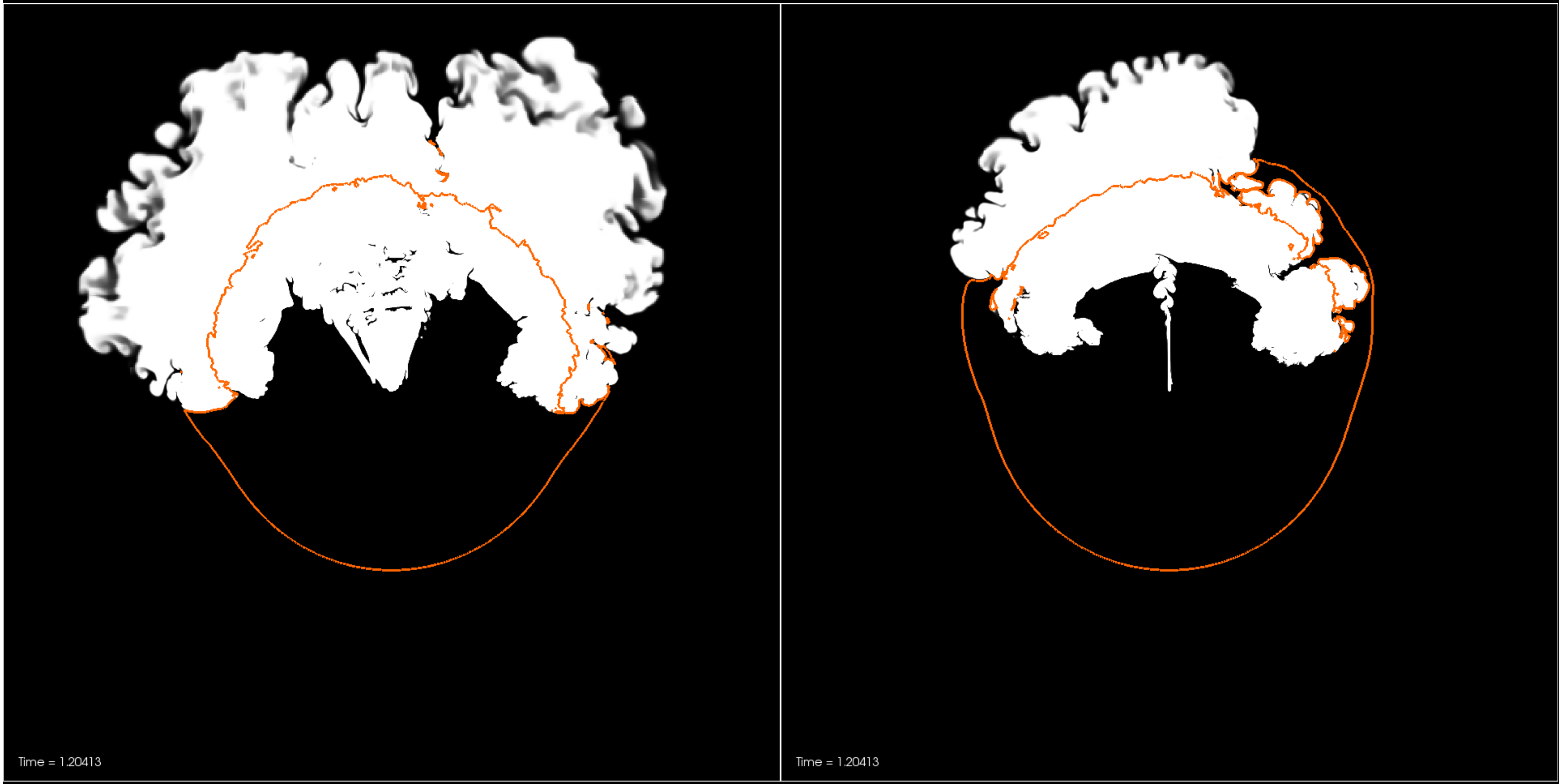


Jordan et al (2008)

White dwarf expands less than in the Röpke et al. model, so the collision on the far side occurs at higher density and with less geometrical dilution. In the Chicago version, the temperature is sufficient to ignite a detonation that consumes the rest of the star.

The answer depends on the subgrid model and the ignition conditions

Ellipsoidal off center ignition vs ignition as a single spherical bubble off-center.



Summary - M_{Ch} model

- Characteristics of the explosion are set by the location and frequency of the ignition points, the flame model used for the deflagration stage, and the conditions assumed for the transition to detonation.

- First principles calculations are advancing but aren't there yet. Need a better understanding of the burning in the deflagration phase and the conditions for a transition to detonation.

- The observable properties of the supernova will also be affected by the ignition density (affects both the binding energy and electron capture), the C/O ratio, the metalicity, and the rotation rate

Light Curves

After the white dwarf has expanded a few times its initial radius its internal energy (and entropy) will be chiefly due to radiation, that is -

$$T^3/\rho \approx \text{constant}$$

$$\rho \propto 1/r^3, \text{ so}$$

$$\mathrm{T} \propto 1/r$$

$$\varepsilon = aT^4/\rho \propto 1/r$$

Before the radiation can diffuse out the supernova has expanded from a ~2 times 10^8 to 10^{15} cm. During that time, the internal energy goes down from ~10^{51} erg to ~10^{44} erg. The remaining internal energy is totally inadequate to power the light curve (10^{49} erg).

Energy from explosion:

$E \sim 10^{51}$ erg

$T \sim 10^{10}$ K $\qquad$ $R \sim$ few x 10^{8} cm

Light can escape when the diffusion time equals the age:

$$\tau_{diff} \sim t$$

$$\frac{R^2 \kappa \rho}{c} \sim t \qquad \kappa = \kappa_{es} + \kappa_{line} \sim 0.1 \, \mathrm{cm^2 \, g^{-1}}$$

$$\rho \sim \frac{3M}{4\pi R^3} \qquad M = 1.4 M_\odot = (1.4) * 2 \times 10^{33} \, \mathrm{gm}$$

$$R = v\,t \qquad v \sim 7000 \, \mathrm{km \, s^{-1}}$$

$$t \approx \frac{3R^2 \kappa M}{4\pi R^3 c} \approx \frac{3\kappa M}{4\pi v\, t\, c}$$

$$\Rightarrow t_{peak} \approx \sqrt{\frac{3\kappa \mathrm{M}}{4\pi \mathrm{vc}}} = 1.8 \times 10^{6} \, \mathrm{s} \quad \Rightarrow R \sim 10^{15} \, \mathrm{cm}$$

But then adiabatic expansion implies that the the interior temperature has dropped by 10^{6} and the interior energy is negligible.

Radioactivity is essential to keep the supernova hot and shining!

Radioactivity

$$^{56}\mathrm{Ni} + \mathrm{e}^- \rightarrow {}^{56}\mathrm{Co} + \nu \qquad \tau_{1/2} = 6.1\ \mathrm{days}$$

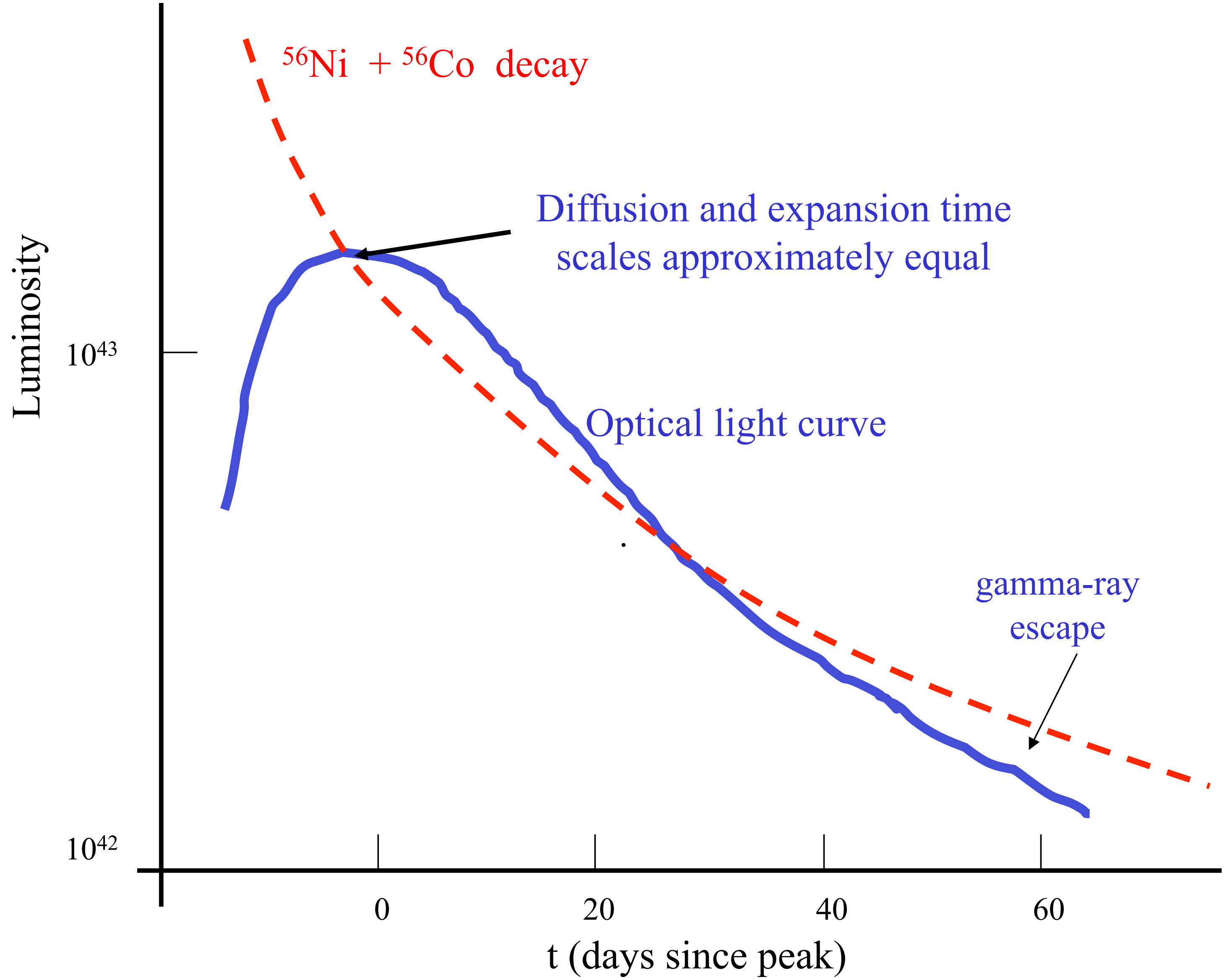
$q = 3.0 \times 10^{16}$ erg/gm

$$^{56}\mathrm{Co} + \mathrm{e}^- \rightarrow {}^{56}\mathrm{Fe} + \nu \qquad \tau_{1/2} = 77.1\ \mathrm{days}$$

$q = 6.4 \times 10^{16}$ erg/gm

0.6 solar masses of radioactive Ni and Co can thus provide 1.1×10^{50} erg at late times after adiabatic expansion is essentially over.

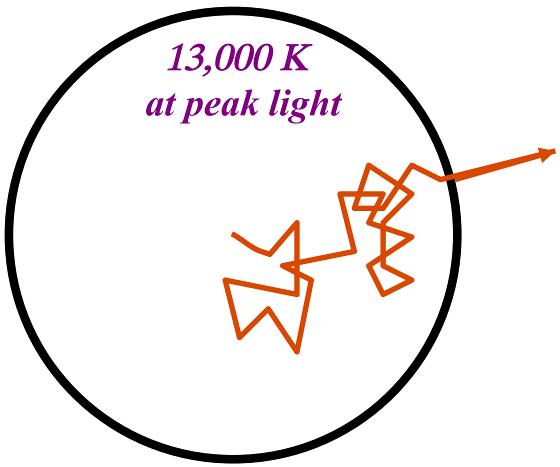
Qualitative Type Ia Supernova Light Curve



Why is there a Philipps Relation?

Pinto & Eastman (2001)
New Astronomy

Broader = Brighter



Photons must diffuse through a forest of lines in a differentially expanding medium.

Doppler shift causes a migration from line to line.

The trapped radiation is mostly uv and the uv optical depth is very large because of a forest of iron lines.

Photons escape chiefly by fluorescence.

Dan Kasen's explanation of the Phillipp's Relation:

More ^{56}Ni implies a larger luminosity at peak.

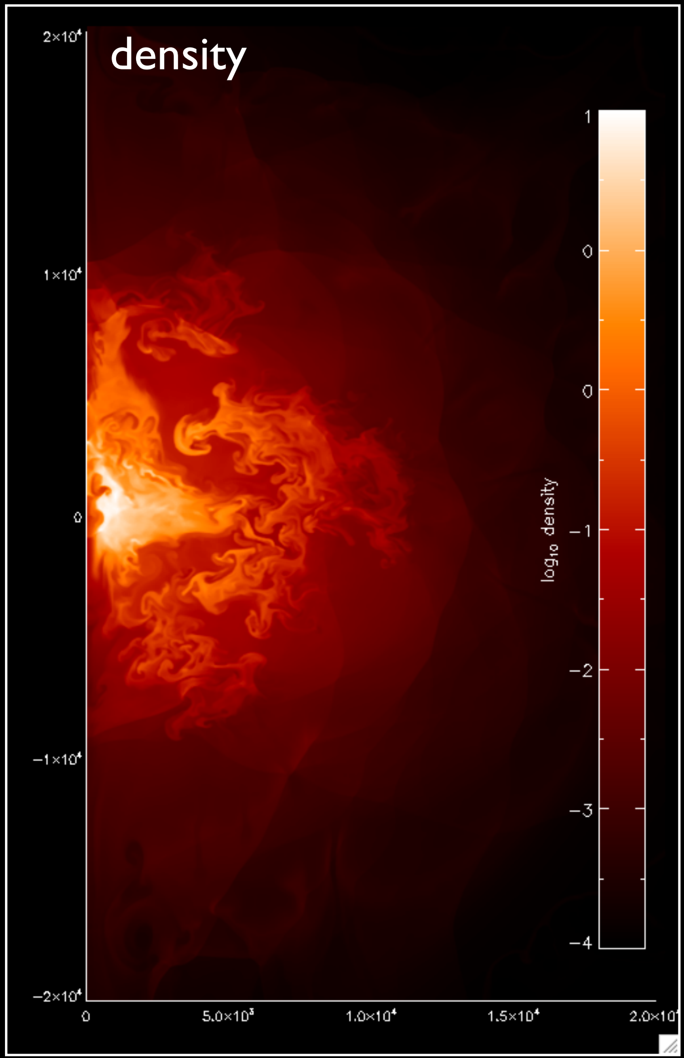
But more ^{56}Ni also implies higher temperature in the interior. This in turn implies that Fe, Co, Ni are more highly ionized (III rather than II)

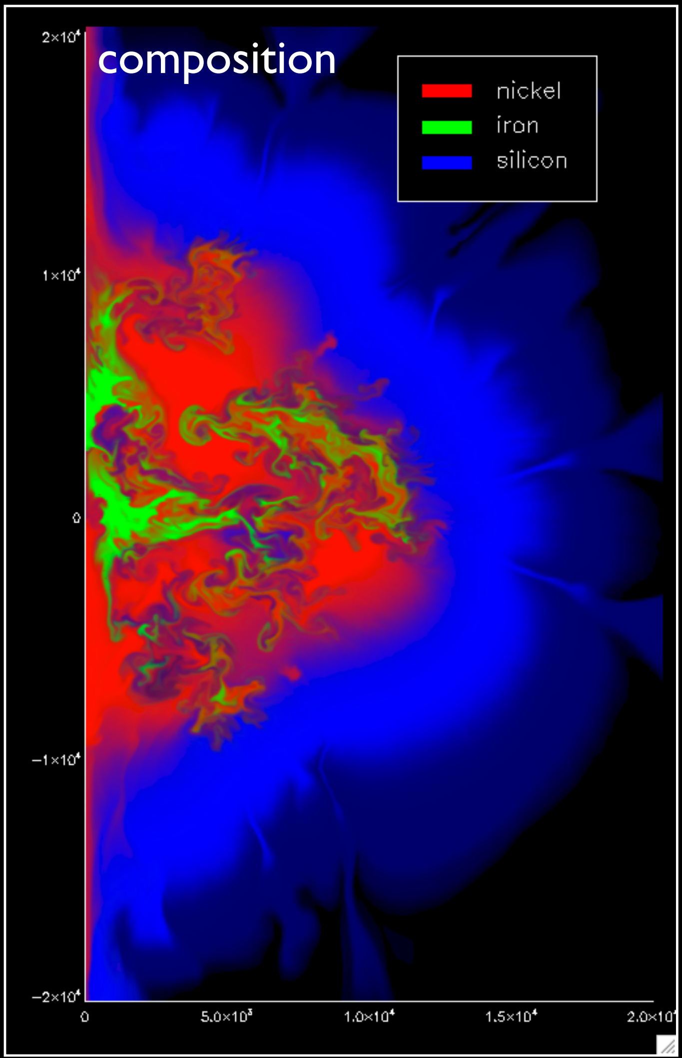
The more highly ionized Fe is less effective at redistributing the blue light into the red because it has fewer lines.

Hence hotter implies more optical opacity (actually less optical efficiency)

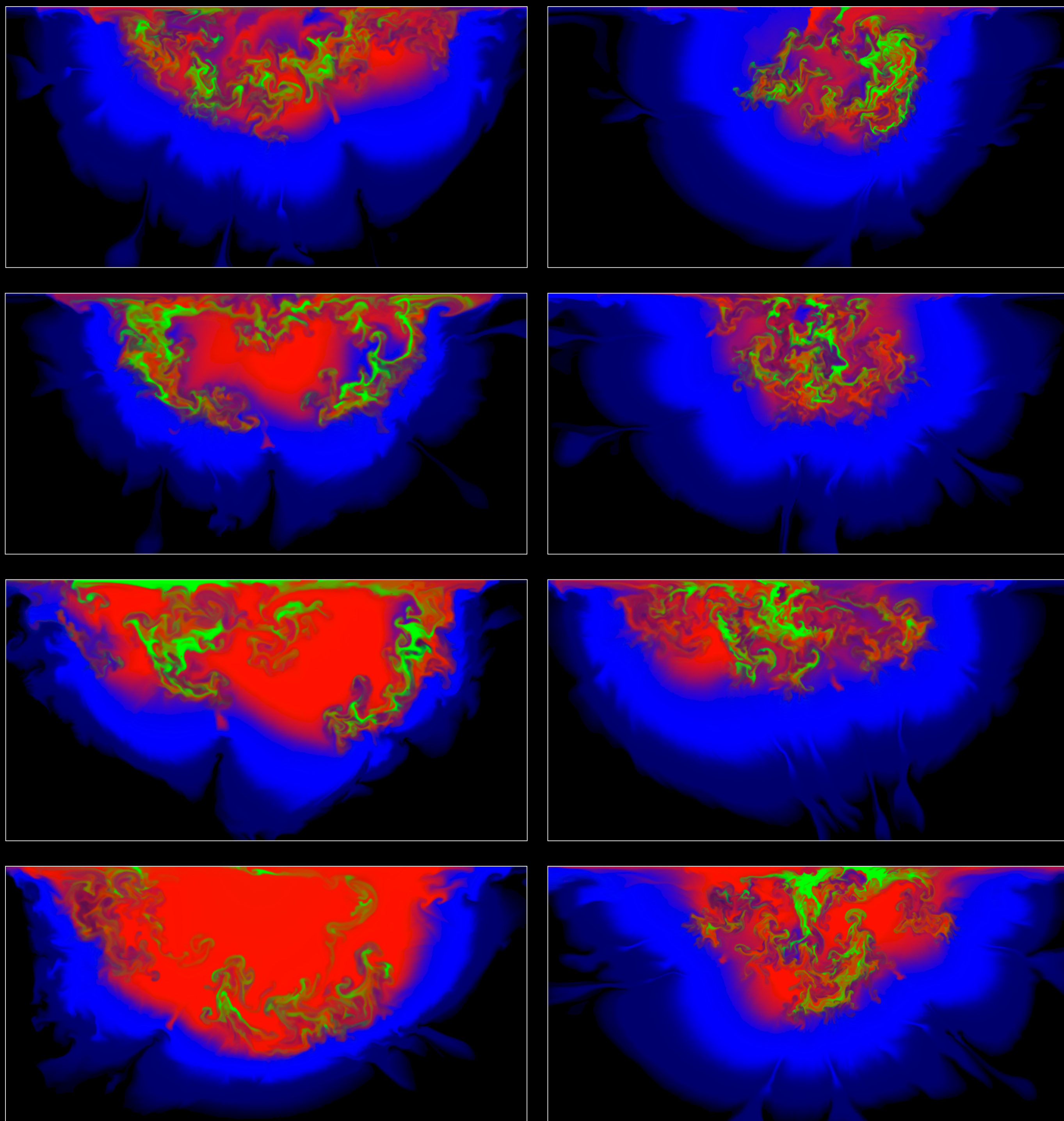
2-D Delayed Detonation Model

(calculations by Röpke, Kasen, and Woosley) 0.7 Msun of ^{56}Ni

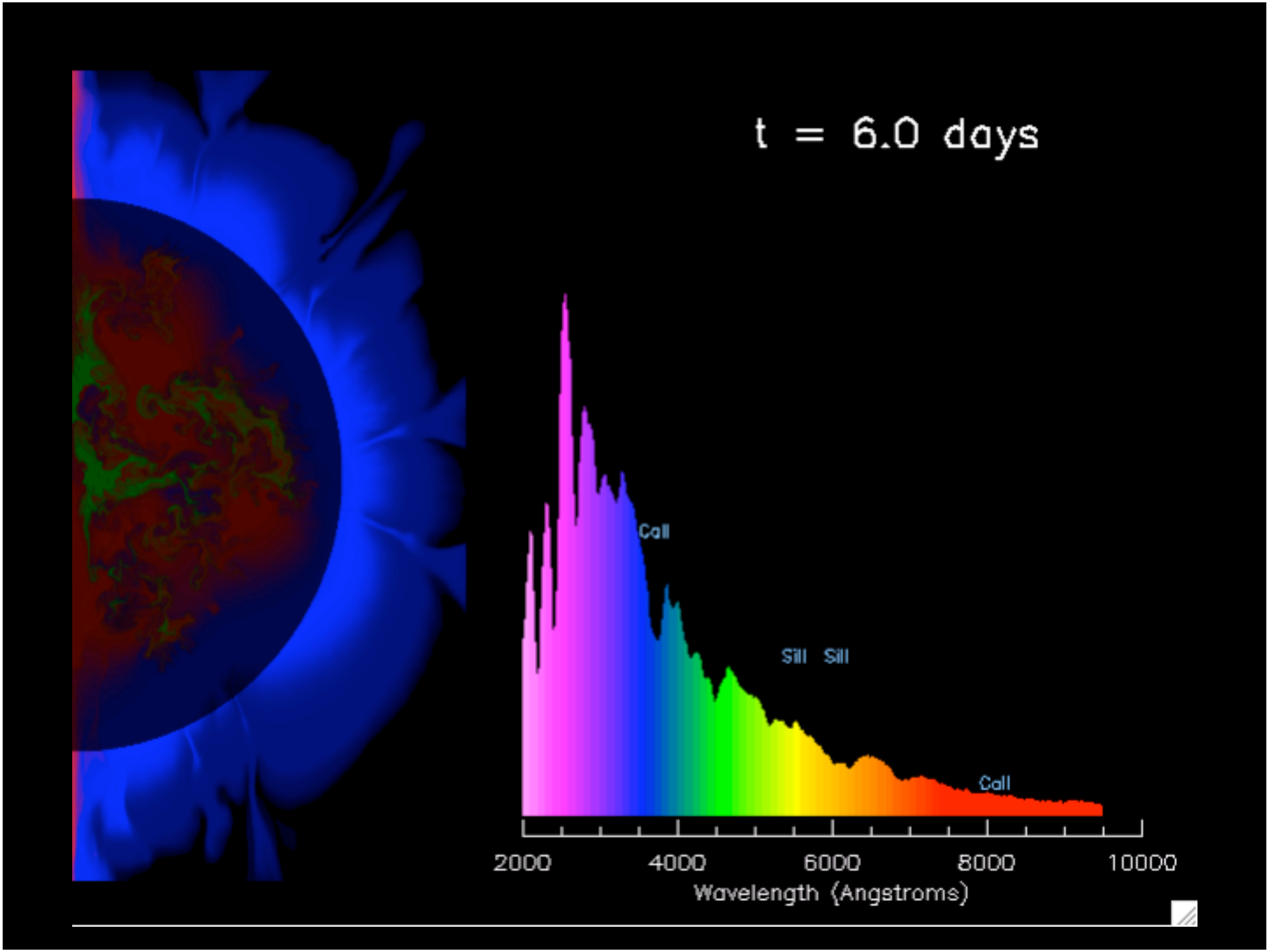




strong deflagration
weak detonation

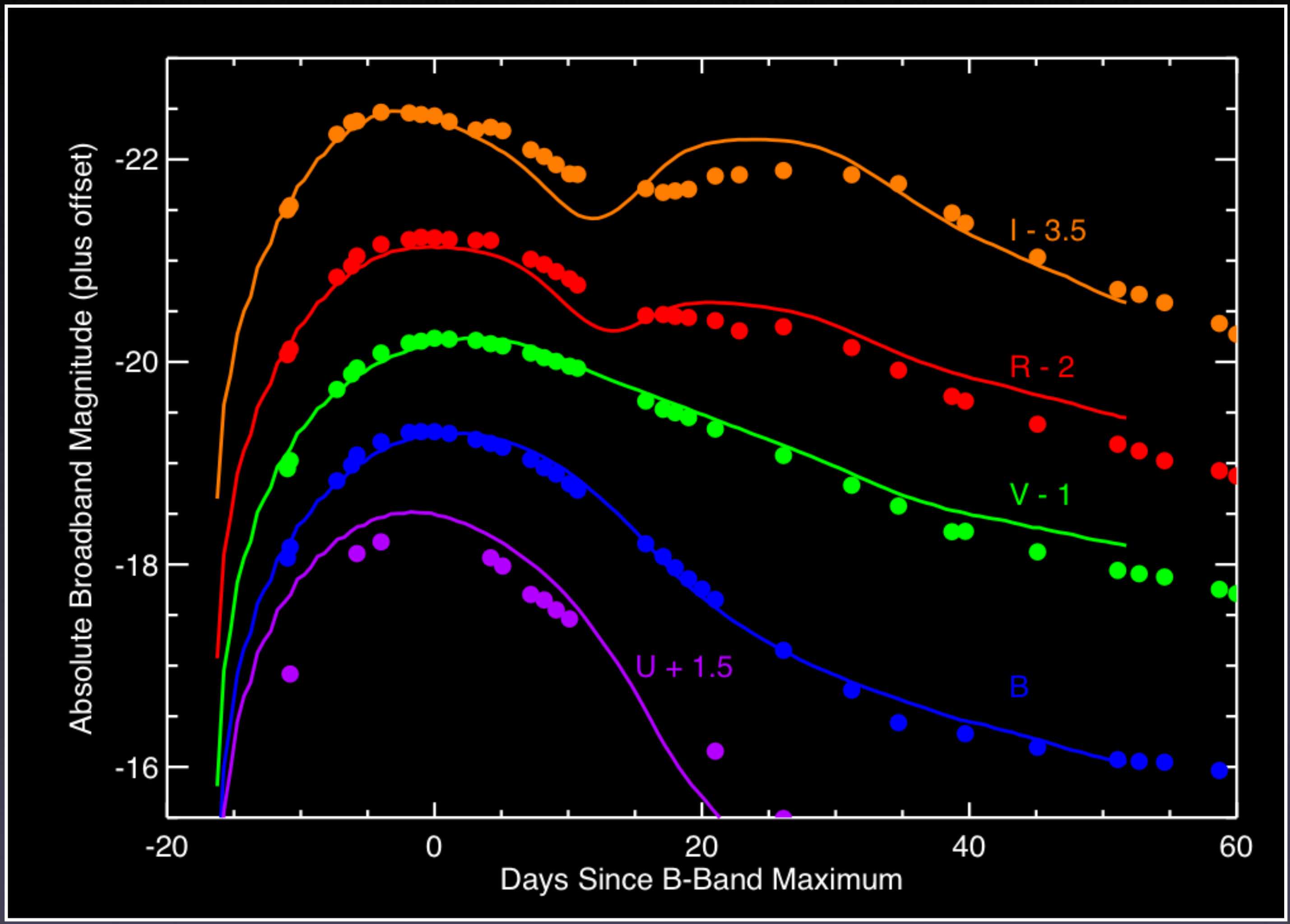


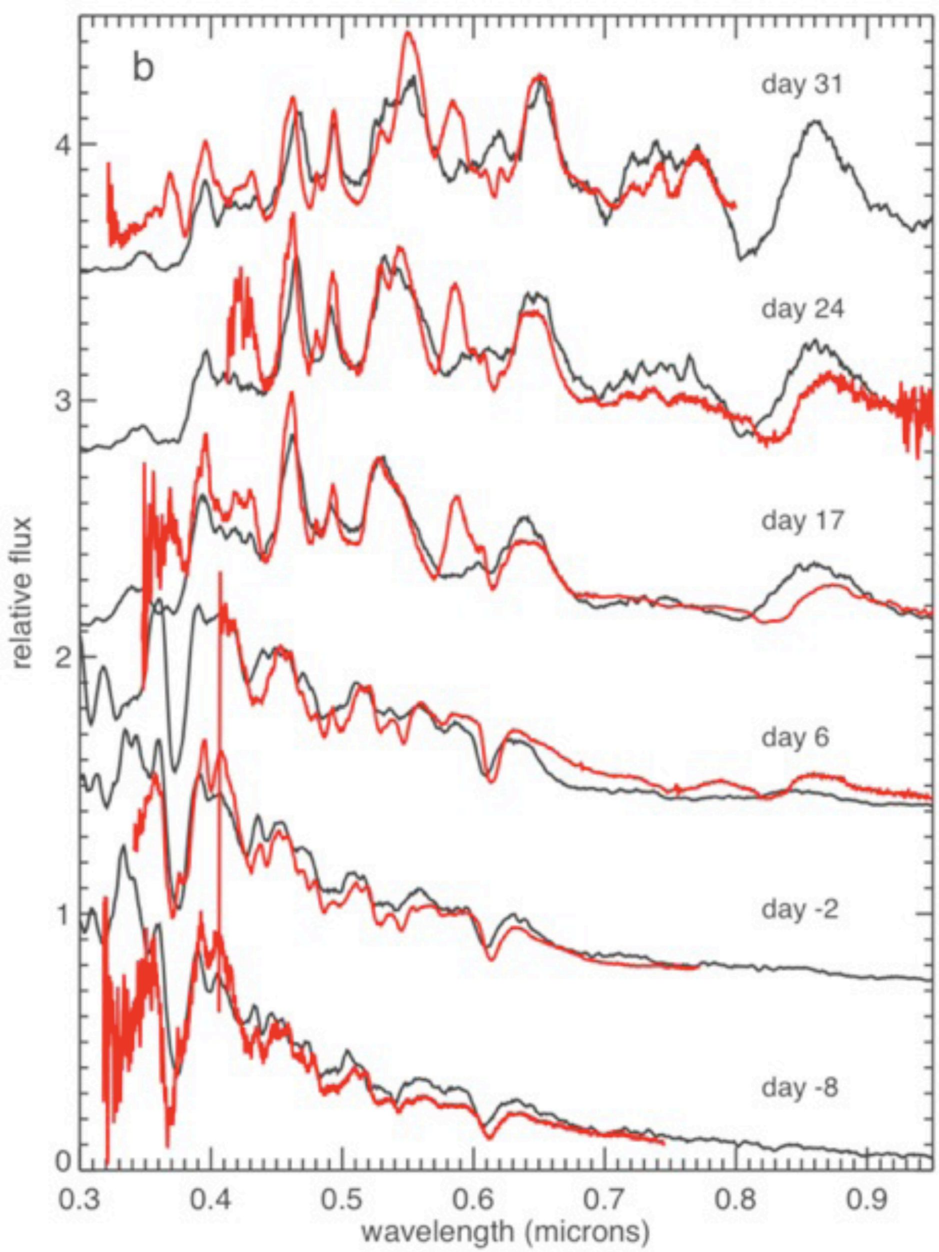
weak deflagration
strong detonation


t = 6.0 days
CaII
SiII SiII
CaII
2000 4000 6000 8000 10000
Wavelength (Angstroms)

Light Curve Comparison

2D delayed detonation model compared to SN 2003du

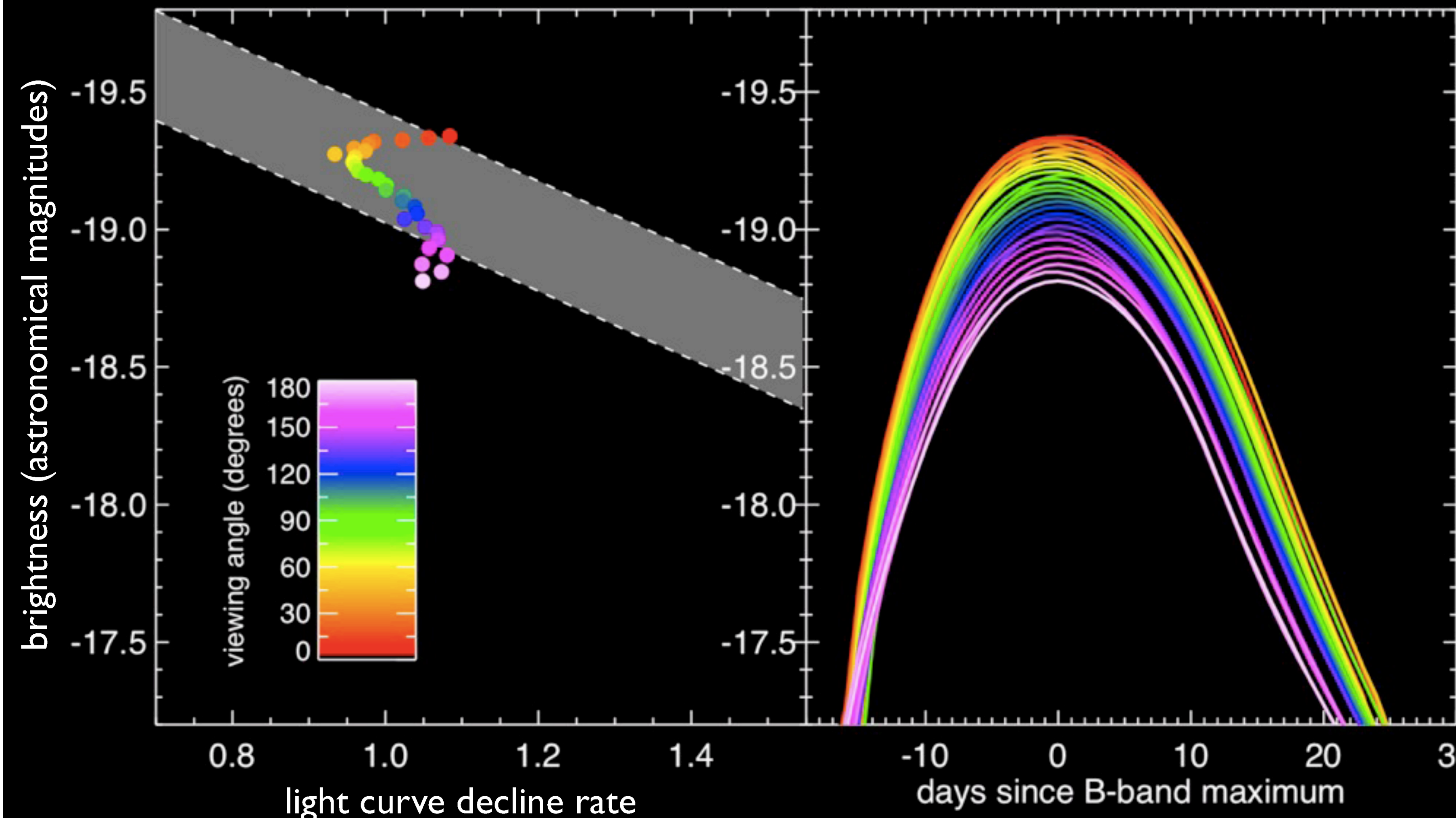




And the spectrum validates the approach as well

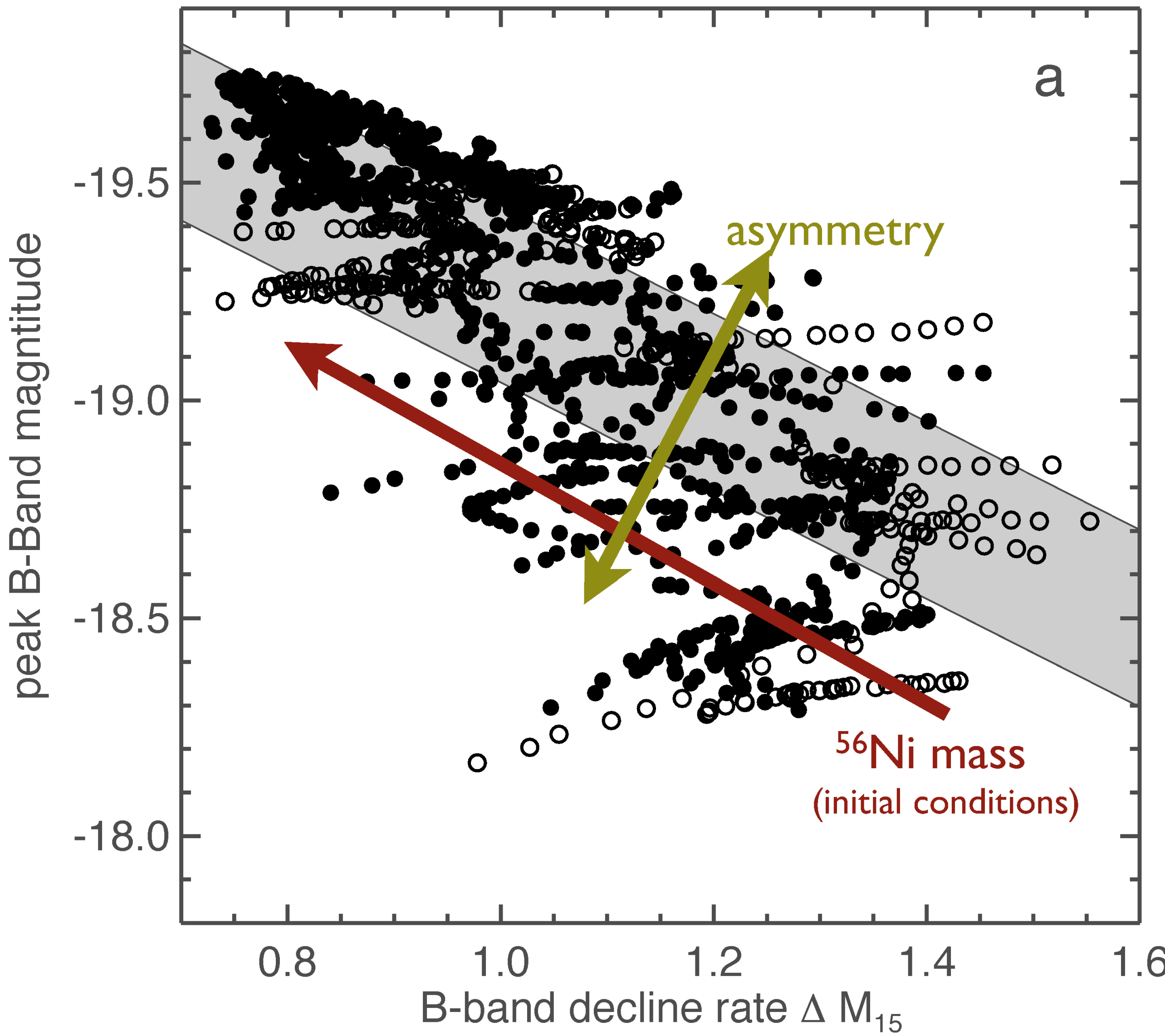
asymmetry and light curve diversity

effect on the width luminosity relation for standardizing candles



Kasen, Roepke, and Woosley (2009, Nature)

model width-luminosity relation

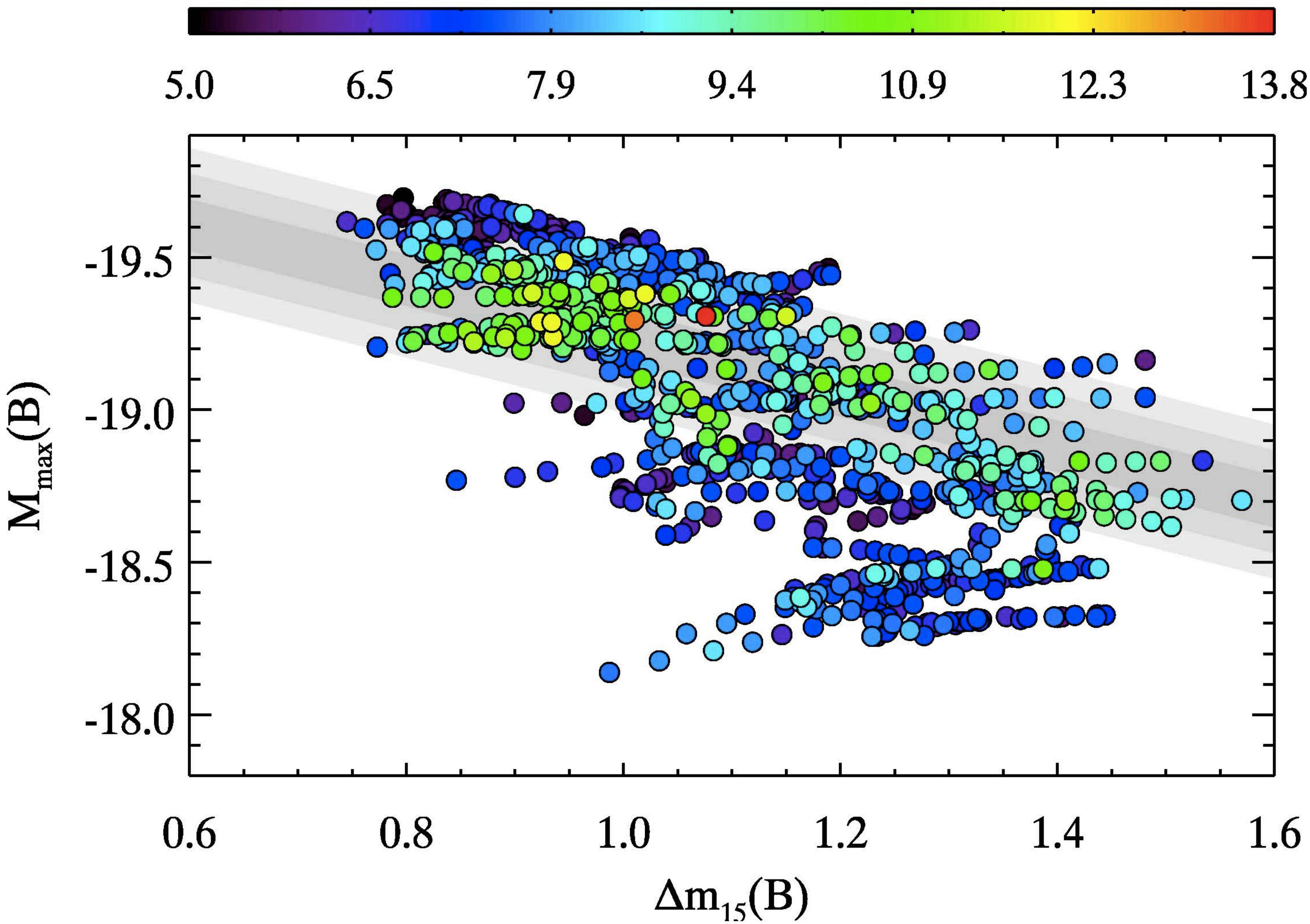


44 2D models
30 viewing
angles each

Blondin et al. (2011)

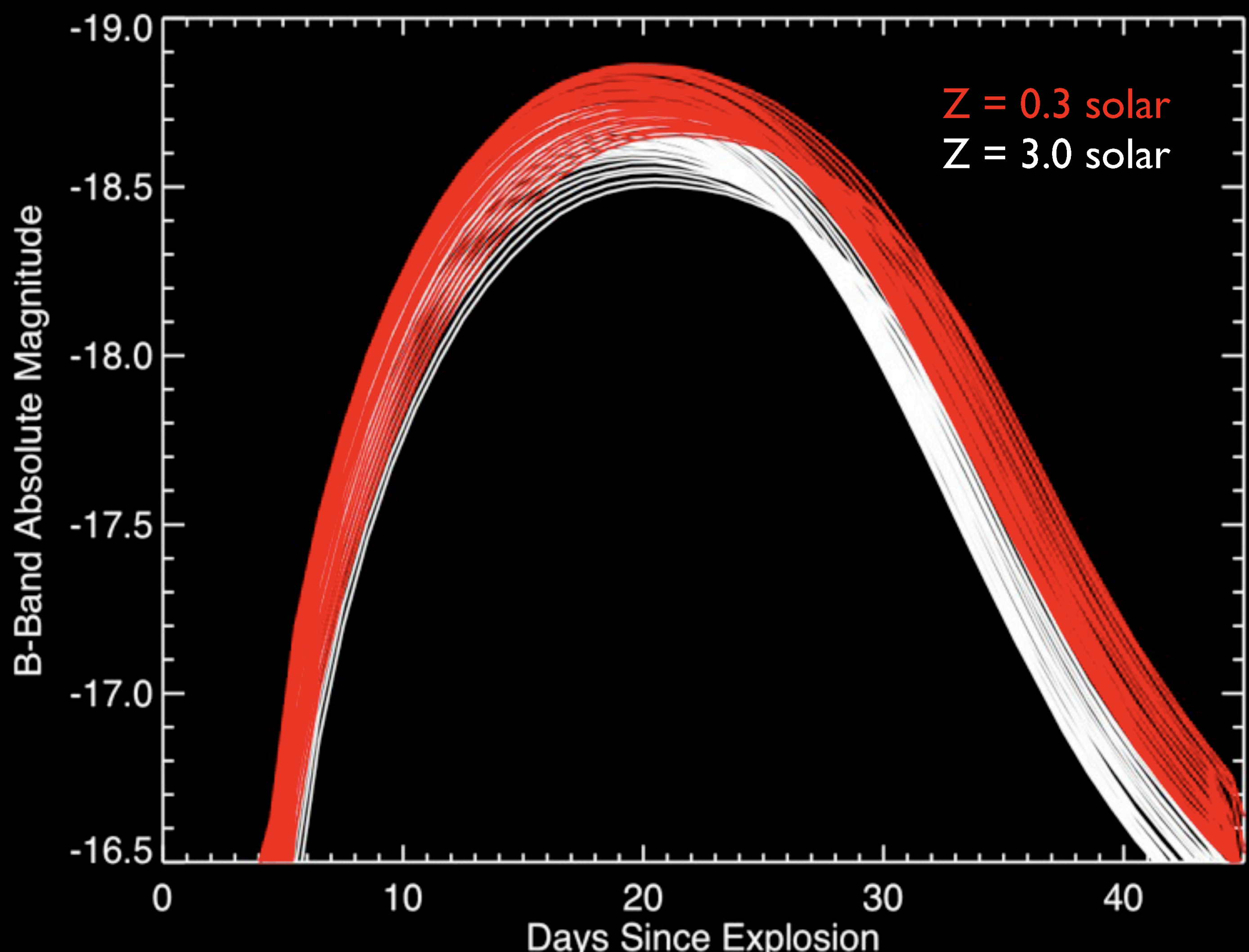
66,000 model spectra; 2231 observed spectra (CfA)

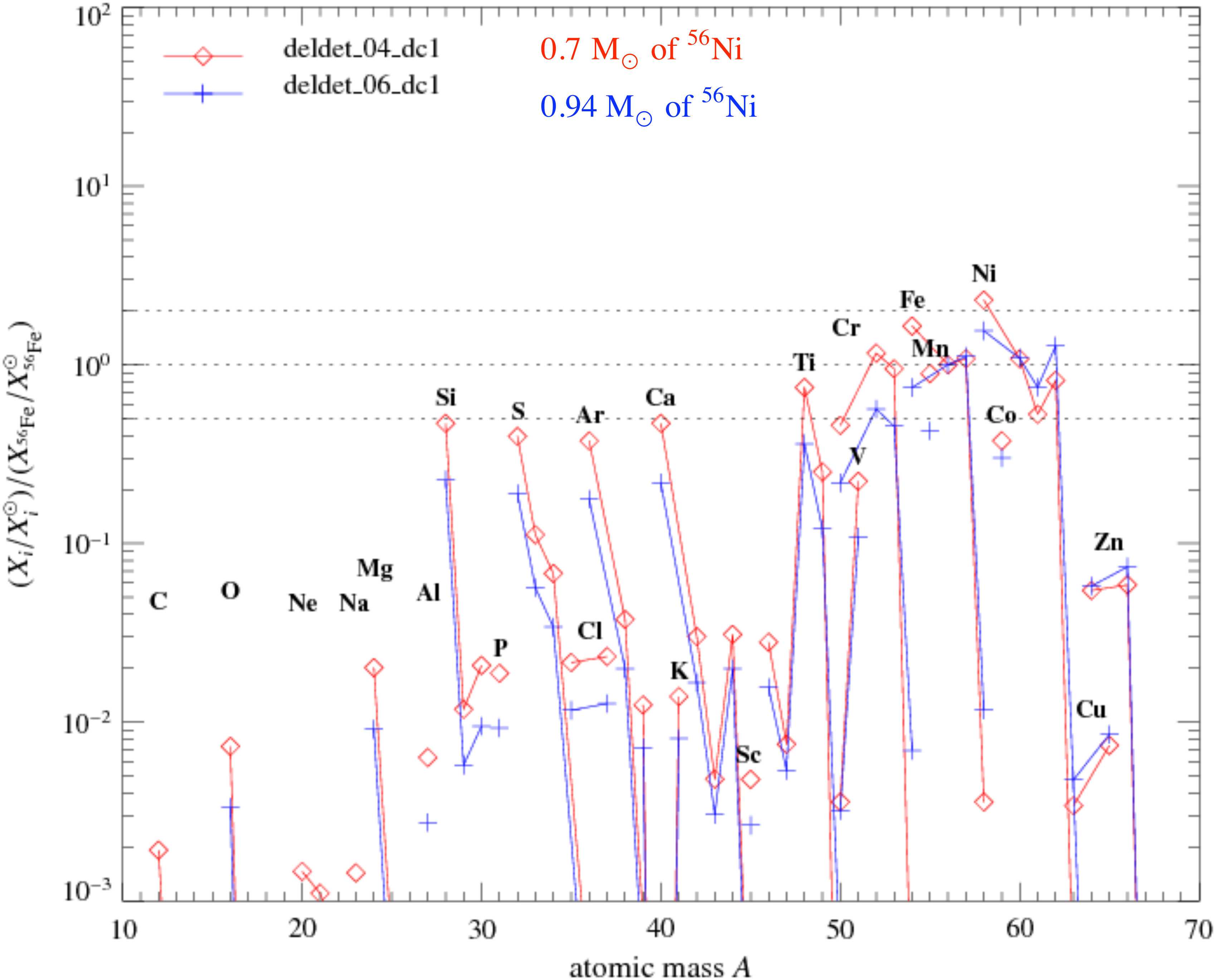
Goodness of spectral fit (Si feature)



white dwarf metal content effects light curve brightness

(e.g., Timmes et al, 2006, Kasen et al. 2009)

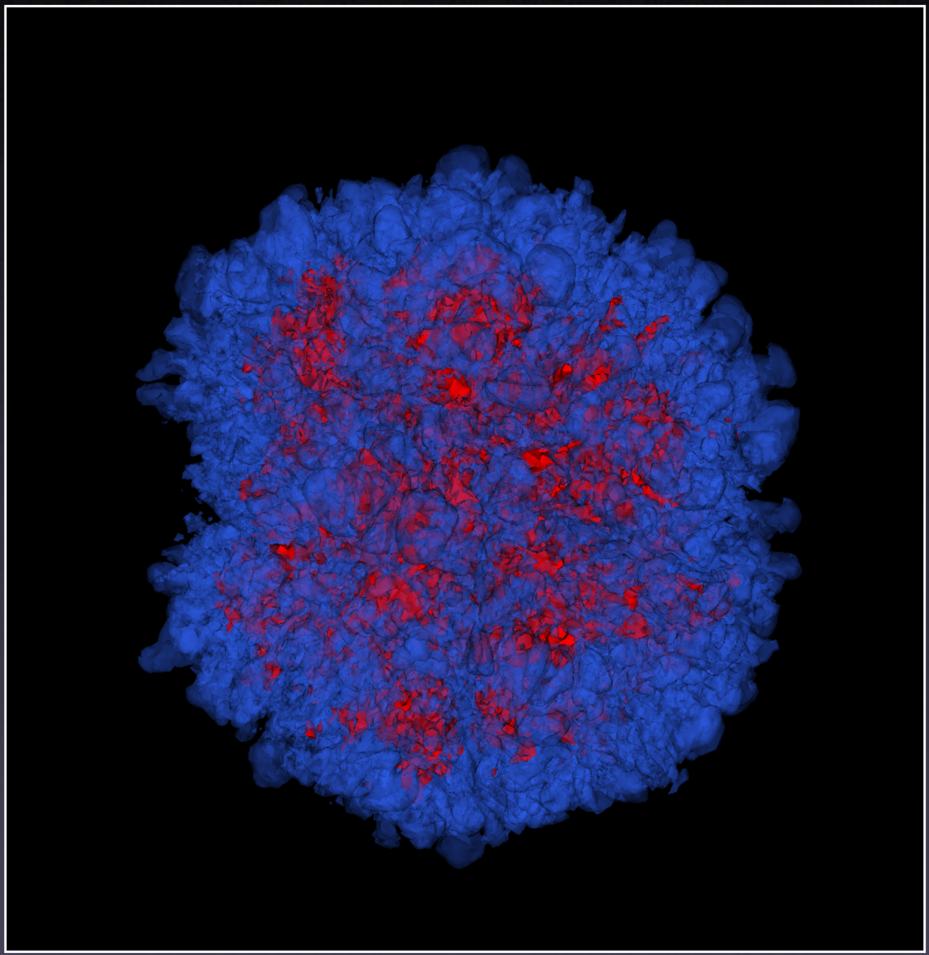


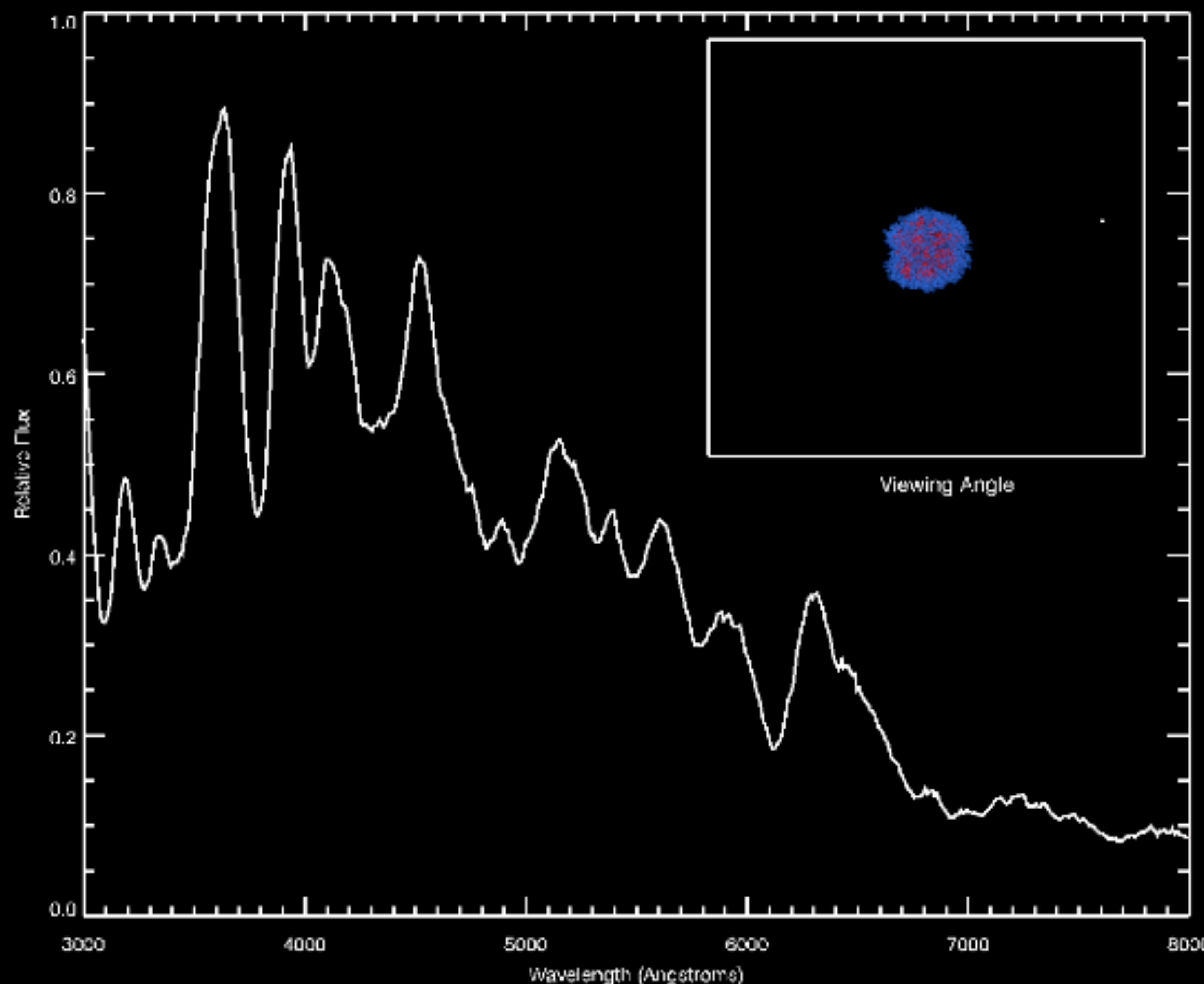


deldet_04_dc1
deldet_06_dc1
0.7 $M_\odot$ of ^{56}Ni
0.94 $M_\odot$ of ^{56}Ni
$(X_i/X_i^\odot)/(X_{^{56}\mathrm{Fe}}/X_{^{56}\mathrm{Fe}}^\odot)$
atomic mass A
C
O
Ne
Na
Mg
Al
Si
P
S
Cl
Ar
K
Ca
Sc
Ti
V
Cr
Mn
Fe
Co
Ni
Cu
Zn

The Future: 3-D supernova spectrum calculations

pure deflagration model from Roepke et al, 2007





Relative Flux
Wavelength (Angstroms)
Viewing Angle
0.0
0.2
0.4
0.6
0.8
1.0
3000
4000
5000
6000
7000
8000

Caveat: There exist other models…

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A 12 MINUTE ORBITAL PERIOD DETACHED WHITE DWARF ECLIPSING BINARY*

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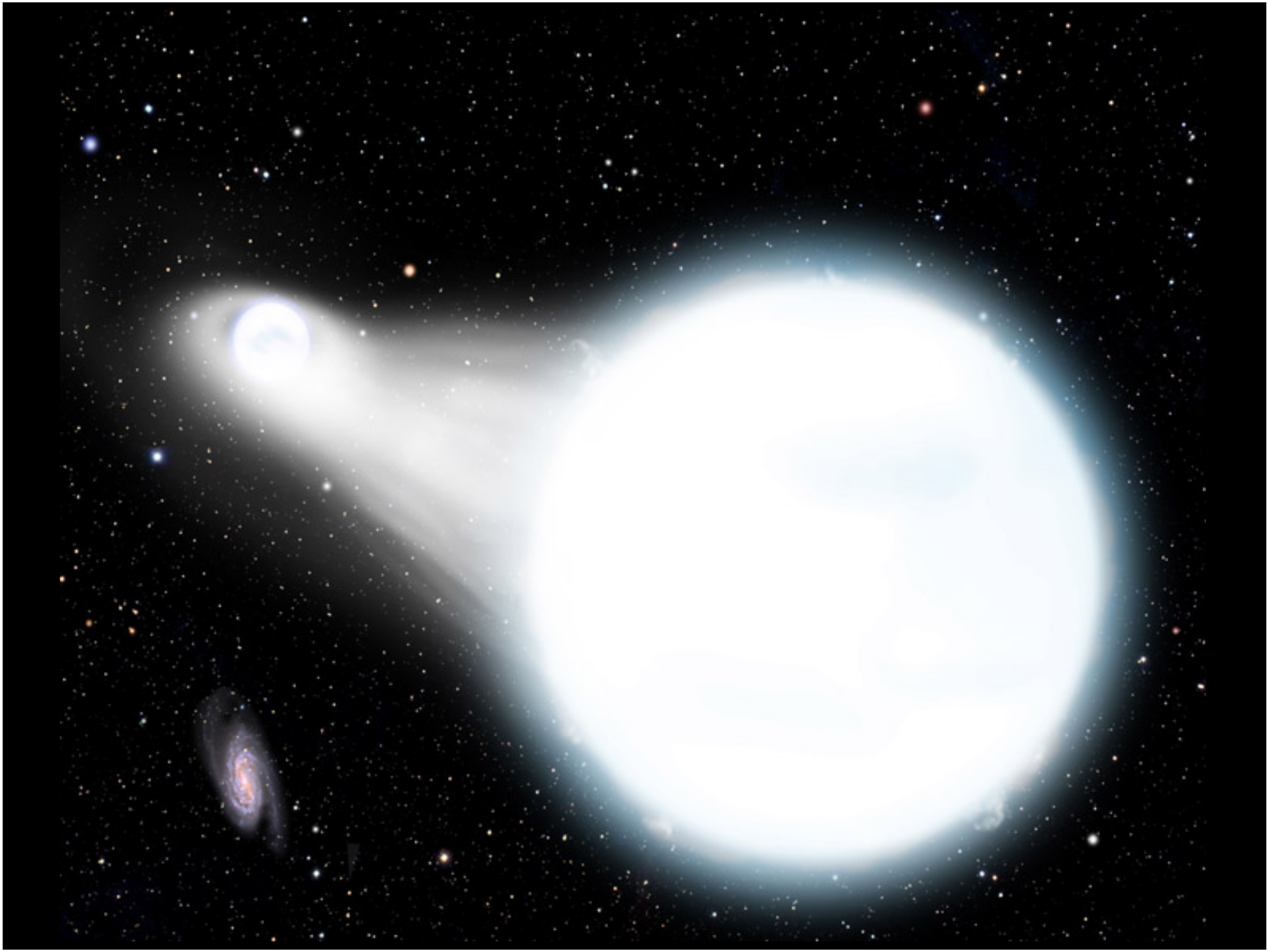
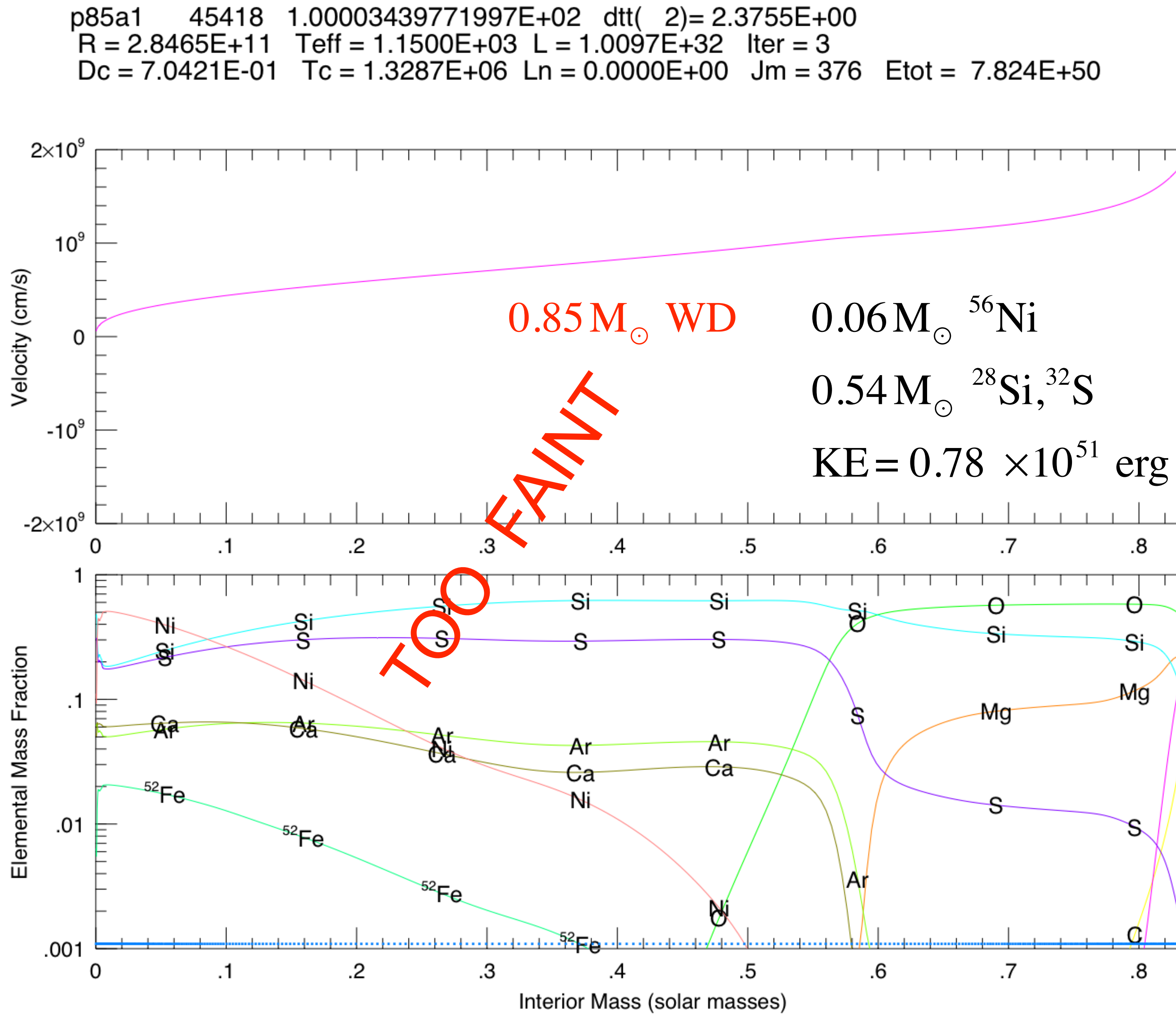
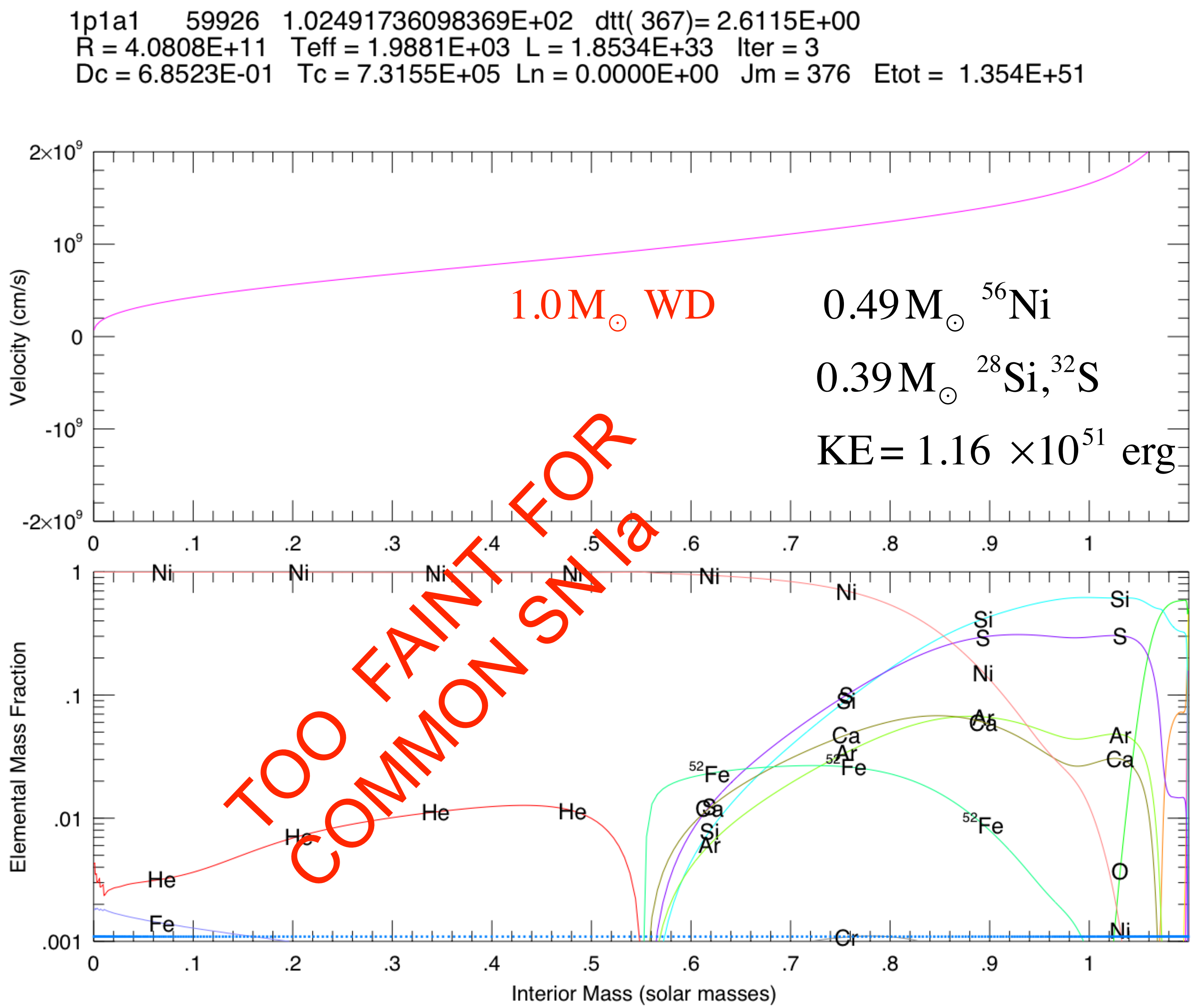
Draft version July 13, 2011

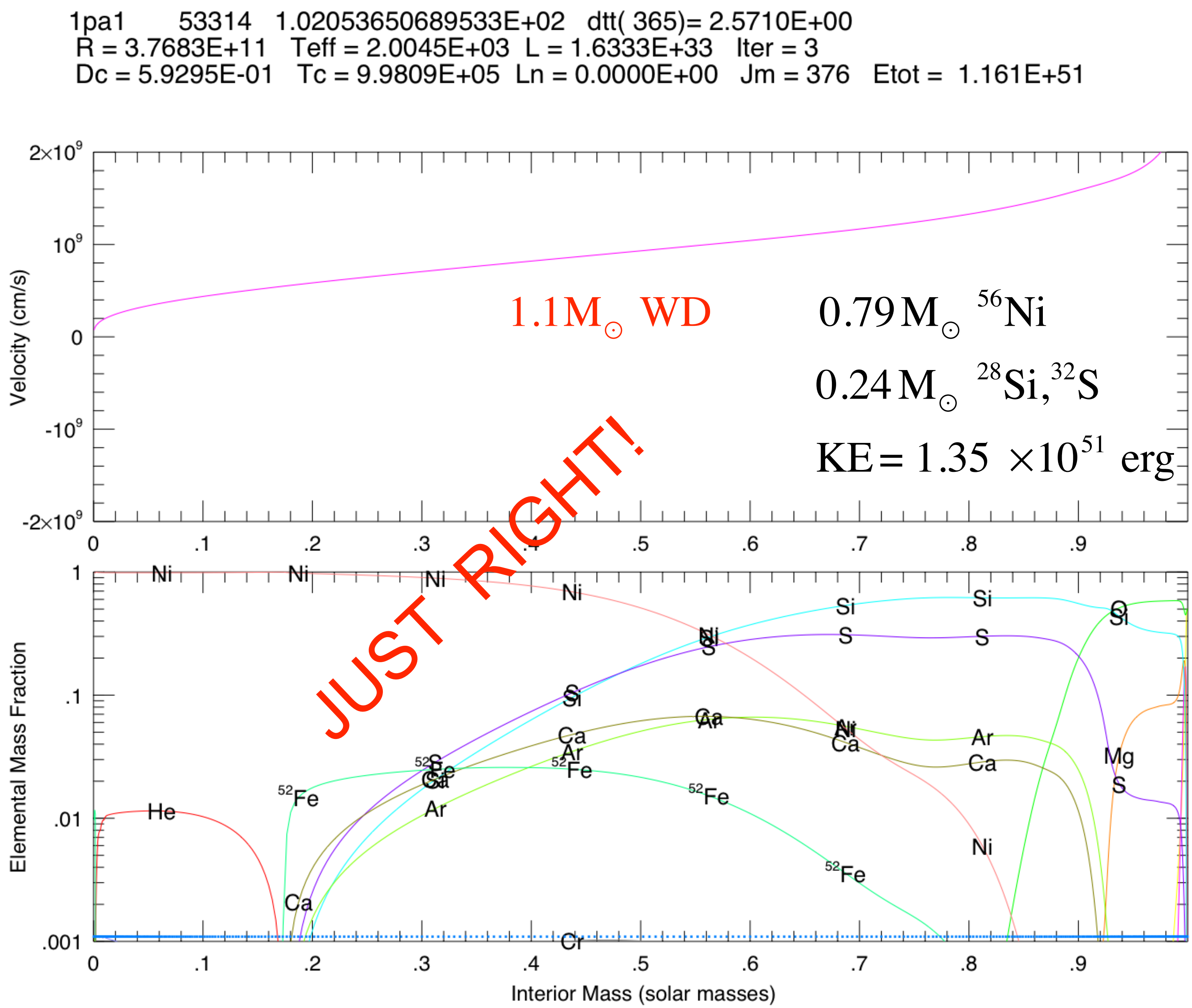
ABSTRACT

We have discovered a detached pair of white dwarfs (WDs) with a 12.75 min orbital period and a 1,315 km s^{-1} radial velocity amplitude. We measure the full orbital parameters of the system using its light curve, which shows ellipsoidal variations, Doppler boosting, and primary and secondary eclipses. The primary is a 0.25 $M_\odot$ tidally distorted helium WD, only the second tidally distorted WD known. The unseen secondary is a 0.55 $M_\odot$ carbon-oxygen WD. The two WDs will come into contact in 0.9 Myr due to loss of energy and angular momentum via gravitational wave radiation. Upon contact the systems may merge yielding a rapidly spinning massive WD, form a stable interacting binary, or possibly explode as an underluminous supernova type Ia. The system currently has a gravitational wave strain of 10^{-22}, about 10,000 times larger than the Hulse-Taylor pulsar; this system would be detected by the proposed LISA gravitational wave mission in the first week of operation. This system's rapid change in orbital period will provide a fundamental test of general relativity.

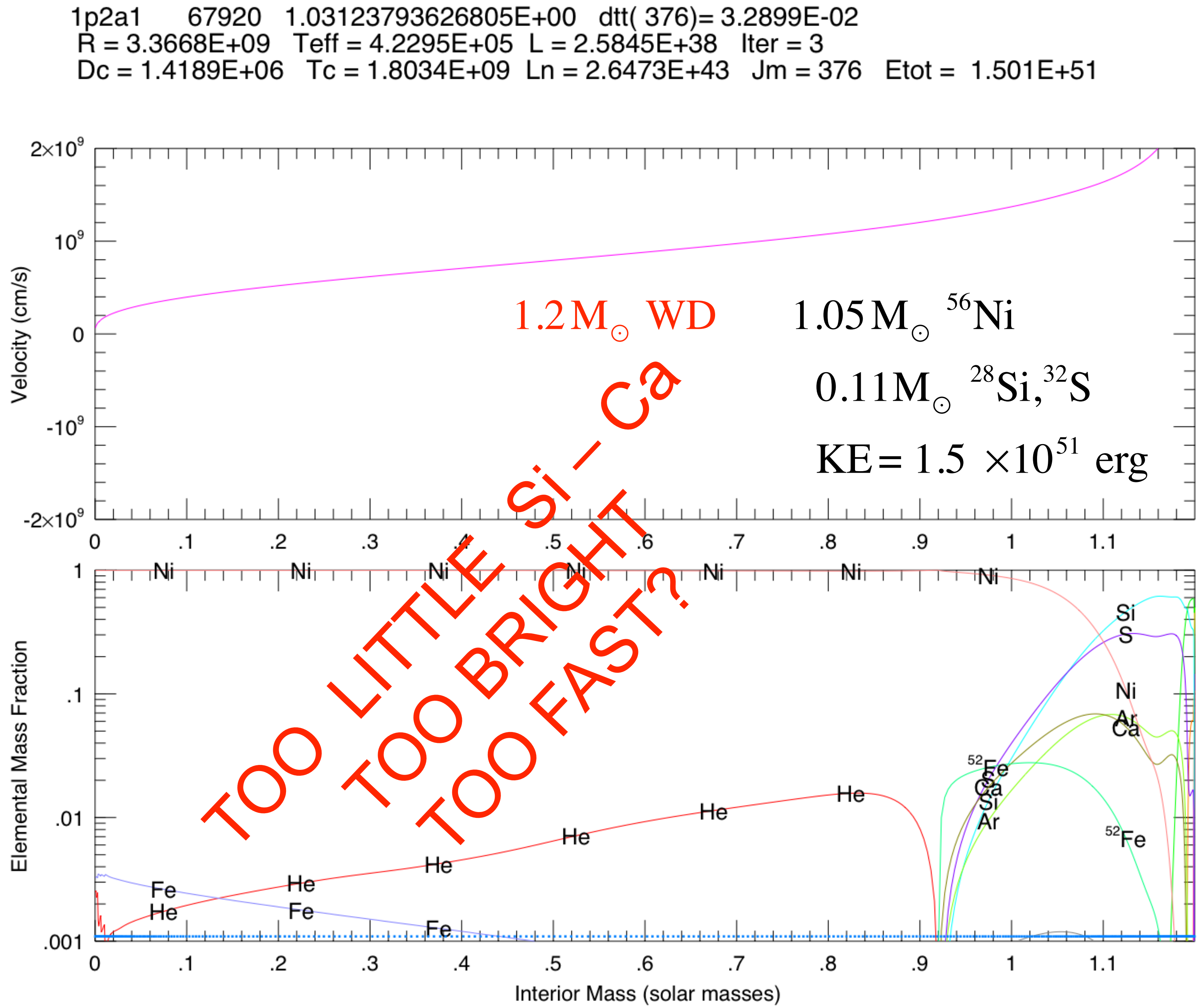



p85a1 45418 1.00003439771997E+02 dtt(2)= 2.3755E+00
R = 2.8465E+11 Teff = 1.1500E+03 L = 1.0097E+32 Iter = 3
Dc = 7.0421E-01 Tc = 1.3287E+06 Ln = 0.0000E+00 Jm = 376 Etot = 7.824E+50
0.85 M☉ WD
0.06 M☉ 56Ni
0.54 M☉ 28Si, 32S
KE = 0.78 ×10^51 erg
TOO FAINT
Velocity (cm/s)
Elemental Mass Fraction
Interior Mass (solar masses)


1p1a1 59926 1.02491736098369E+02 dtt(367)= 2.6115E+00
R = 4.0808E+11 Teff = 1.9881E+03 L = 1.8534E+33 Iter = 3
Dc = 6.8523E-01 Tc = 7.3155E+05 Ln = 0.0000E+00 Jm = 376 Etot = 1.354E+51
1.0 M⊙ WD
0.49 M⊙ 56Ni
0.39 M⊙ 28Si, 32S
KE = 1.16 ×10^51 erg
TOO FAINT FOR COMMON SN Ia
Velocity (cm/s)
Elemental Mass Fraction
Interior Mass (solar masses)



1pa1 53314 1.02053650689533E+02 dtt(365)= 2.5710E+00
R = 3.7683E+11 Teff = 2.0045E+03 L = 1.6333E+33 Iter = 3
Dc = 5.9295E-01 Tc = 9.9809E+05 Ln = 0.0000E+00 Jm = 376 Etot = 1.161E+51
$1.1 M_\odot$ WD
$0.79 M_\odot$ ^{56}Ni
$0.24 M_\odot$ $^{28}Si, ^{32}S$
$KE = 1.35 \times 10^{51}$ erg
JUST RIGHT!
Velocity (cm/s)
Elemental Mass Fraction
Interior Mass (solar masses)
Ni
Si
S
Ca
Ar
^{52}Fe
He
Mg
O
Cr


1p2a1 67920 1.03123793626805E+00 dtt(376)= 3.2899E-02
R = 3.3668E+09 Teff = 4.2295E+05 L = 2.5845E+38 Iter = 3
Dc = 1.4189E+06 Tc = 1.8034E+09 Ln = 2.6473E+43 Jm = 376 Etot = 1.501E+51
Velocity (cm/s)
1.2 M⊙ WD
1.05 M⊙ 56Ni
0.11 M⊙ 28Si, 32S
KE = 1.5 ×10^51 erg
TOO LITTLE Si – Ca
TOO BRIGHT
TOO FAST?
Elemental Mass Fraction
Ni
He
Fe
Si
S
Ar
Ca
52Fe
Interior Mass (solar masses)

SUB-CHANDRA MODELS?

Above 1.2 solar masses, things become rapidly worse. Electron capture overproduces ^{54}Fe, ^{58}Ni. Little intermediate mass elements and what there is moves too fast.

Recall objections to original carbon detonation model.

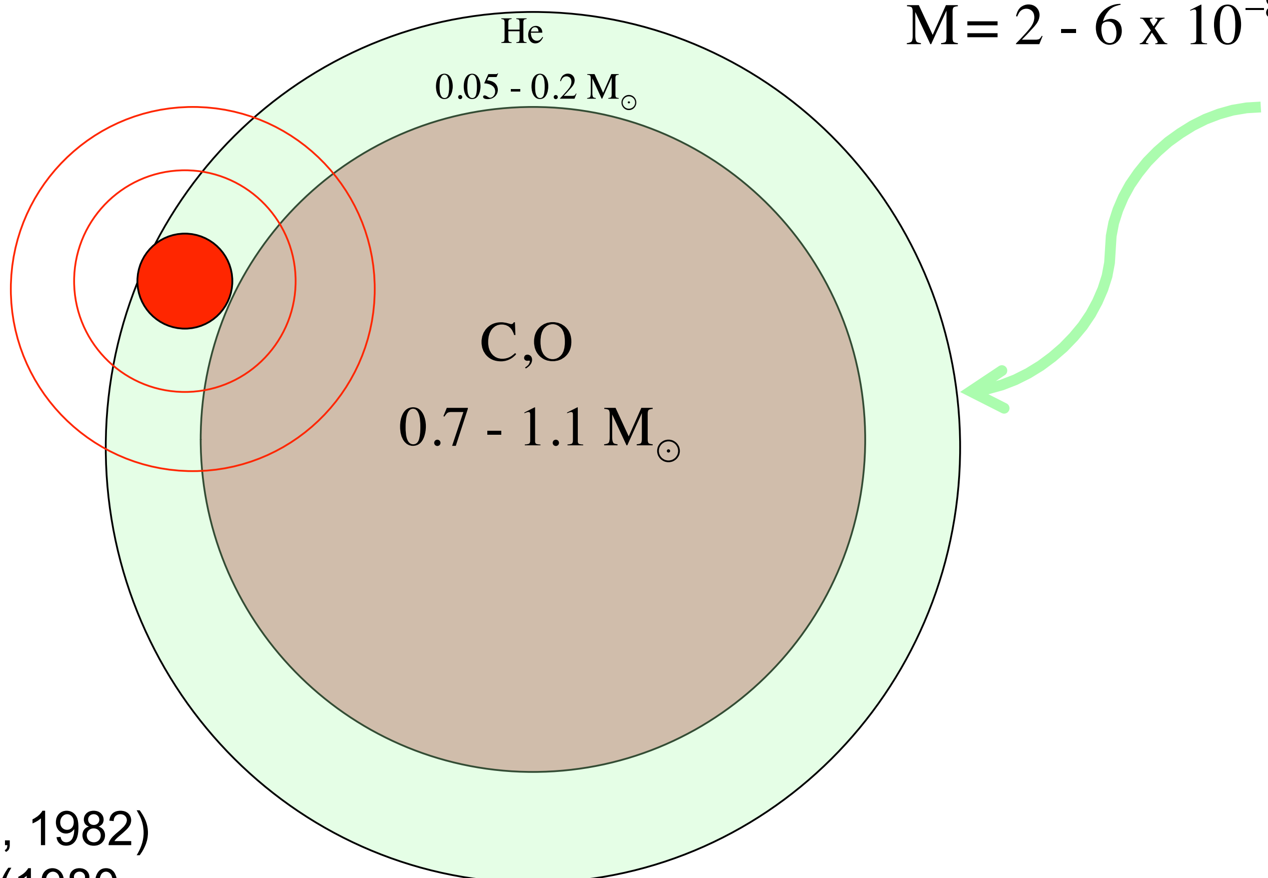
If sub-MCh models are to be common SN Ia, one has to explain why nature frequently selects to detonate 1.1 +- 0.05 solar mass CO-dwarfs and not the more common lighter ones (and hide the helium if helium is required to initiate the carbon detonation).

See also Woosley and Kasen (*ApJ*, **734**, 28, (2011))

SUB-CHANDRASEKHAR MASS MODELS WITH HELIUM SHELLS

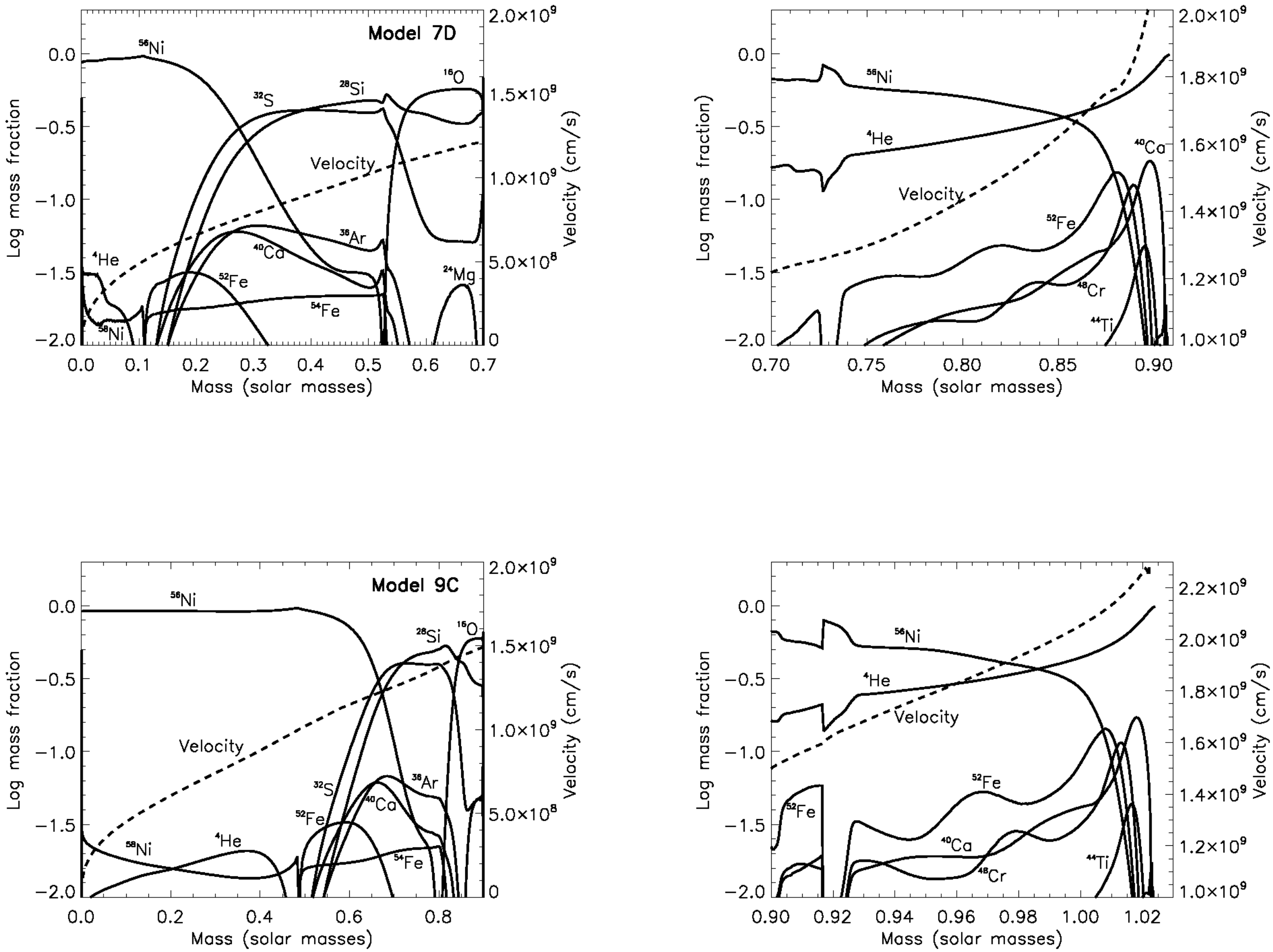
A critical mass of He accretes from a companion. The helium ignites and detonates. This may set off a secondary detonation of the carbon

$\dot{M} = 2 - 6 \times 10^{-8}\ M_\odot\ y^{-1}$

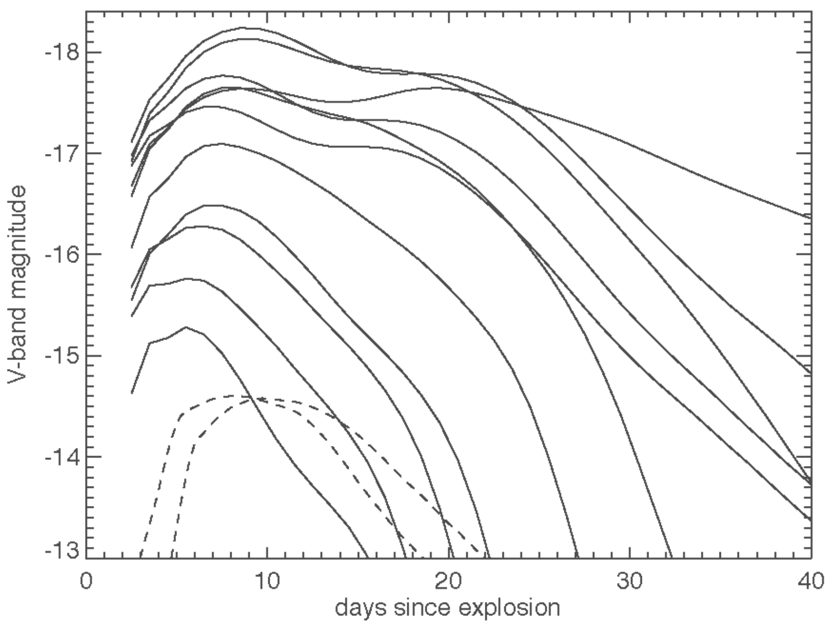


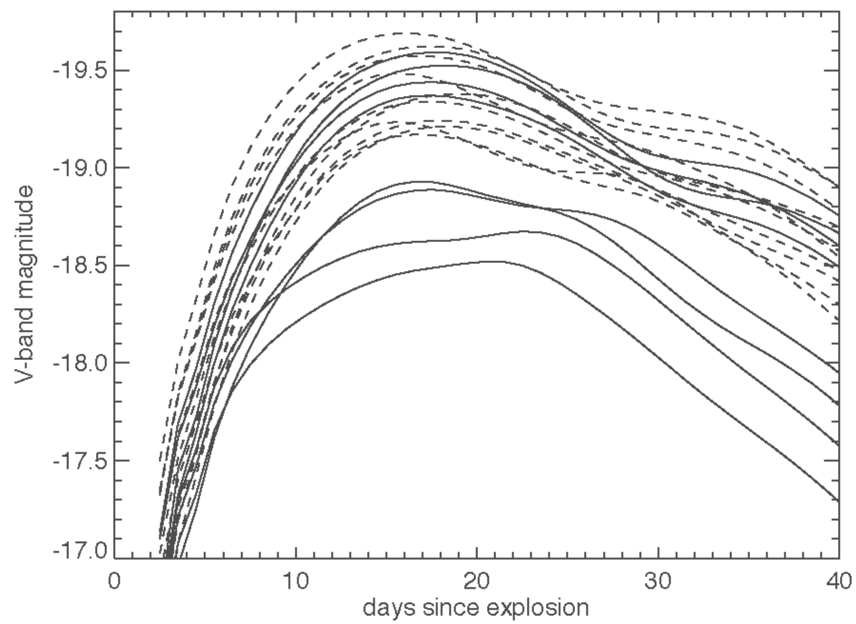
Nomoto (1980, 1982)
Woosley et al (1980, 1986, 1994)

Two examples of sub-Chandrasekhar mass explosions



The general class of sub-Chandrasekhar mass models can give a wide variety of transients ranging from very luminous SN Ia to super “novae”.



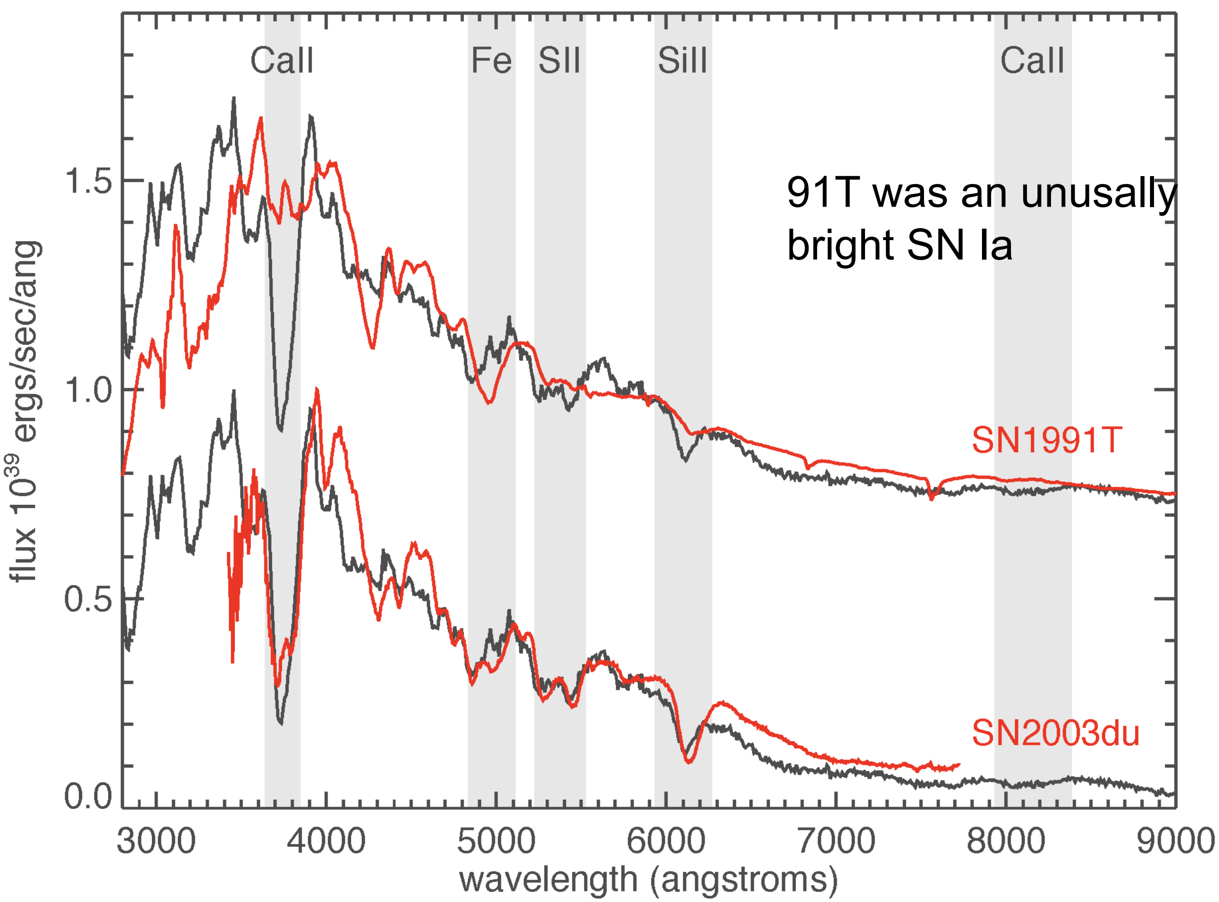


He shell only explodes

Entire star explodes

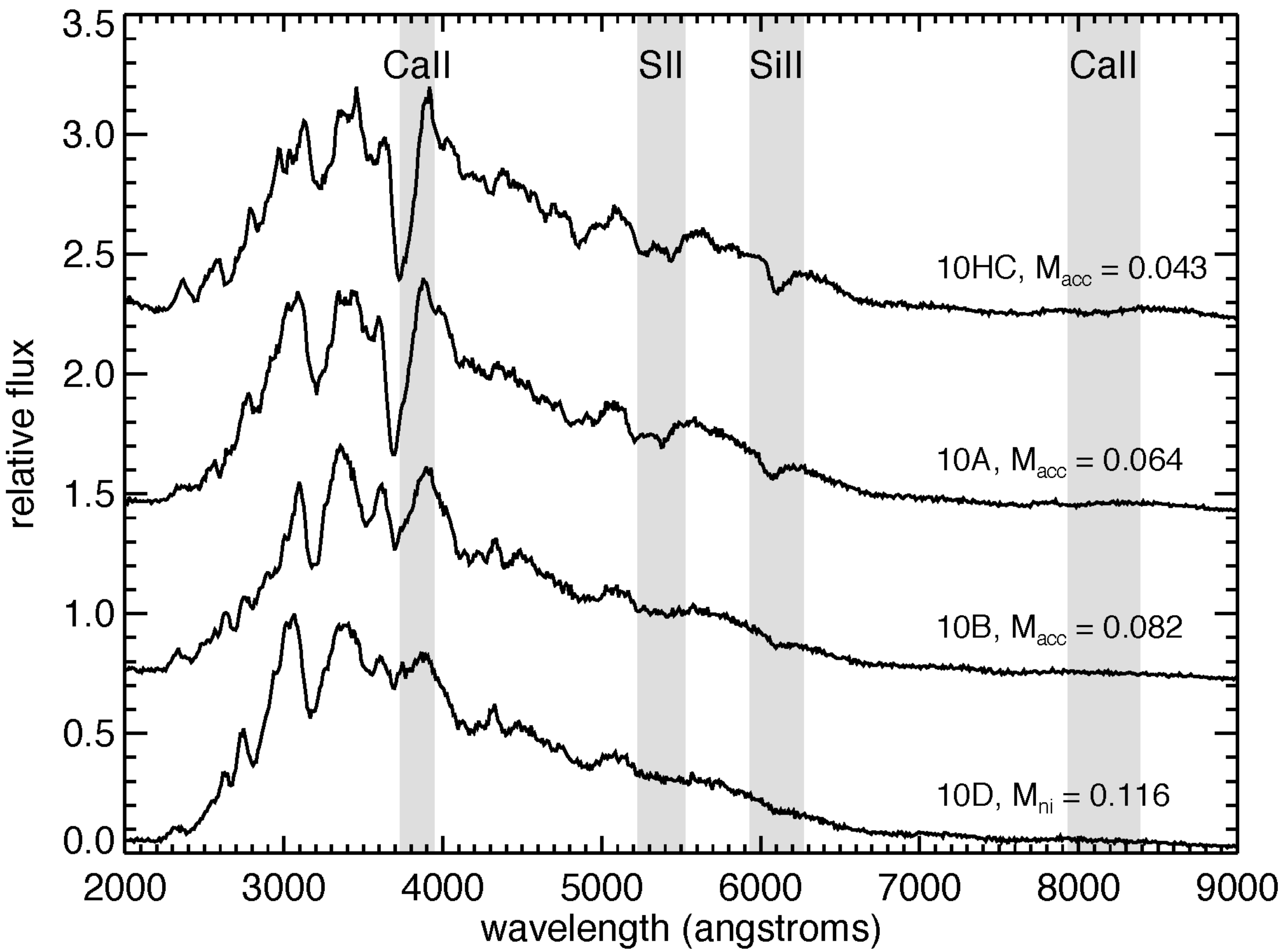
Some of these look like SN Ia. Most don't

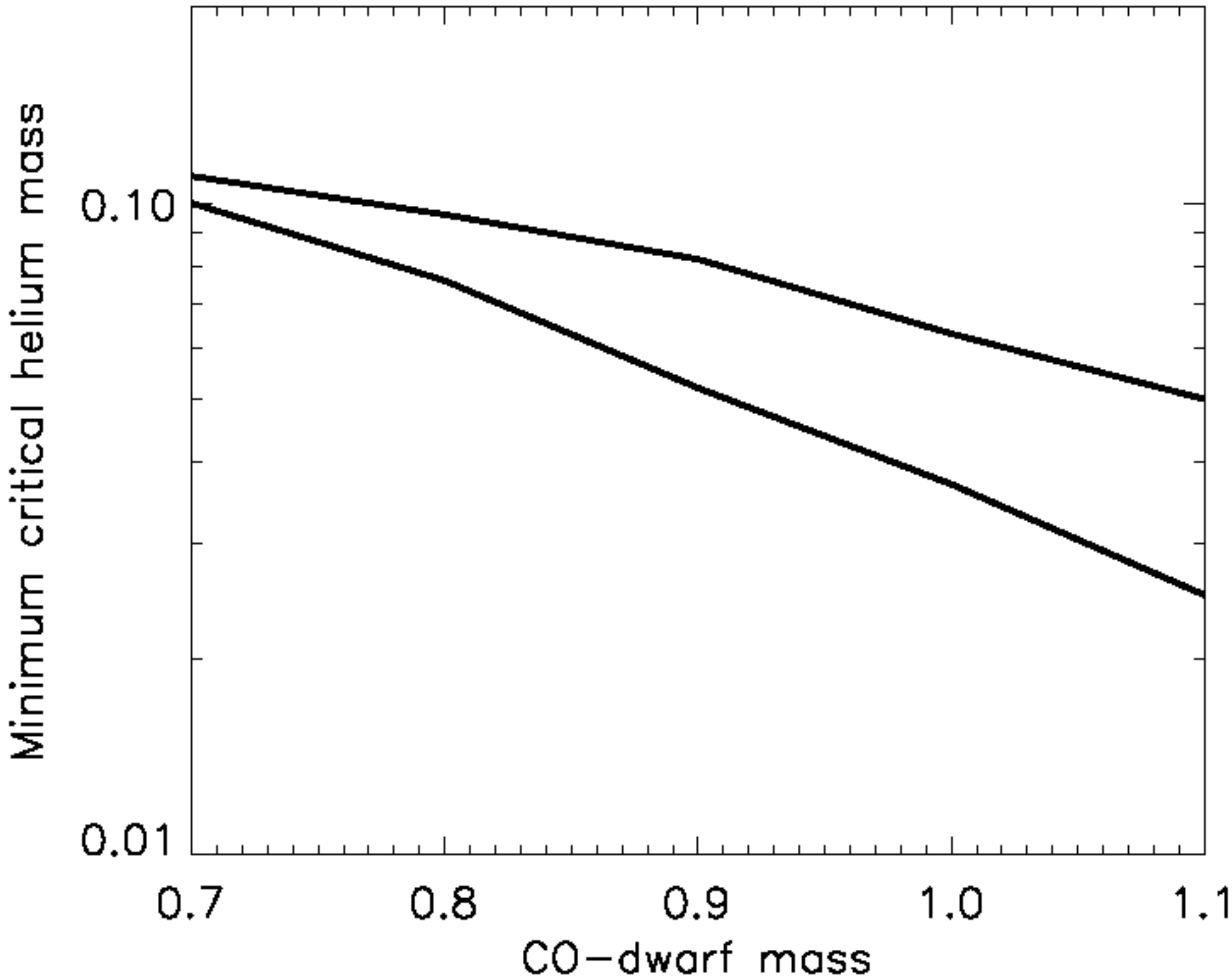
Model 10HC (hot 1.0 solar mass CO WD accreting at 4 x 10^{-8} solar masses per year) – peak light spectrum vs observations. Good agreement with typical SN Ia 2003du



"Hot" WD here means a white dwarf with L = 1 Lsun

This set of calculations shows the effect of helium shells of increasing mass on the peak light spectra. Only those with the lowest helium shell masses look like SN Ia. Where are the others?





Minimum helium shell mass required to initiate a CO core detonation for cold WD accretors (top) and hot WD accretors (bottom).