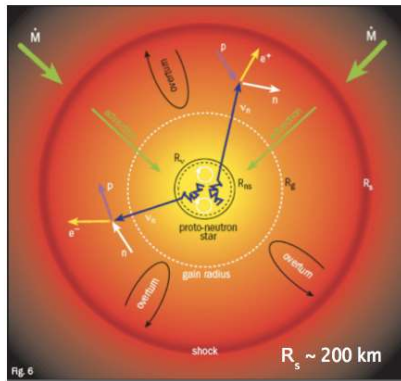## Slide 1

Neutrinos & SN Explosion Mechanism
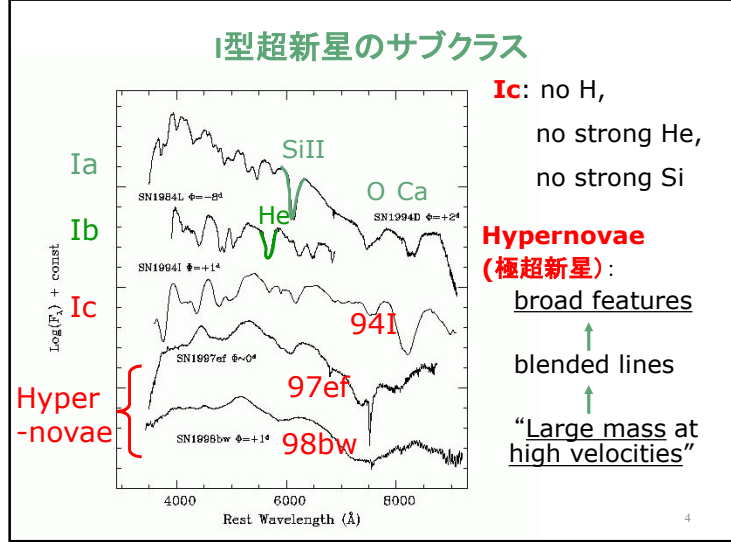
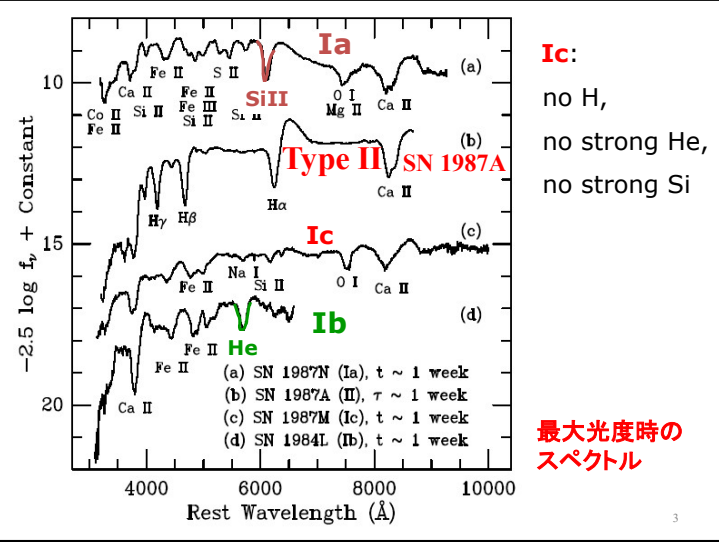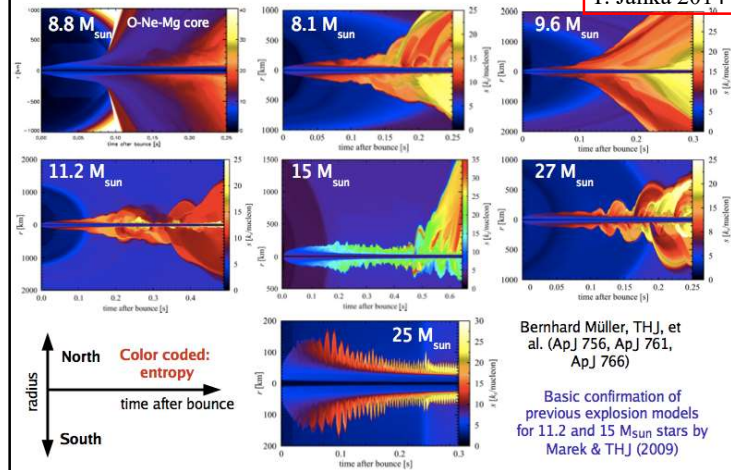T. Janka 2014

Explosions powered by neutrino heating, supported by violent, large-scale hydrodynamic instabilities in the postshock layer
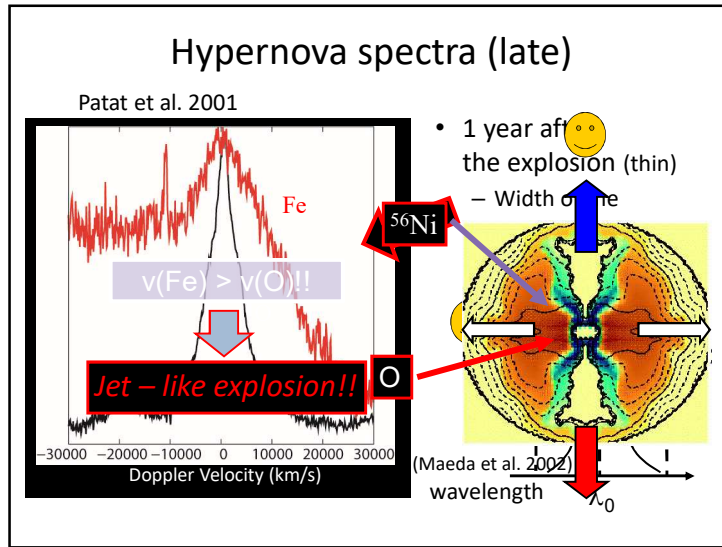
Fig. 6

$R_s \sim 200$ km

- **"Neutrino-heating mechanism":** Neutrinos `revive' stalled shock by energy deposition
  (Colgate & White 1966, Wilson 1982, Bethe & Wilson 1985);

- **Convective processes & hydrodynamic instabilities** support heating mechanism
  (Herant et al. 1992, 1994; Burrows et al. 1995, Janka & Müller 1994, 1996; Fryer & Warren 2002, 2004; Blondin et al. 2003; Blondin & Mezzacappa 2007, Scheck et al. 2004,06,08, Iwakami et al. 2008, 2009, Ohnishi et al. 2006).

Slide 2

Relativistic 2D CCSN Explosion Models

T. Janka 2014

8.8 M$_{sun}$ O-Ne-Mg core   8.1 M$_{sun}$ 9.6 M$_{sun}$

11.2 M$_{sun}$ 15 M$_{sun}$ 27 M$_{sun}$

25 M$_{sun}$

North — **Color coded: entropy** — time after bounce

radius

South

Bernhard Müller, THJ, et al. (ApJ 756, ApJ 761, ApJ 766)

Basic confirmation of previous explosion models for 11.2 and 15 M$_{sun}$ stars by Marek & THJ (2009)

Slide 3

Ic:

no H,

no strong He,

no strong Si

Ia

SiII

Type II SN 1987A

Ic

Ib

He

(a) SN 1987N (Ia), t ~ 1 week
(b) SN 1987A (II), τ ~ 1 week
(c) SN 1987M (Ic), t ~ 1 week
(d) SN 1984L (Ib), t ~ 1 week

最大光度時のスペクトル

Slide 4

I型超新星のサブクラス

Ic: no H,

no strong He,

no strong Si

Ia

Ib

Ic

Hyper-novae

SiII

He

O Ca

SN1984L Φ=−8^d

SN1994D Φ=+2^d

SN1994I Φ=+1^d

94I

SN1997ef Φ~0^d

97ef

SN1998bw Φ=+1^d

98bw

Hypernovae (極超新星):

broad features

↑

blended lines

↑

"Large mass at high velocities"

Hypernova spectra (late)

Patat et al. 2001

Fe

^{56}Ni

v(Fe) > v(O)!!

Jet − like explosion!!

O

−30000 −20000 −10000 0 10000 20000 30000
Doppler Velocity (km/s)

- 1 year after the explosion (thin)
  − Width of line

(Maeda et al. 2002)
wavelength

λ_0

超新星を光らせるもの　2

- Shock heating
  − II-P 型超新星の長い Plateauの光源

  − II-P 型超新星の親星は厚い水素層を持った赤色超巨星（あまりMass Lossをしていない大質量星）
  ＝11〜18 M$_\odot$ぐらいの単独星

Baklanov et al. (2005)
SN 1999em D= 12.38 Mpc

R1000_M18_Ni006_E10

Plateau ～100日間

II P 型超新星

V
B
U

t, days

-30

超新星を光らせるもの2, Shock heating

− recombination front (photosphere とほぼ一致）は質量座標で見ると内側へ入って行くが、半径で見るとほぼ動かない（右図
− また、photosphereの温度はほぼ一定であるため、長時間に渡って超新星光度
L 〜 4πR^2 σT$_{ph}$^{4} 〜一定
となる。
− II-L型超新星はII-Pと光の源は同じだが水素層が薄いため、明るさが保たれず減光が早いと考えられる

The photosphere at plateau
almost at rest - not much expanding in R

20
30
40
50
75
90

log T, K

log r, cm

A model for SN 1999em, Baklanov et al.(2005)

Light Curve Modelling of SNe

$$M_{ej}, M(^{56}Ni), KE$$

Light Curve　　　　Spectra

$$\tau_{LC} \sim (\tau_{dyn} \cdot \tau_{diff})^{1/2}$$
$$\sim \left[\frac{R}{v} \quad \frac{\kappa M_{ej}}{R\,c} \right]^{1/2}$$

$$\tau_{LC} \propto \frac{\kappa^{1/2} M_{ej}^{3/4}}{E^{1/4}}$$

$$v_{ph} \propto (E/M_{ej})^{1/2}$$

τ_{LC}

^{56}Ni

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