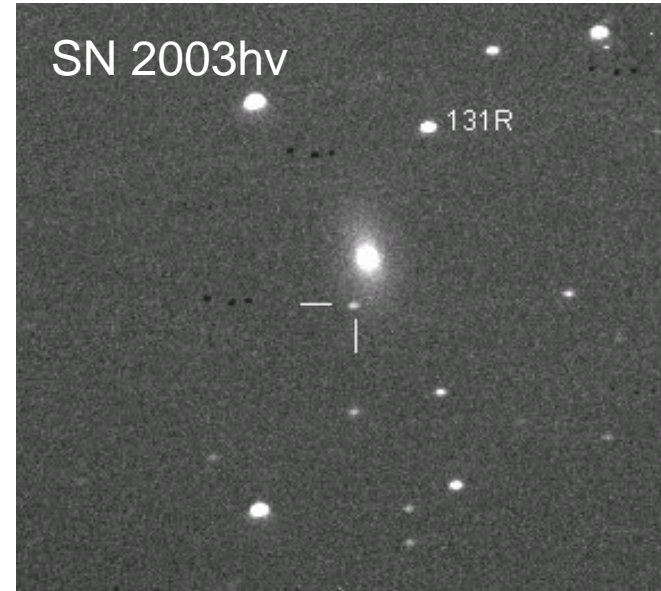
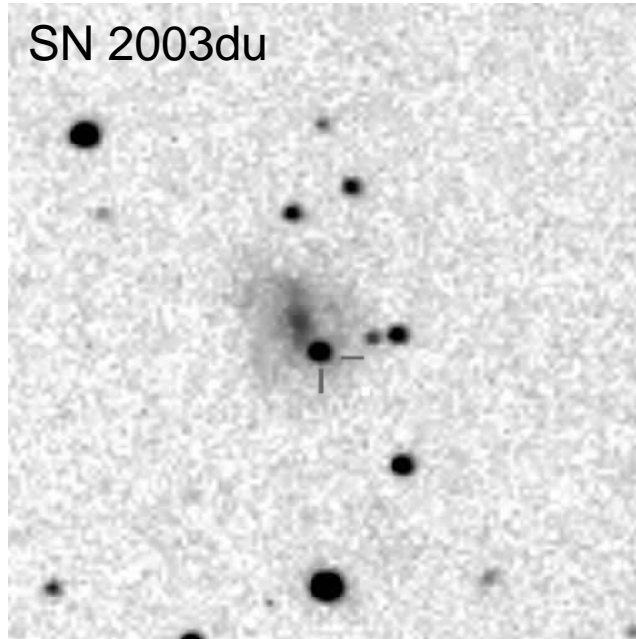


Neutron-rich Nucleosynthesis in Type Ia's: Constraints from NIR Nebular Observations



SN 2003hv in NGC 1201 2003 10 24.002 TU
Josep M. Bosch, Tàrrega (Spain) Mg.14.4Rc

Ken Nomoto

with

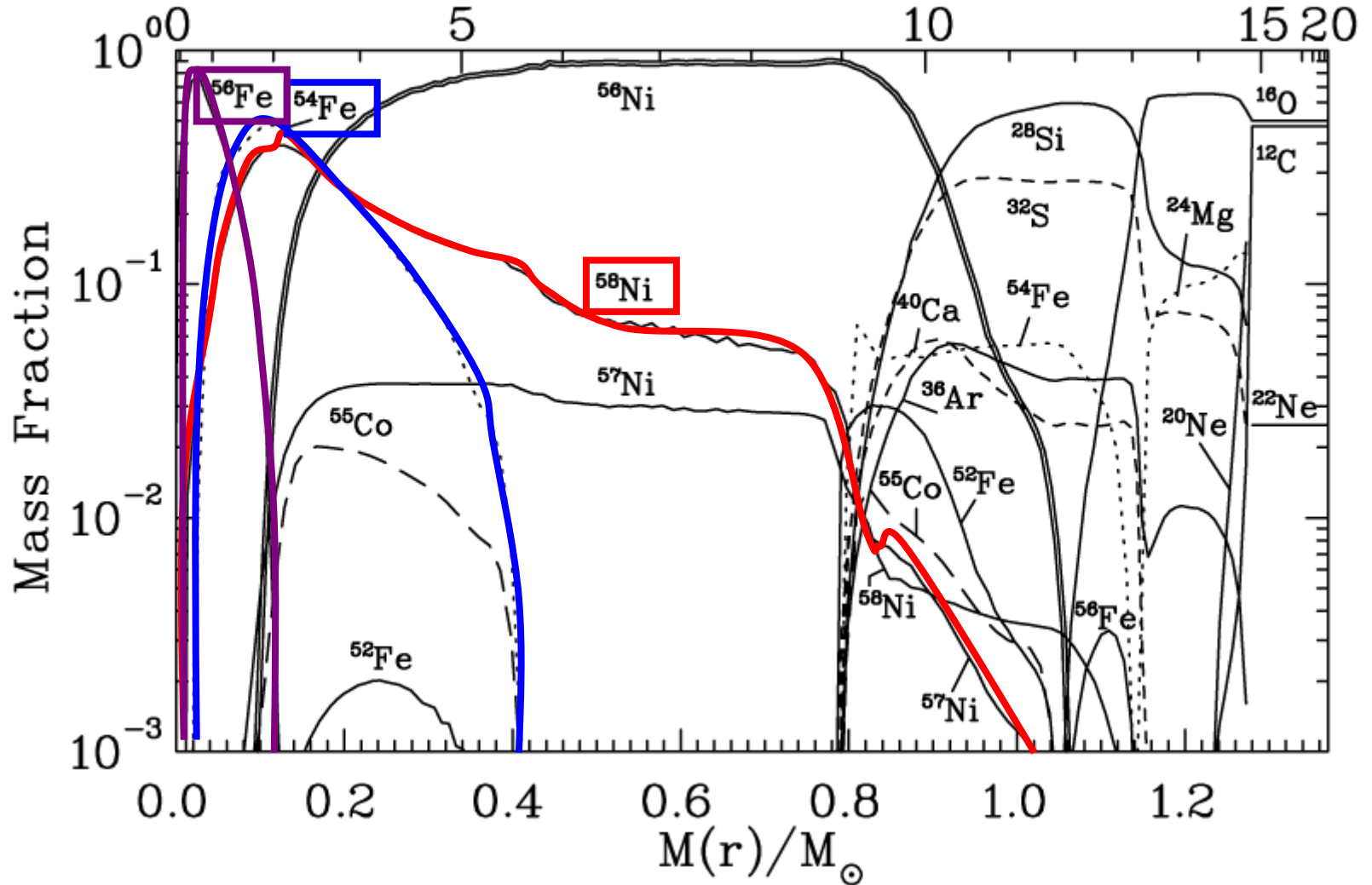
M. Tanaka, K. Motohara, K. Maeda, C. L. Gerardy, N. Tominaga,
T. Ohkubo, P. A. Mazzali, R. A. Fesen, P. Höflich, & J. C. Wheeler

Höflich et al. 2004, ApJ, 617, 1258; Motohara et al. 2006, ApJL, 652, 101

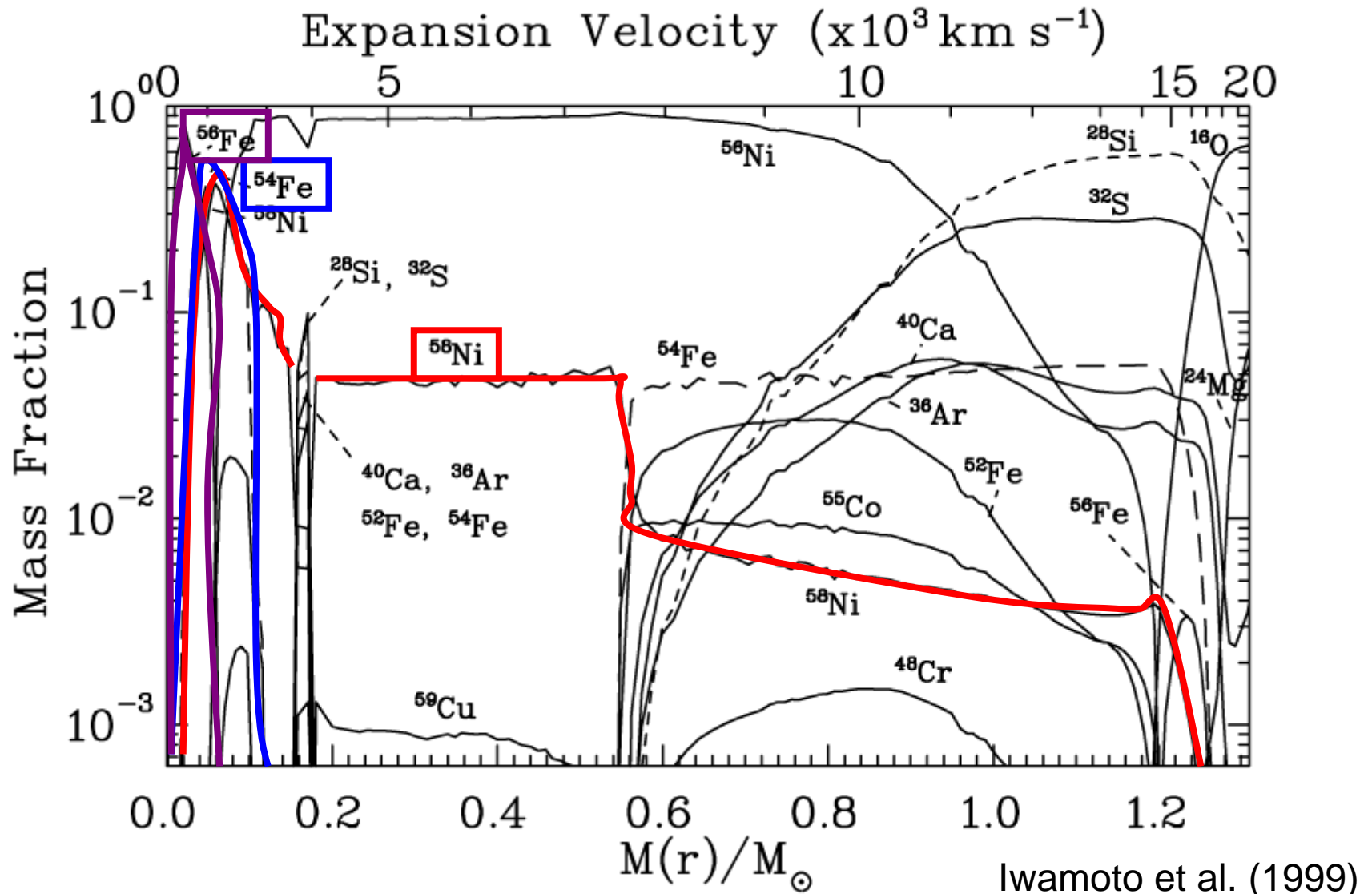
Nucleosynthesis in Deflagration Model (W7)

W7

Expansion Velocity ($\times 10^3 \text{ km s}^{-1}$)

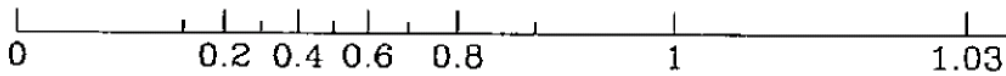
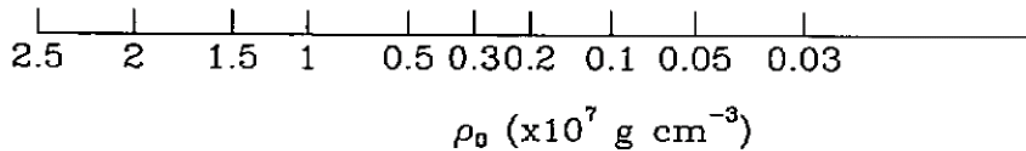
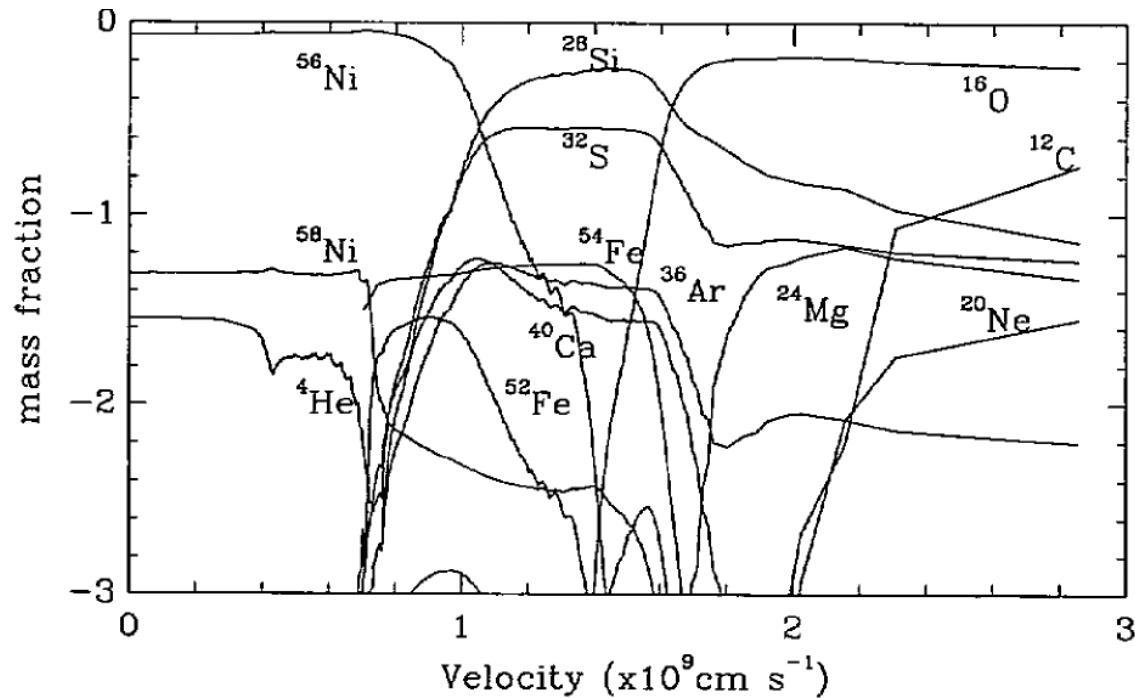


Nucleosynthesis in Delayed Detonation Model (WS15DD2) WS15DD2



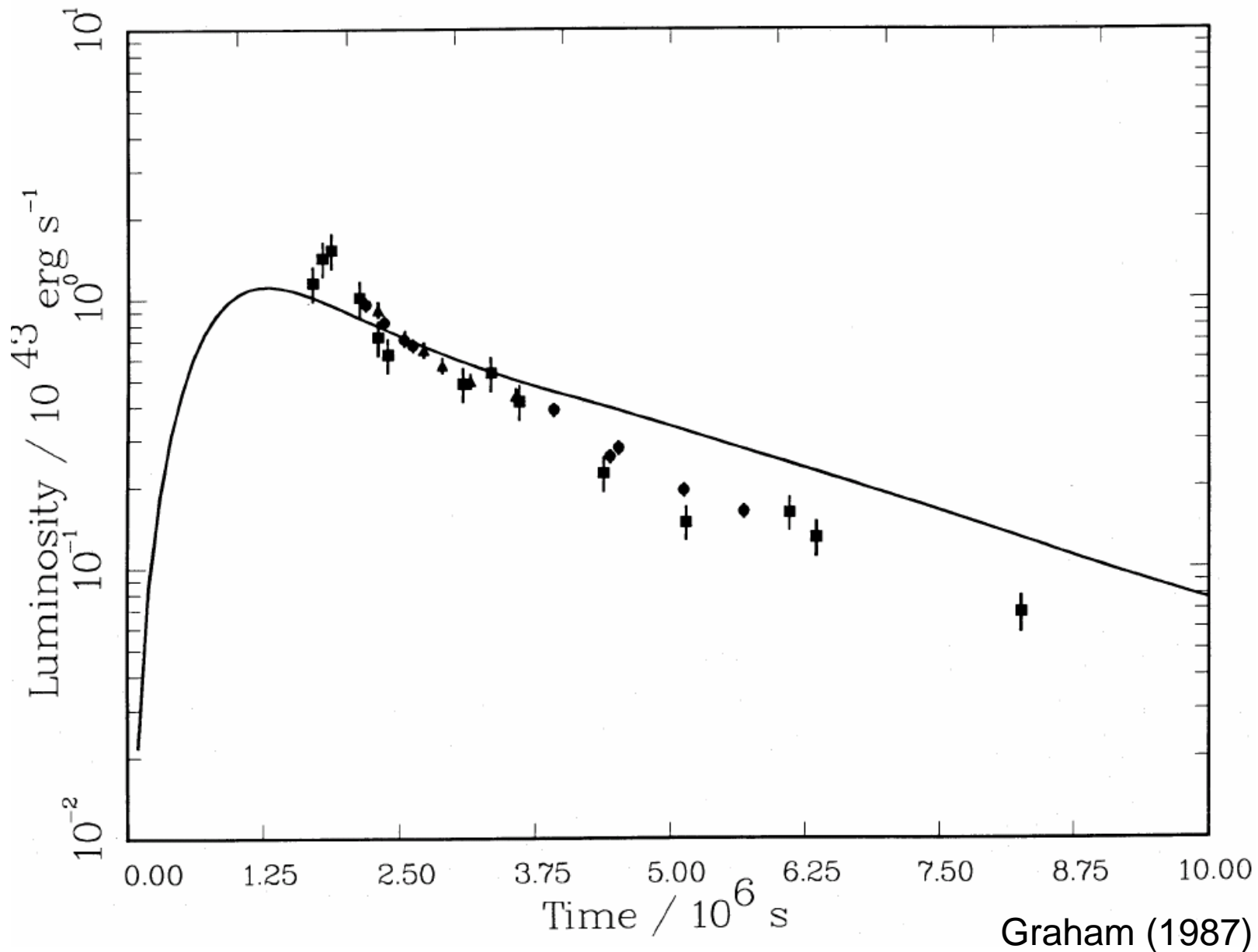
Sub-Chandrasekhar mass Model

Carbon Detonation
 $2.5E7 \text{ g cm}^{-3}$

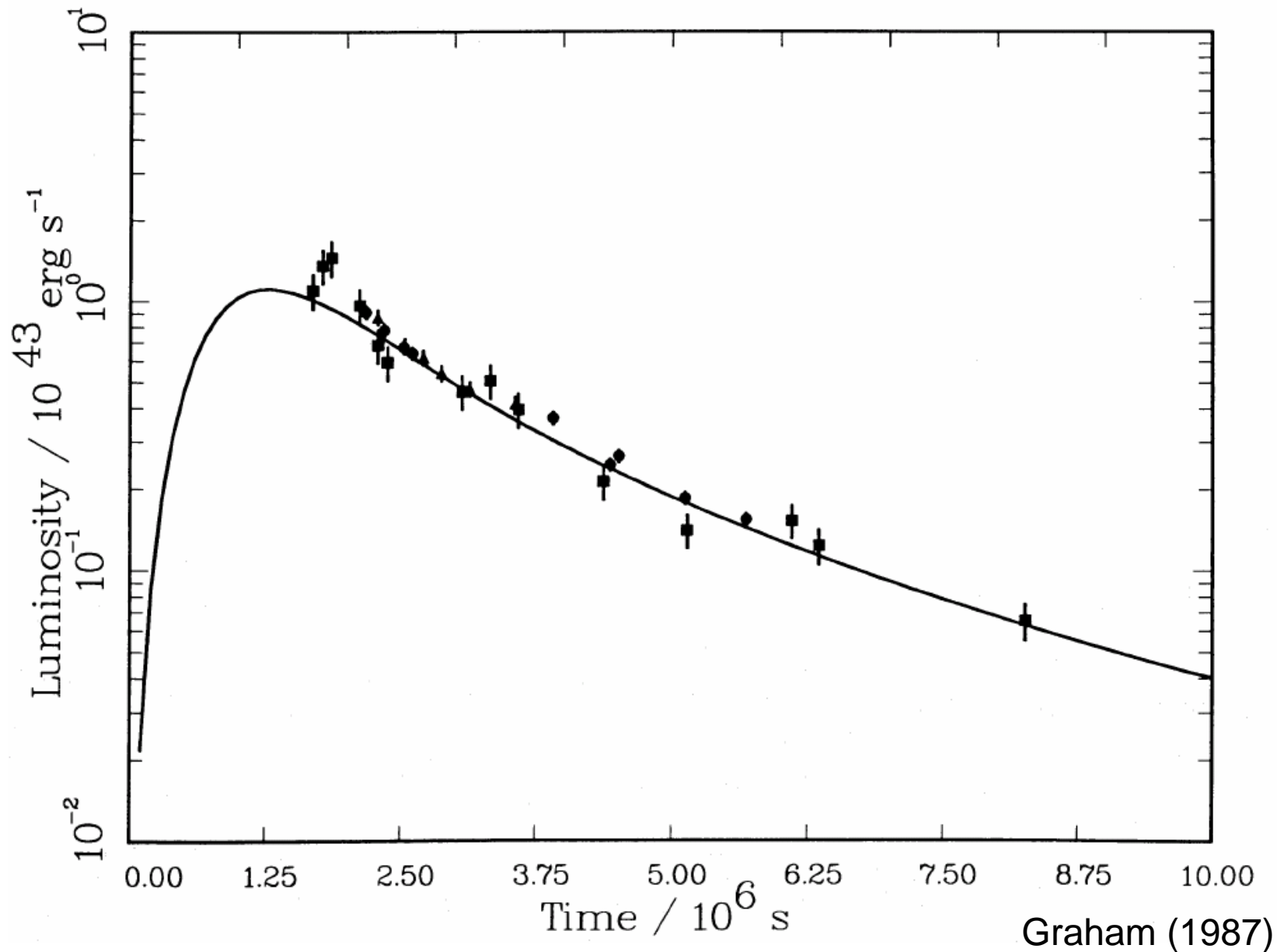


M_r/M_\odot (Shigeyama, Nomoto, Thielemann 1992 ApJ 386)

Bolometric LC without ^{56}Ni Hole

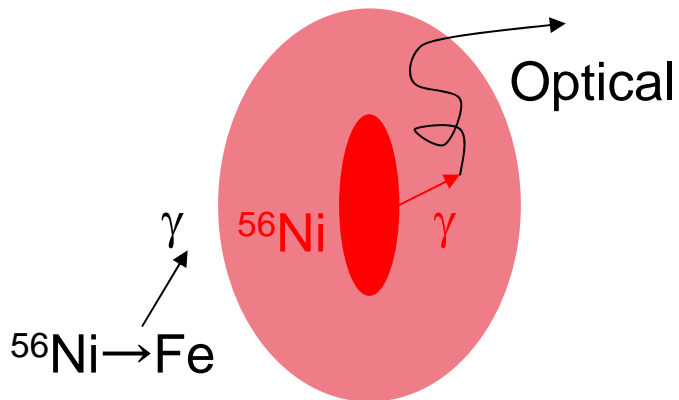


Bolometric LC with ^{56}Ni Hole



Late phase spectra of SNe

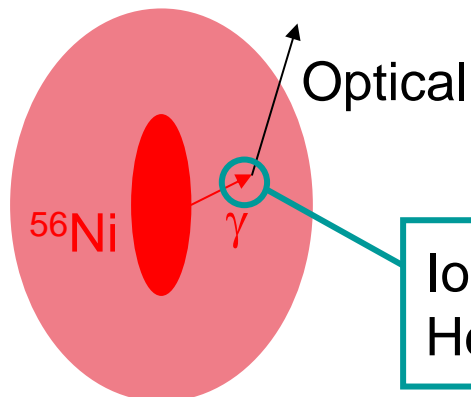
Early Phase ($\tau > 1$)



- γ -rays & optical photons traced by 3D Monte Carlo.
 - Optical photons: gray approximation.

1D: Cappellaro, 1997, A&A, 328, 203

Late Phase ($\tau < 1$)

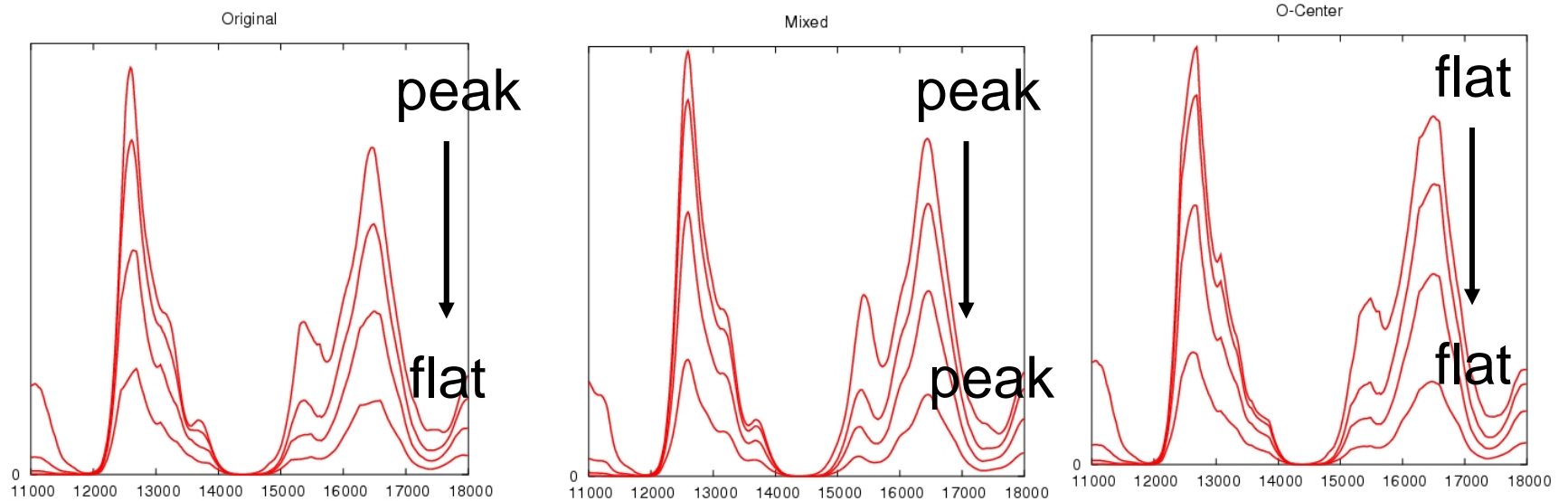


- Local balance in late phases
 - Ionization = Recombination
 - γ -ray, e^+ Heating = Cooling

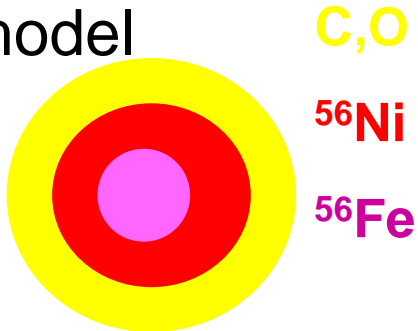
1D: Ruiz-Lapuente & Lucy, 1992, ApJ, 400, 127

Ionization = Recombination
Heating = Cooling

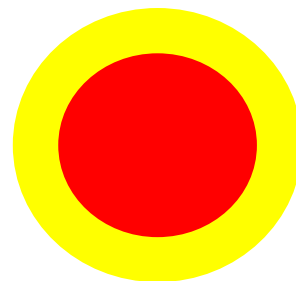
Expected line profiles: temporal evolution



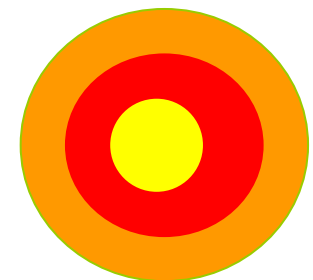
1D model



⁵⁶Ni hole
cf. W7



No ⁵⁶Ni hole



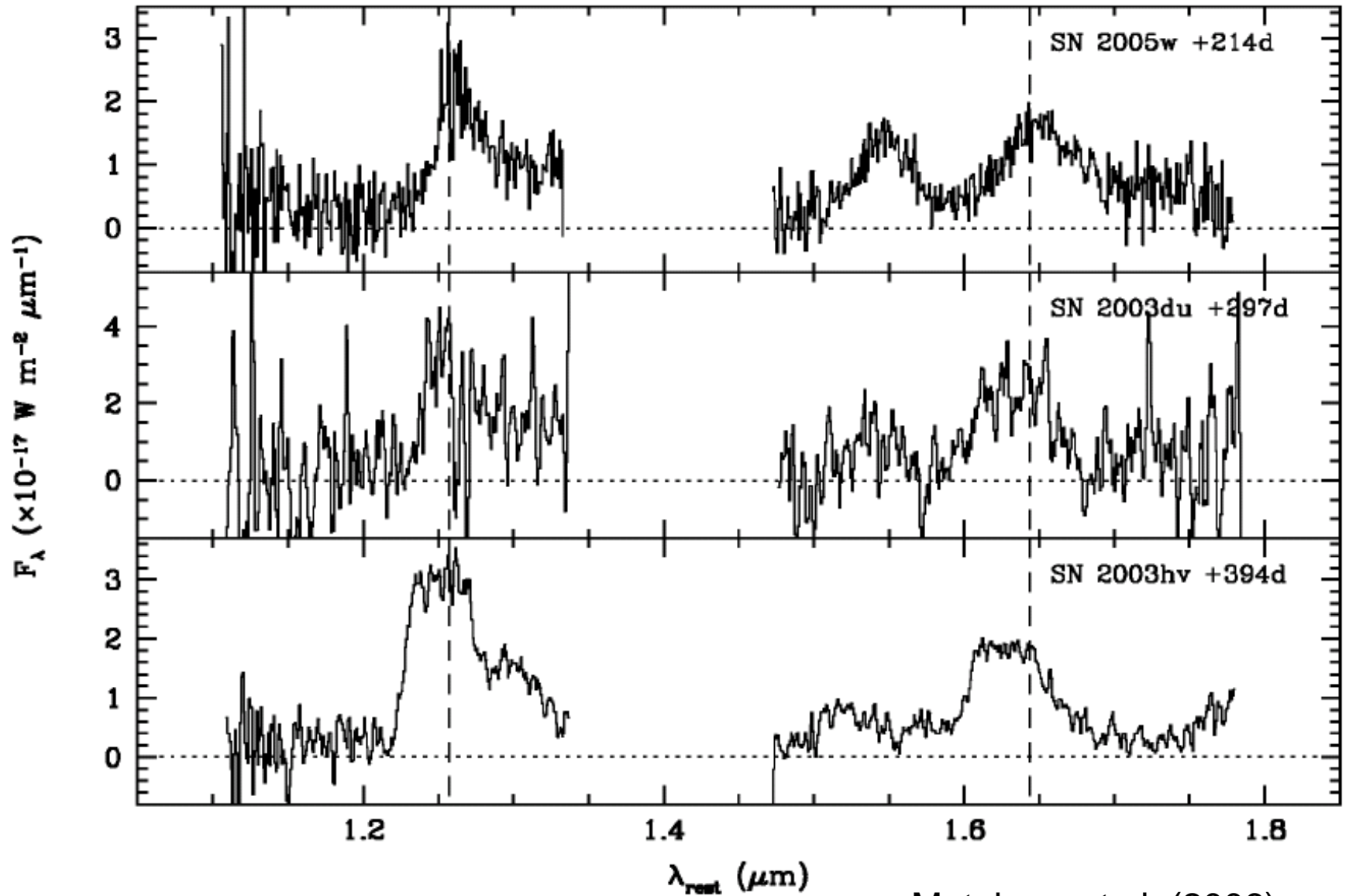
C+O in the center

Subaru Observations

- NIR Nebular Spectra of SNe Ia (PI: K. Nomoto)
 - Instruments
 - CISCO/OHS(OH airglow suppressor)
 - Targets
 - S03B: SN 2003du
 - S04B: SN 2003hv
 - Co-I
 - K. Maeda, K. Motohara, M. Tanaka (U. Tokyo)
 - C. Gerardy, P. Höflich, G. Marion, J.C. Wheeler (U. Texas)
 - R. Fesen (Dartmouth)

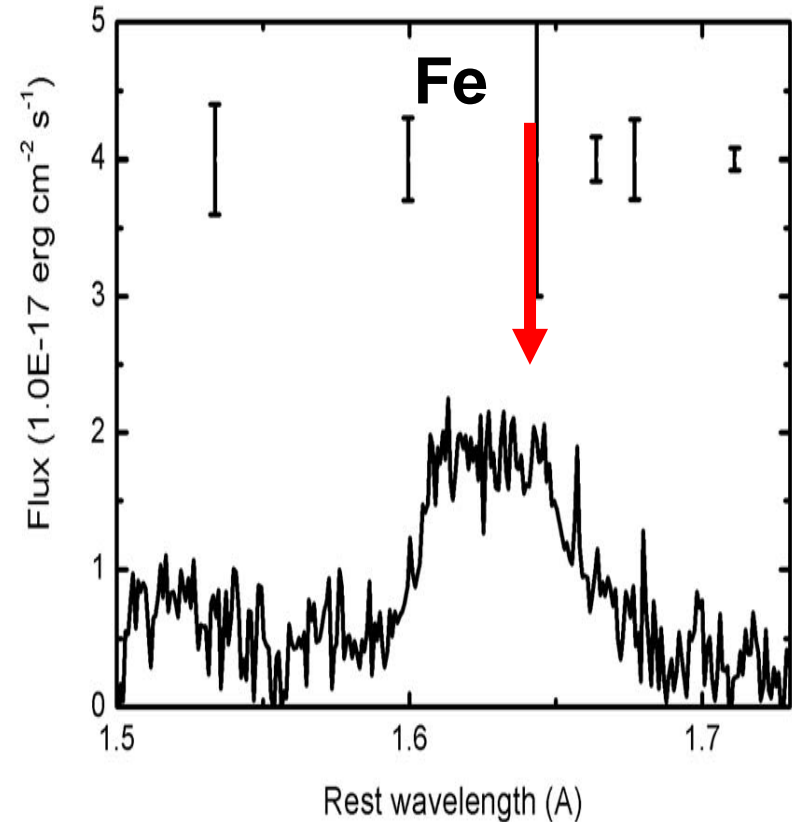
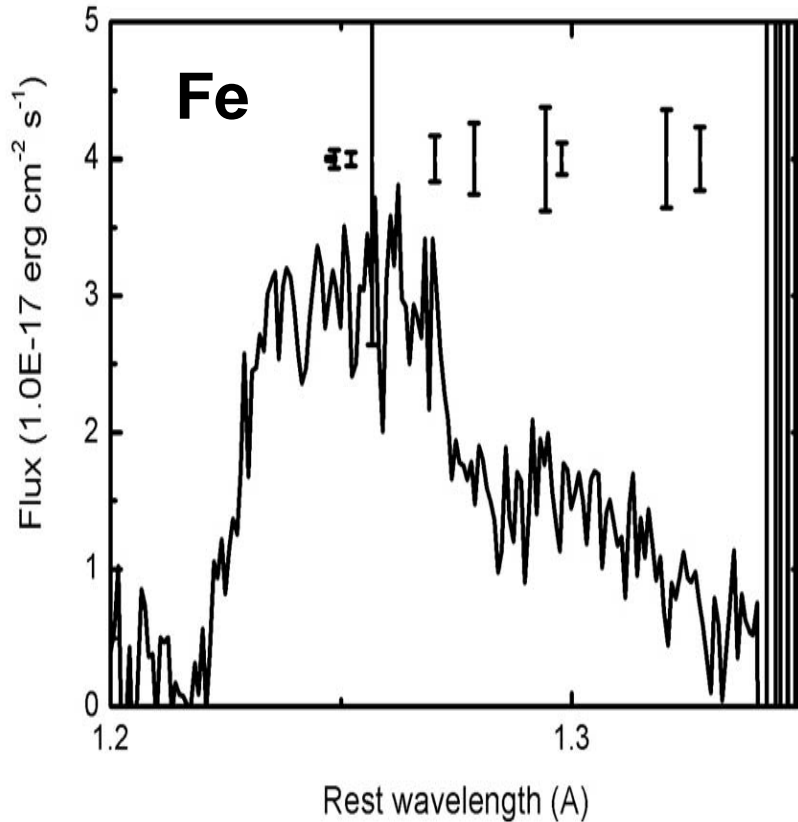


SUBARU/OHS observations of SNe Ia 05W, 03du, 03hv



Motohara et al. (2006)

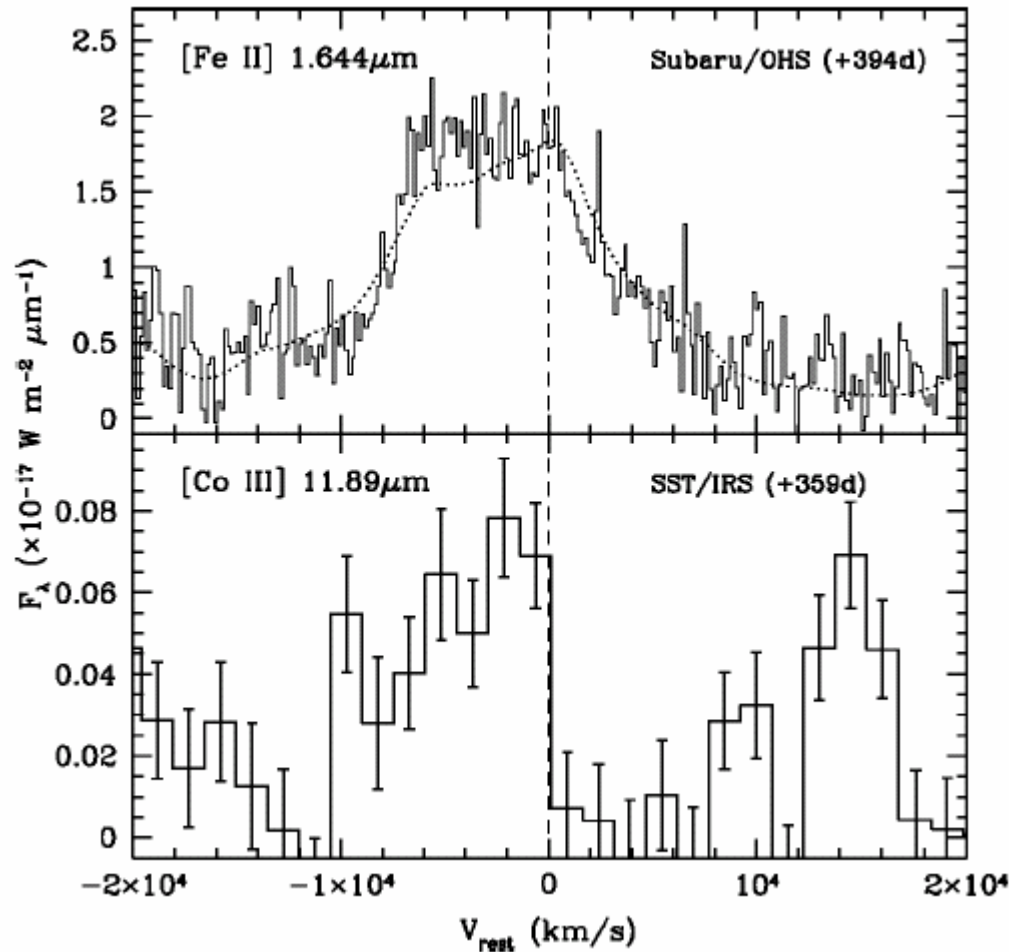
SN 2003hv: Subaru NIR Spectrum



- **Blue shift!**
~1000 – 2000 km/s
- **Flat top!**

Synthetic Spectra @ NIR (03hv)

1. Flat top
2. Blue shift



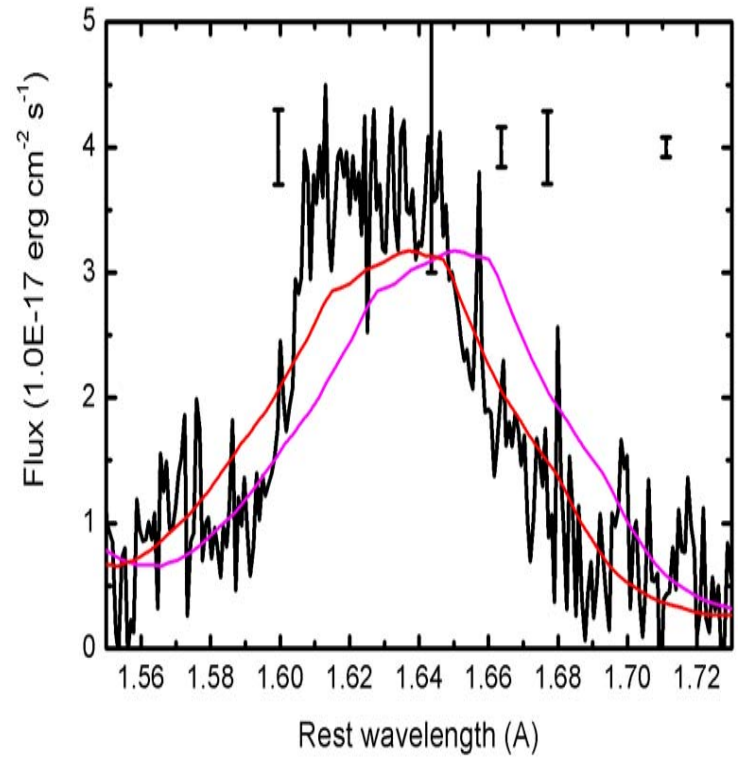
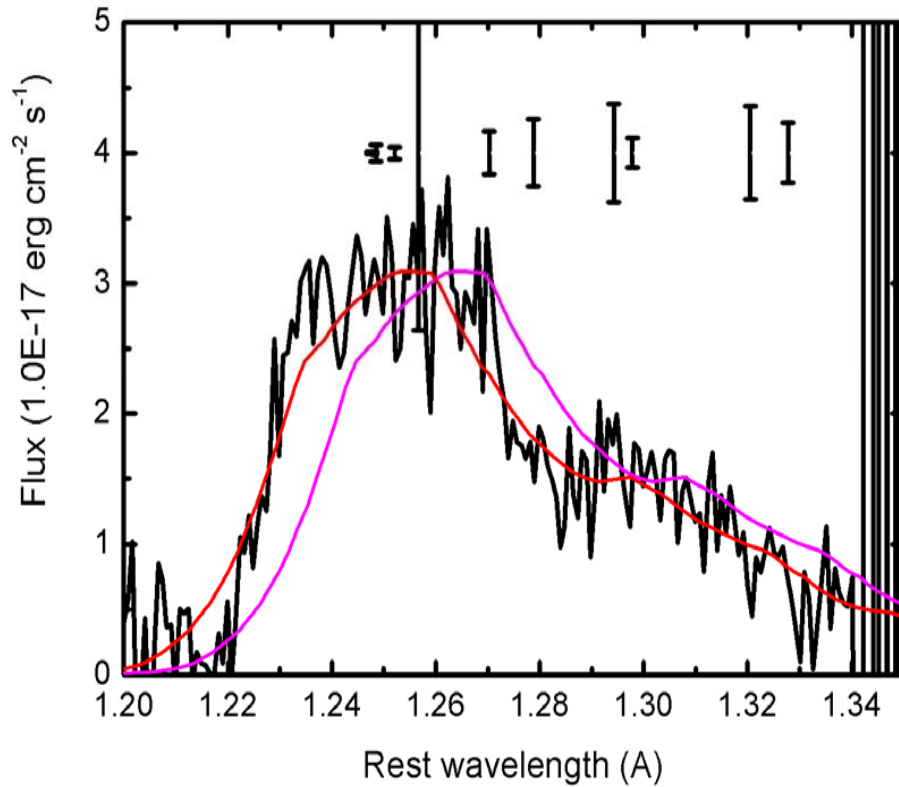
Motohara et al. 2006

Model without ^{56}Ni in the center
(shifted to blue by 2600 km/s)

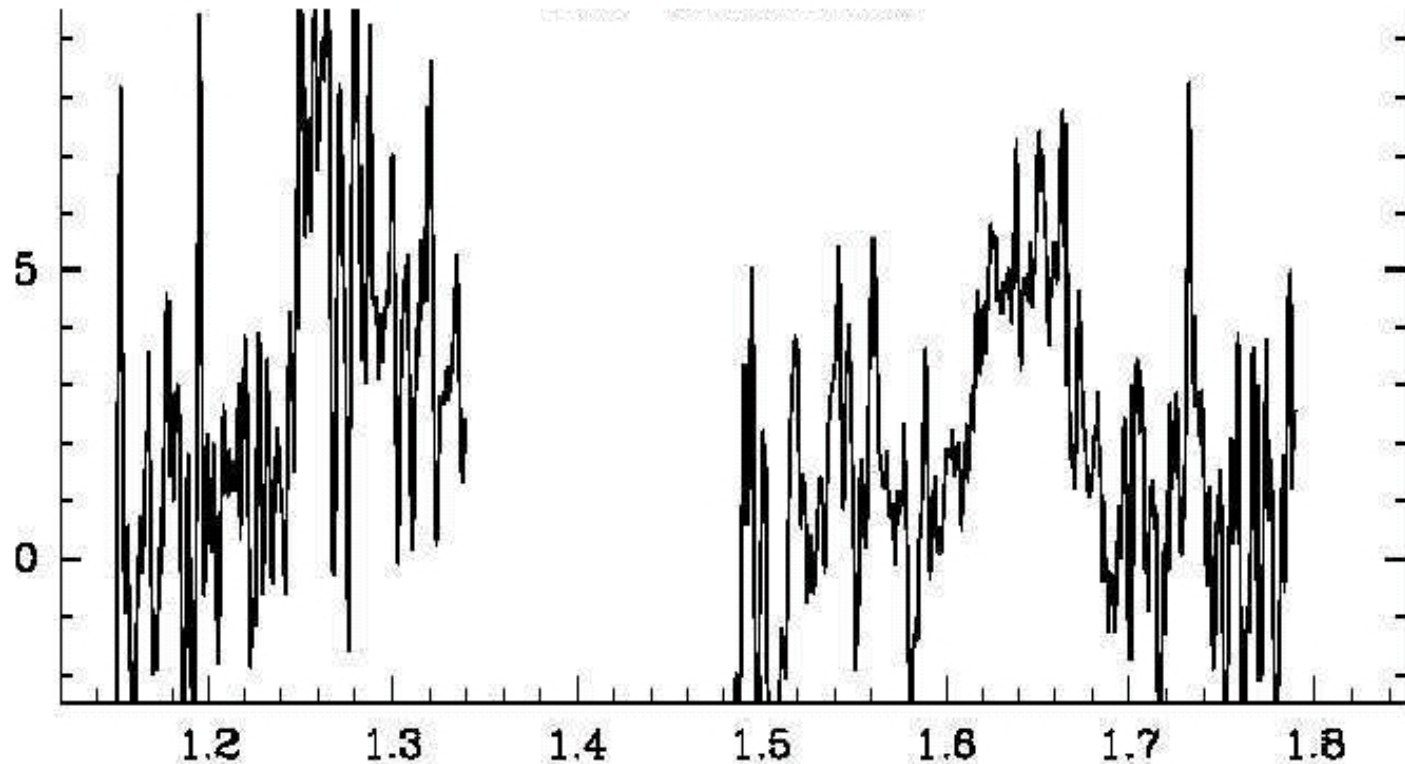
Blue Shift? (03hv)

1. Flat top
2. Blue shift

Model Spectrum
2600 km/s shifted



SN 2003du: Subaru NIR Spectrum



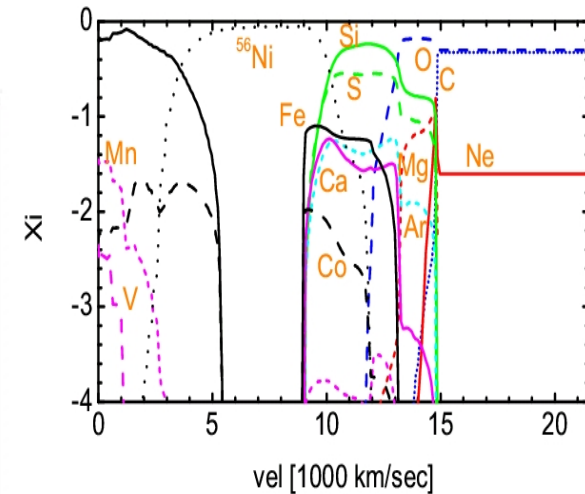
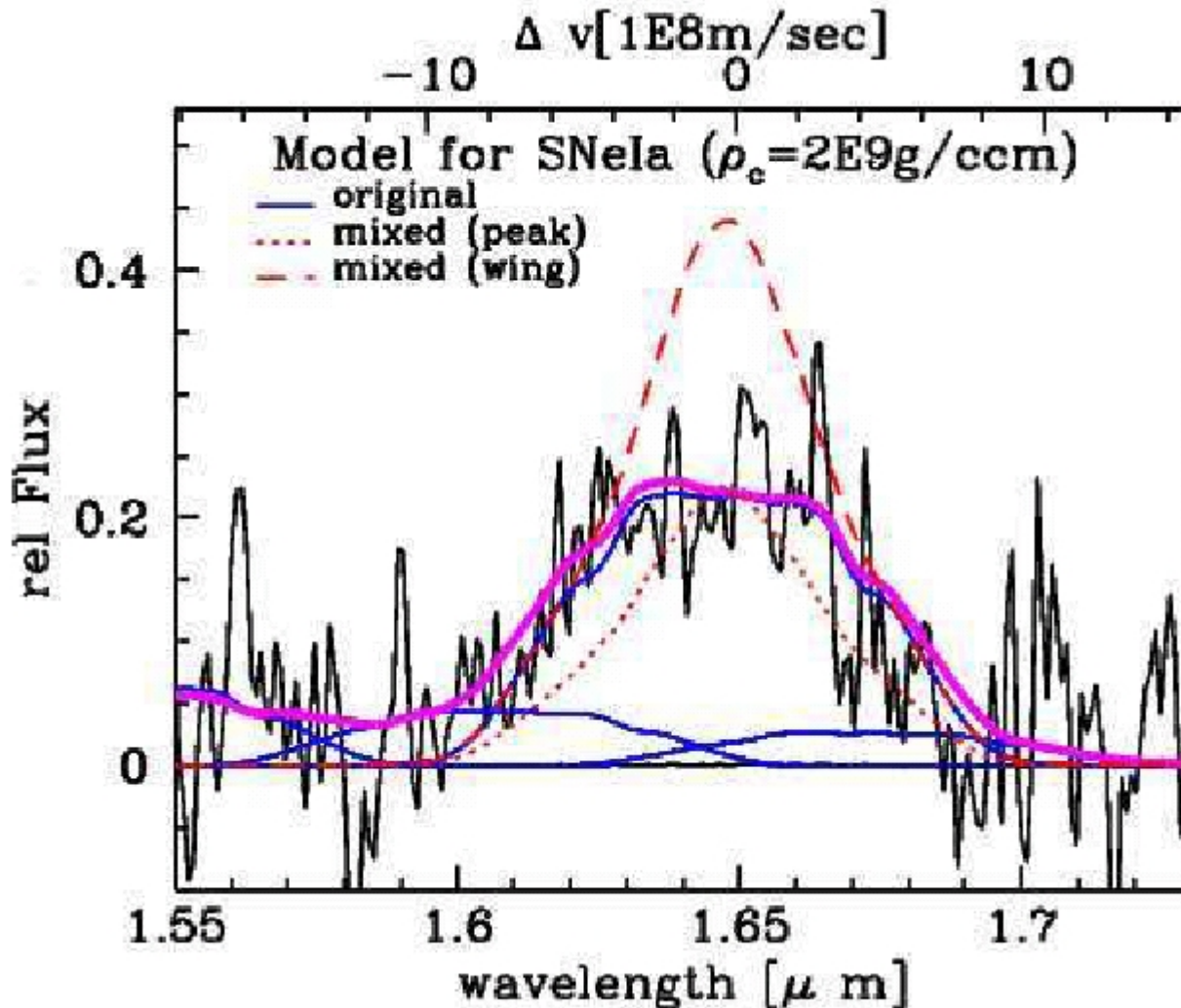
Observed Wavelength (μm)

Höflich et al. 2004

- Blue shift?
~500 km/s
- Flat top ?? (low S/N)

Synthetic Spectra @ NIR (03du)

1. Flat top
2. Blue shift

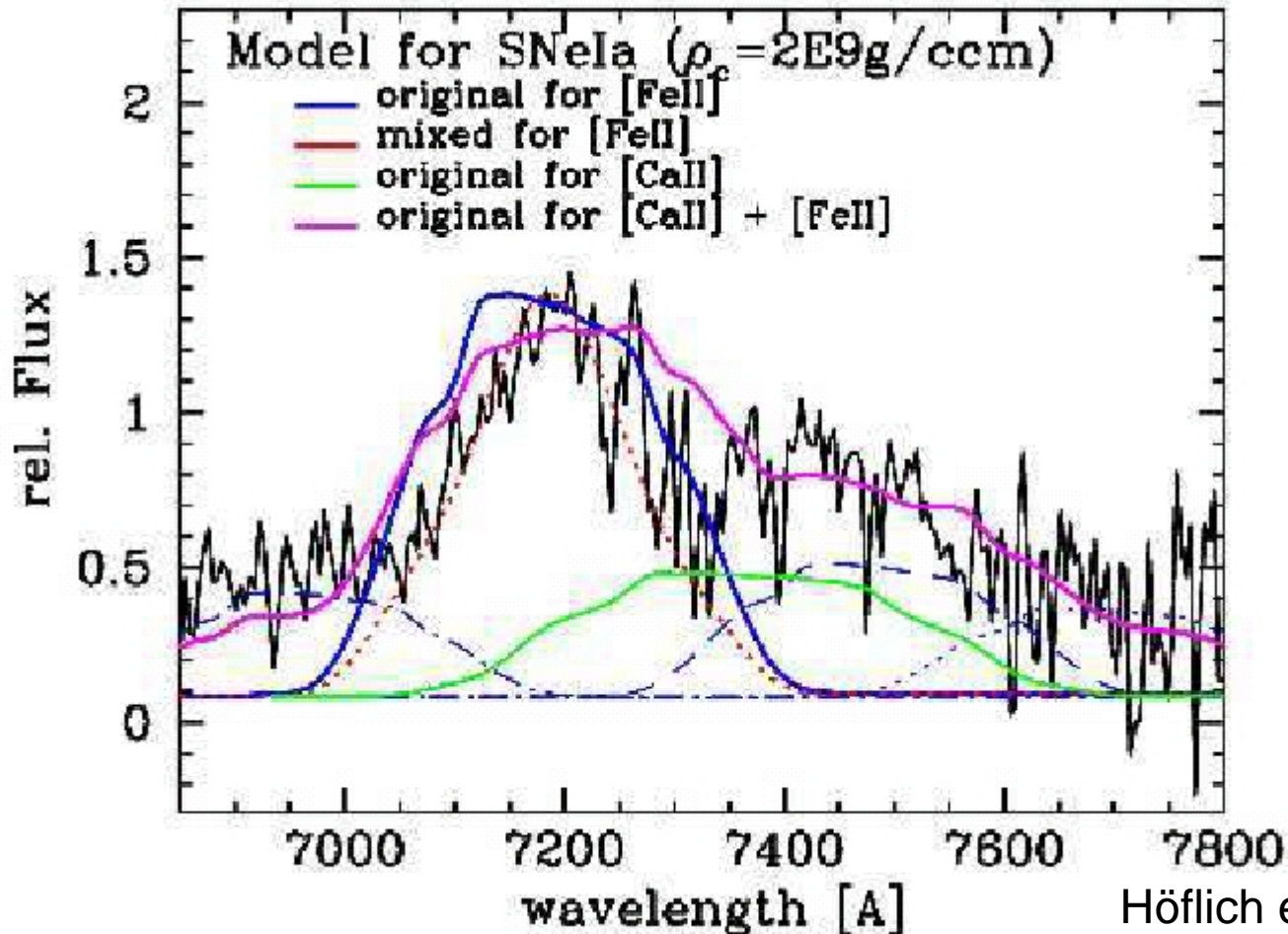


^{56}Ni

Höflich et al. 2004

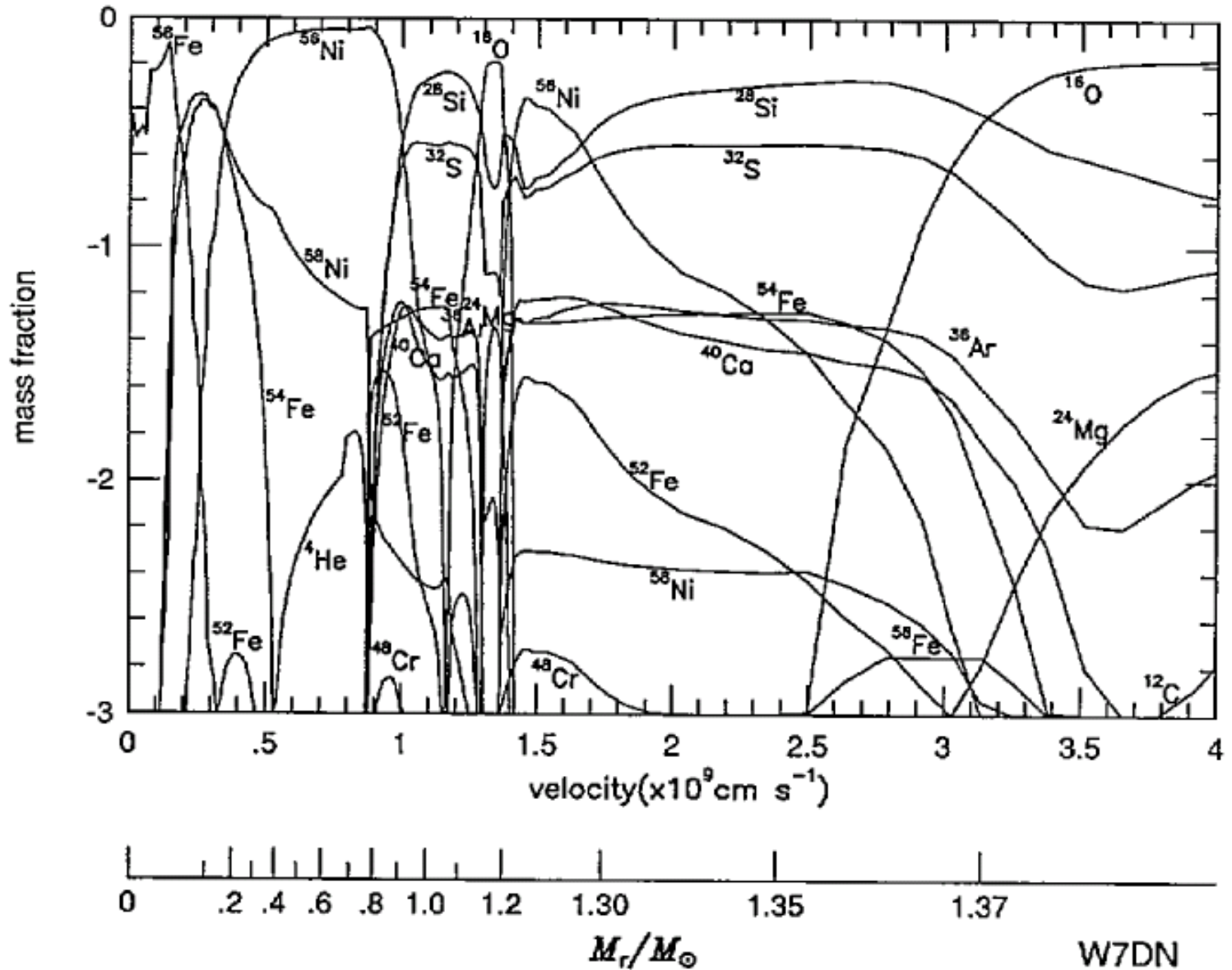
Synthetic Spectra @ Optical (03du)

1. Flat top
2. Blue shift



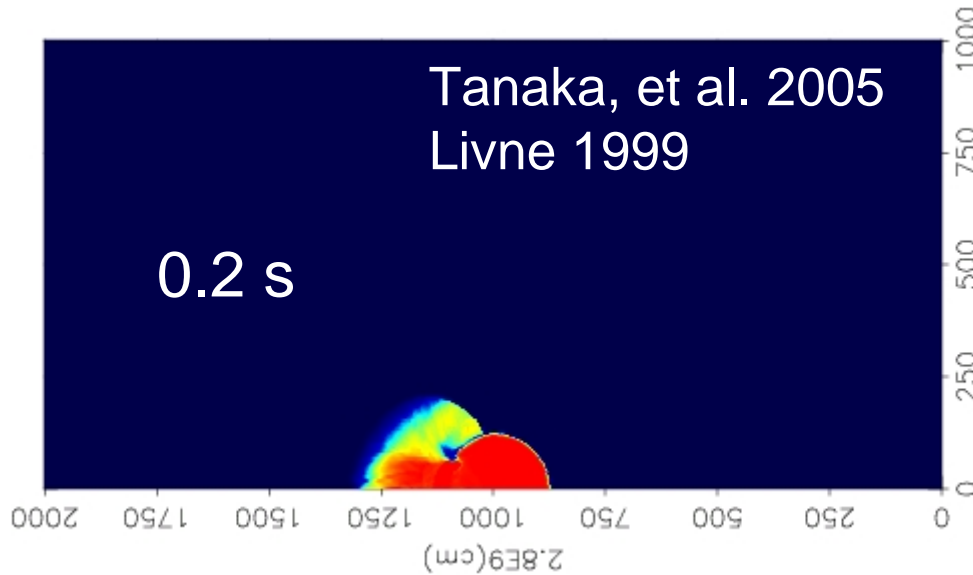
Höflich et al. 2004

Late Detonation Model (Yamaoka et al. 1992)



Off-center delayed detonation ?

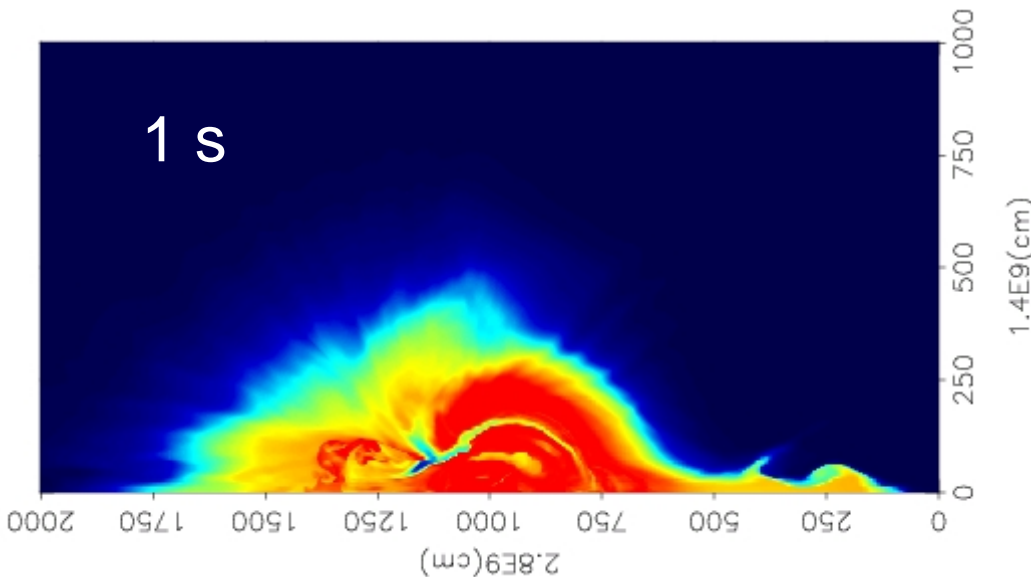
1. Flat top
2. Blue shift



- Distribution of ^{56}Ni is not spherical
- But the deviation from the center is ~ 500 km/s.

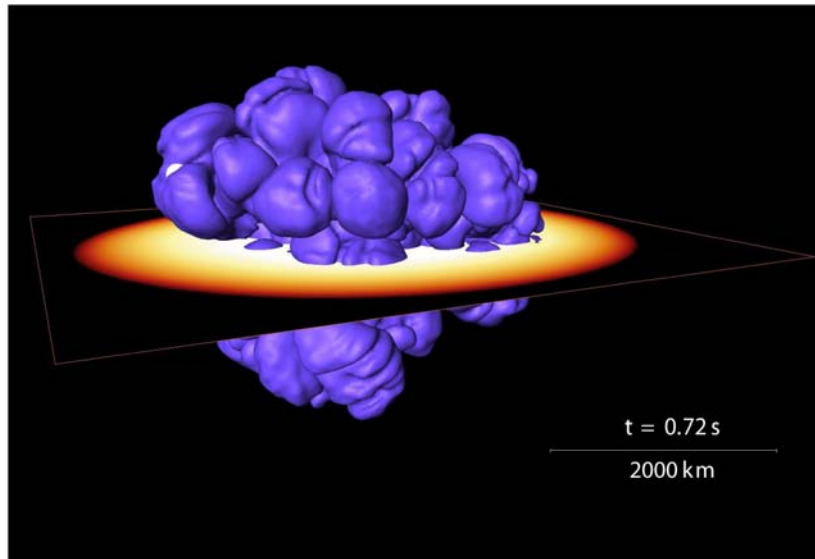
03du ○

03hv ×

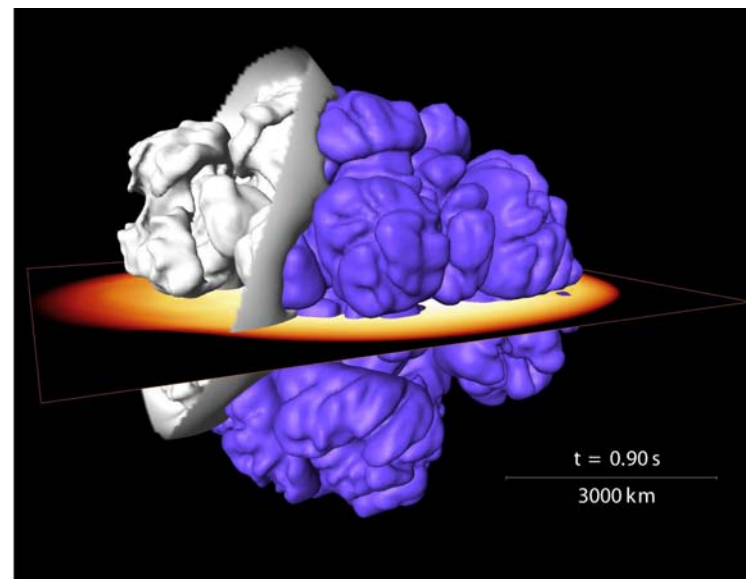
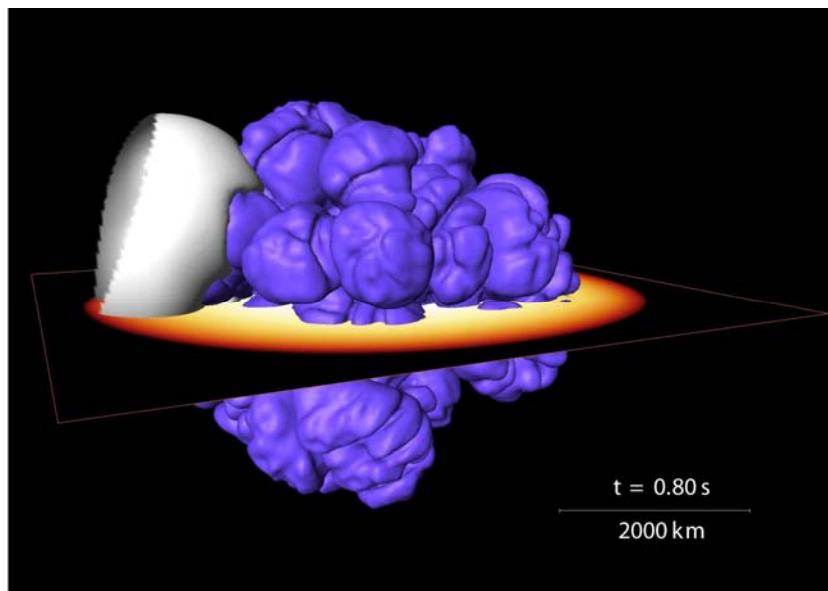


3D delayed detonation ?

Röpke and Niemeyer (2007)



1. Flat top
2. Blue shift



Results

- NIR spectra for two SNe Ia
 - SNe 2003du & 2003hv
 - Flat-topped Fe profile (2 out of 4: 05W, 91T)
 - “no” ^{56}Ni at the central region
 - Deflagration and neutronization at high density
 - No C+O left in the central region
 - Not the Sub Chandrasekhar Mass model
 - Blue shift of the profile
 - DDT is delayed (in Mr): aspherical ?