Cosmology with supernovae of type IIn

S. Blinnikov

based on papers with M. Potashov, P. Baklanov, A. Dolgov

SNe as distance indicators

SNe as distance indicators

Secondary

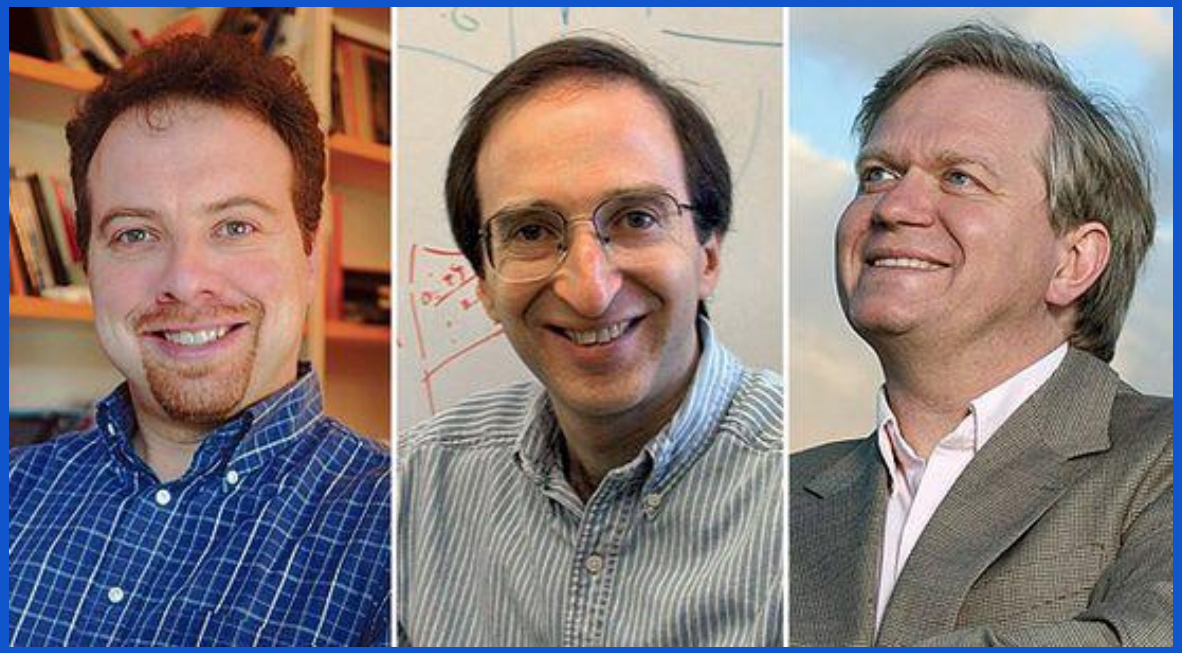
SNe Ia

SNe as distance indicators

Nobel prize in physics 2011

Prize motivation:

for the discovery of the accelerating expansion of the Universe through observations of distant supernovae



Secondary

↓

SNe Ia

Distance indicators

Primary

SNe IIP

Secondary

SNe Ia

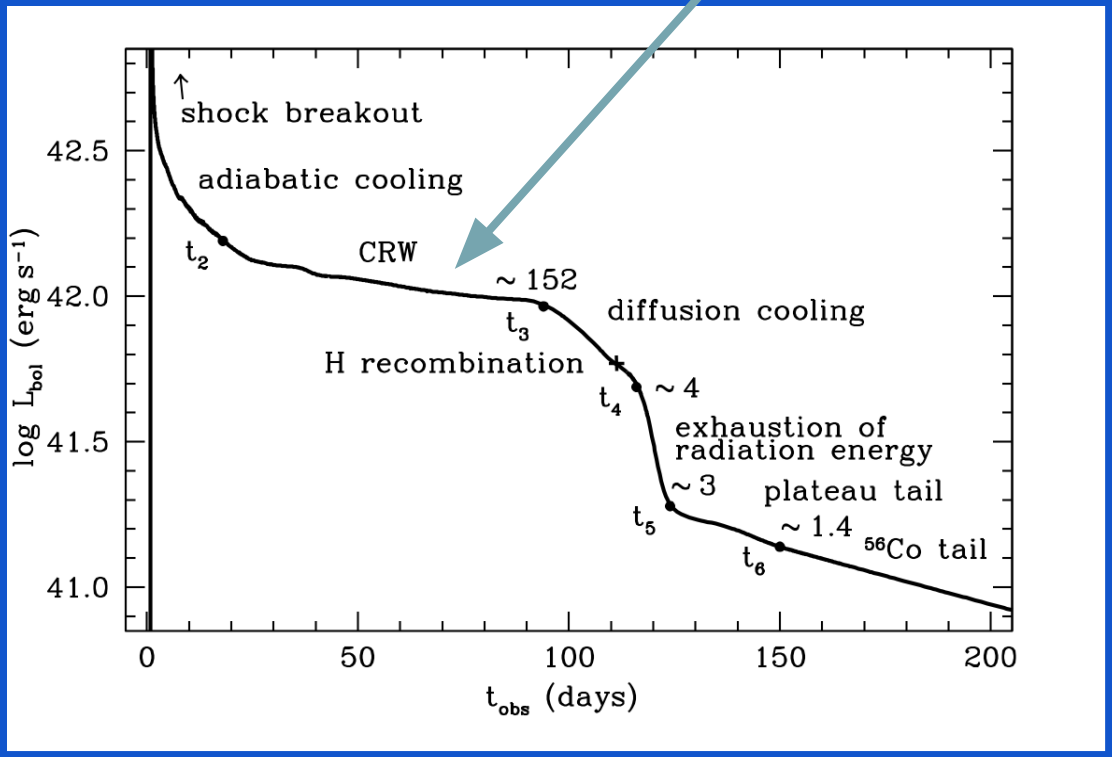
Distance indicators

SN 1999em LC

Secondary

Plateau phase

SNe Ia



V. Utrobin A&A 461, 233 (2007)

Distance indicators

Primary

SNe IIP

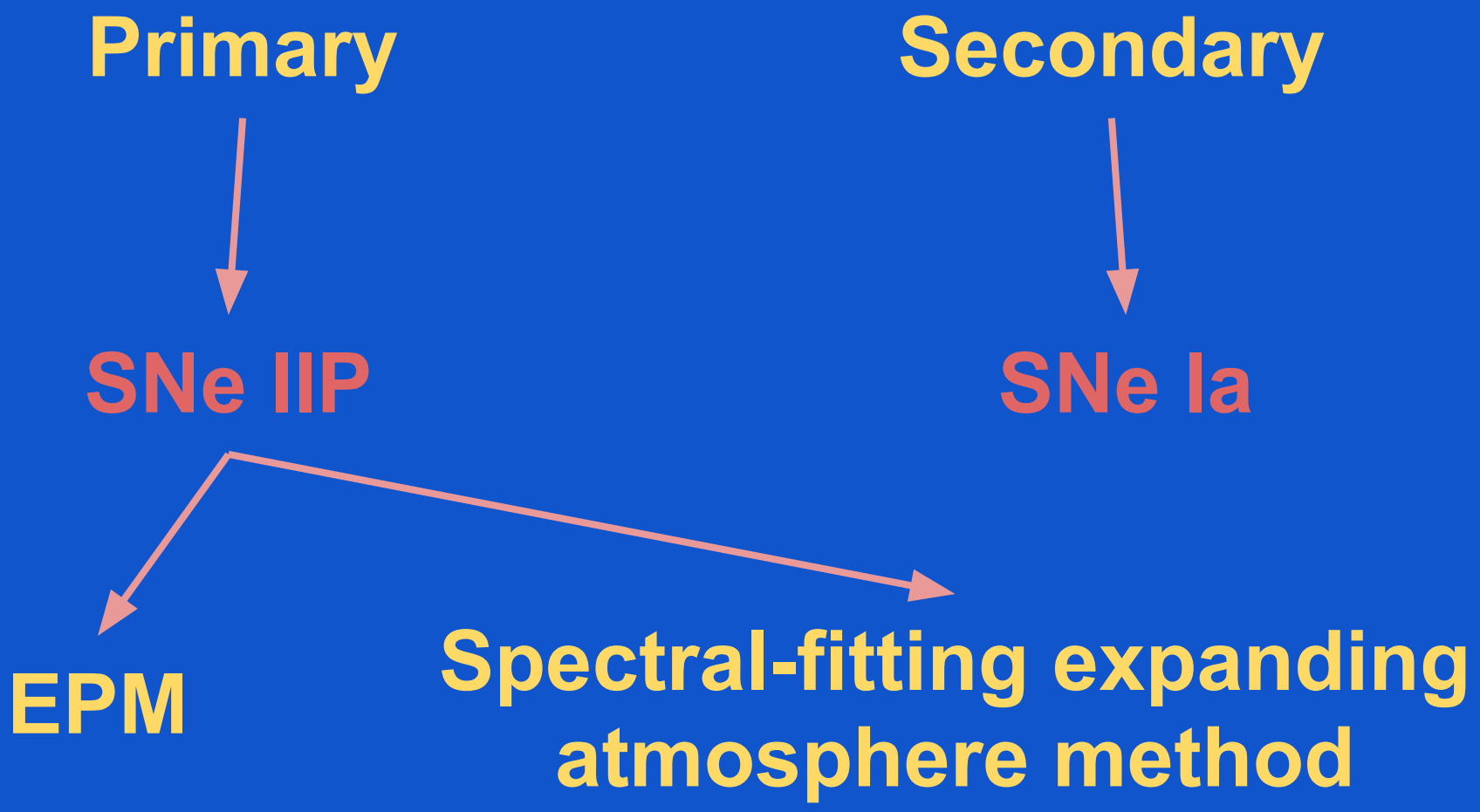
Secondary

SNe Ia

Expanding photosphere method

R. P. Kirshner and J. Kwan, Astrophys. J. 193, 27 (1974)

Distance indicators

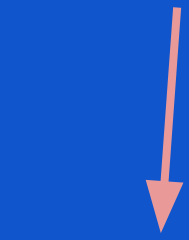


E. Baron, et al. Astrophys. J. Lett. 616, L91 (2004)

Distance indicators

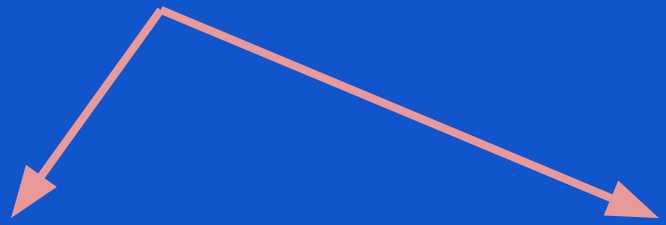
Primary

Secondary



SNe IIP

SNe Ia



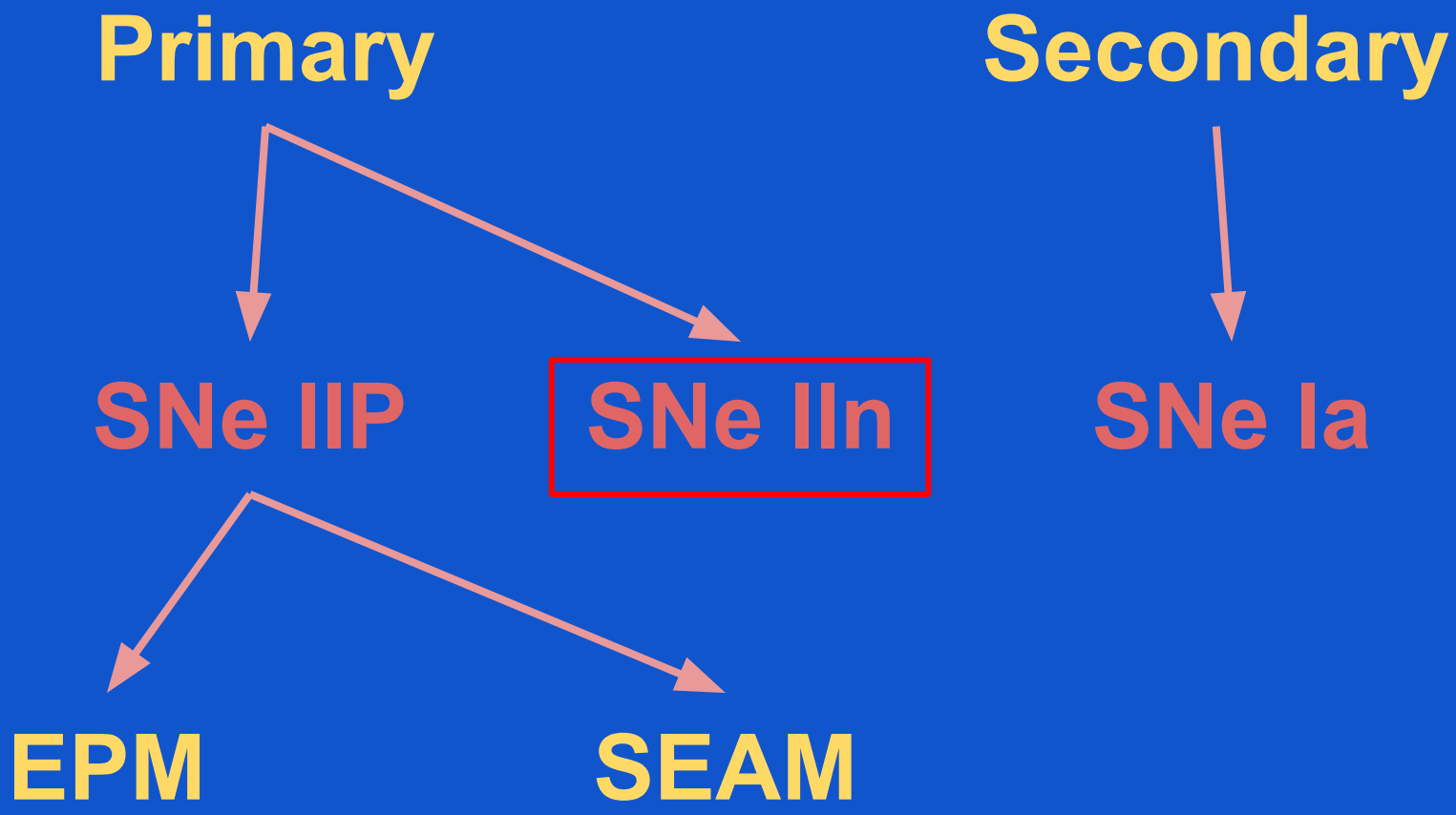
EPM

SEAM

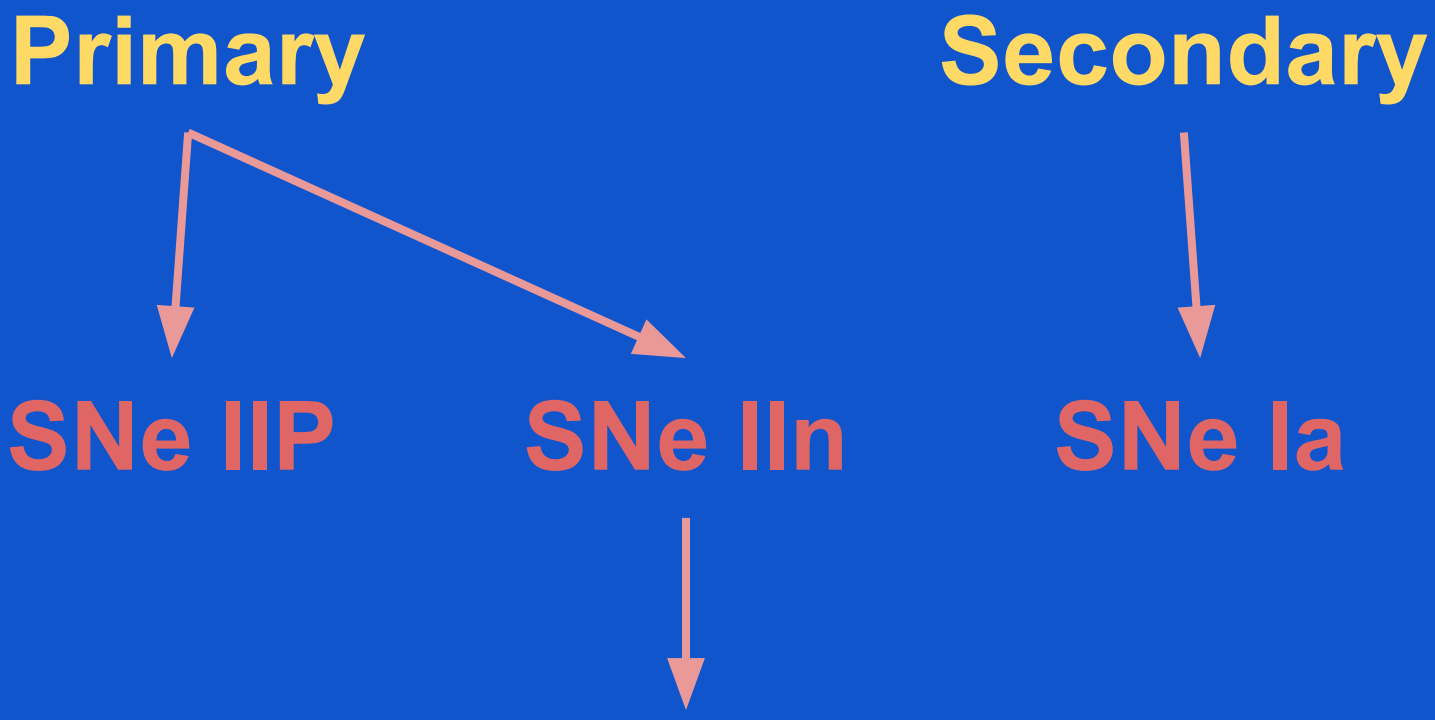
$$v \propto \frac{r}{t}$$

Free expansion!

Distance indicators

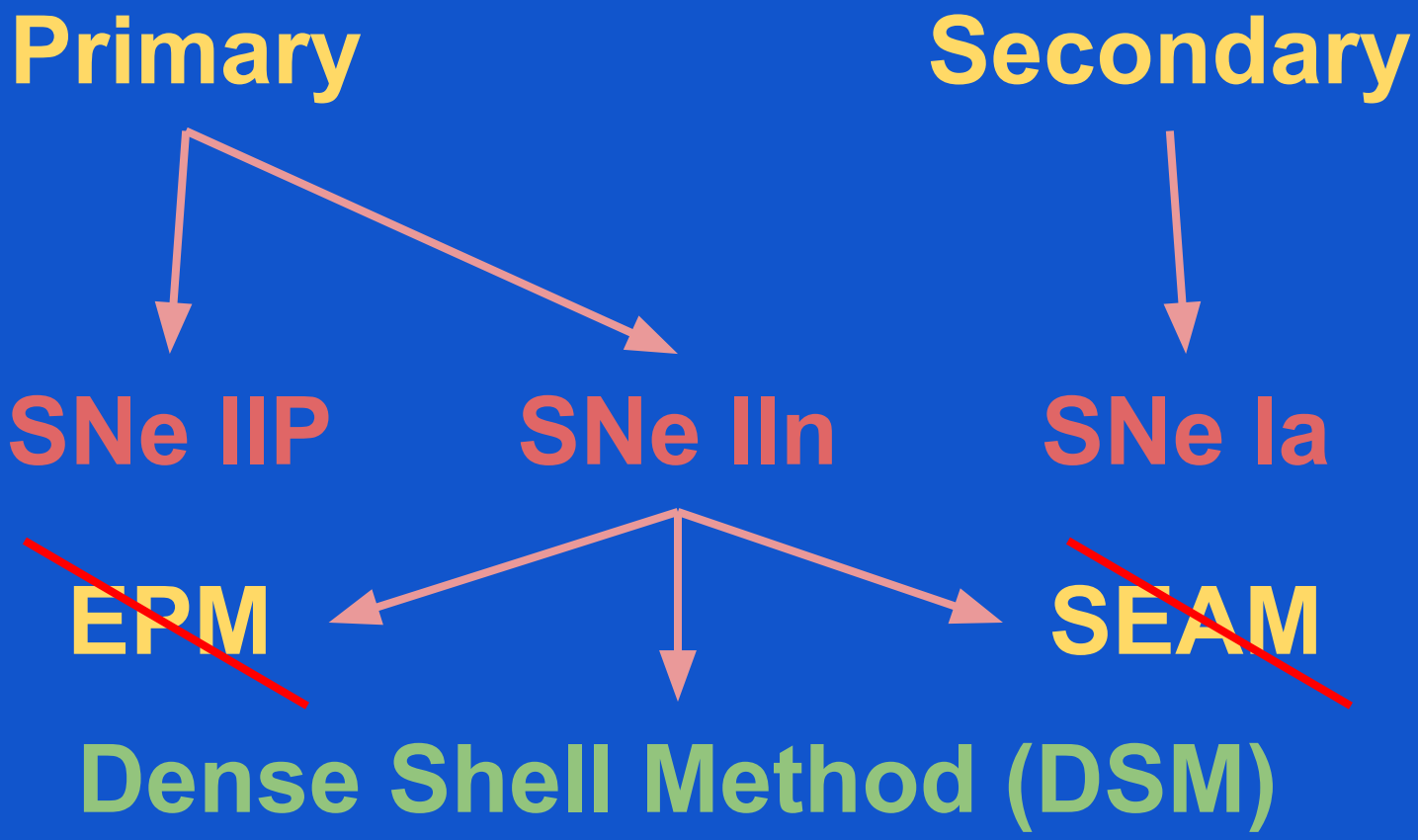


Distance indicators



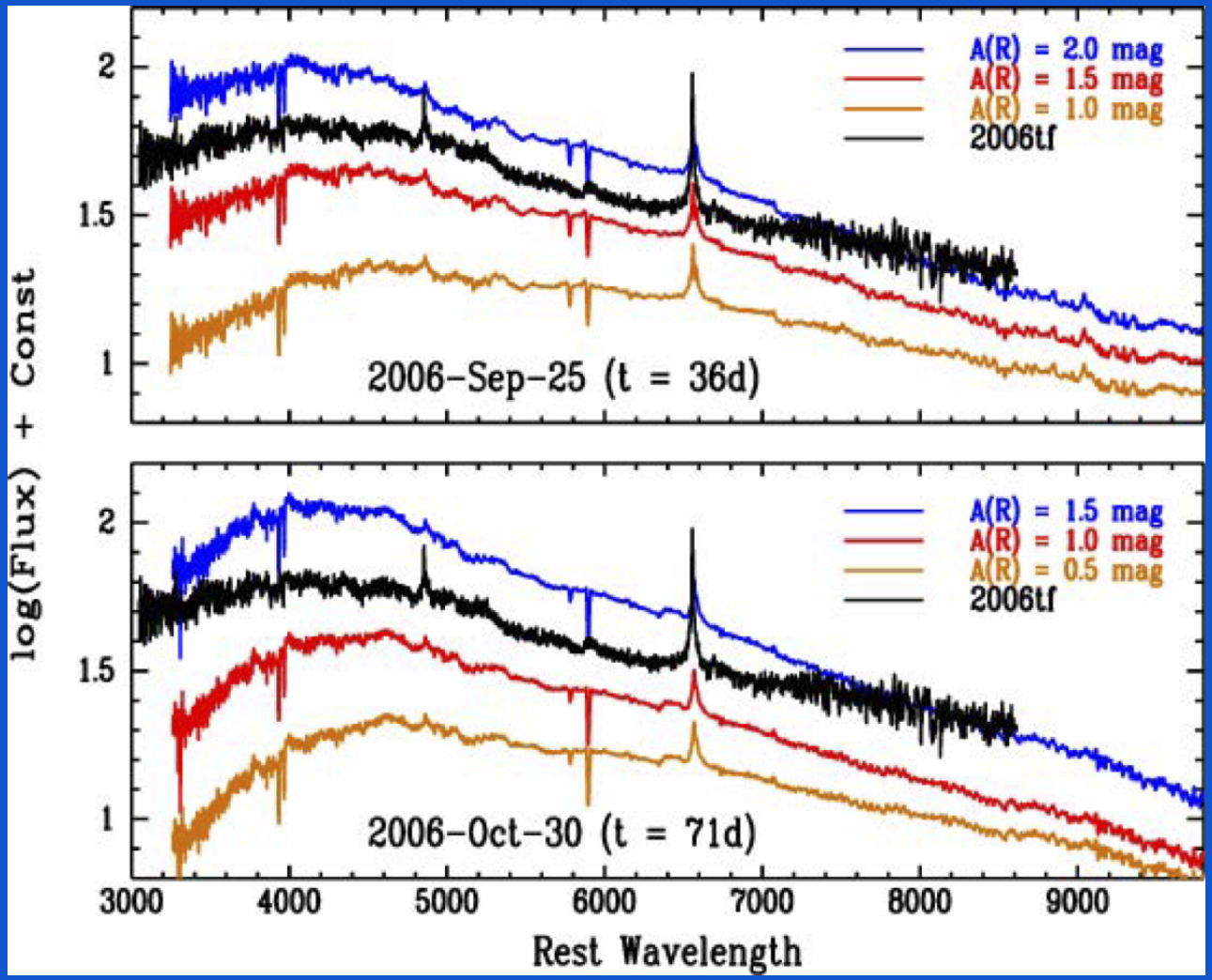
S. Blinnikov, et al. JETP Letters 96, 153 (2012)
M. Potashov, et al. MNRAS Letters 431, 98 (2013)

Distance indicators



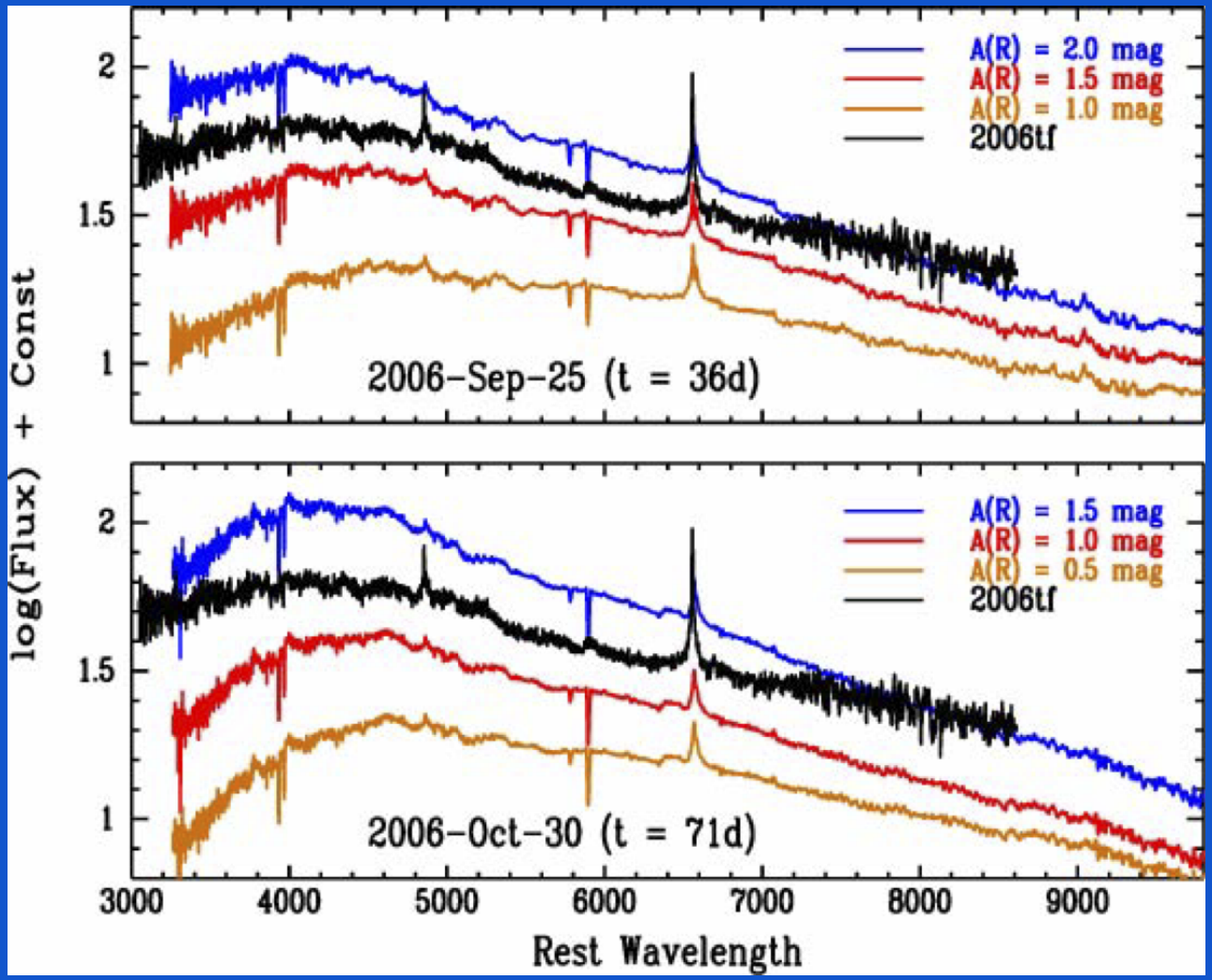
S. Blinnikov, et al. JETP Letters 96, 153 (2012)
M. Potashov, et al. MNRAS Letters 431, 98 (2013)

SN 2006gy spectra



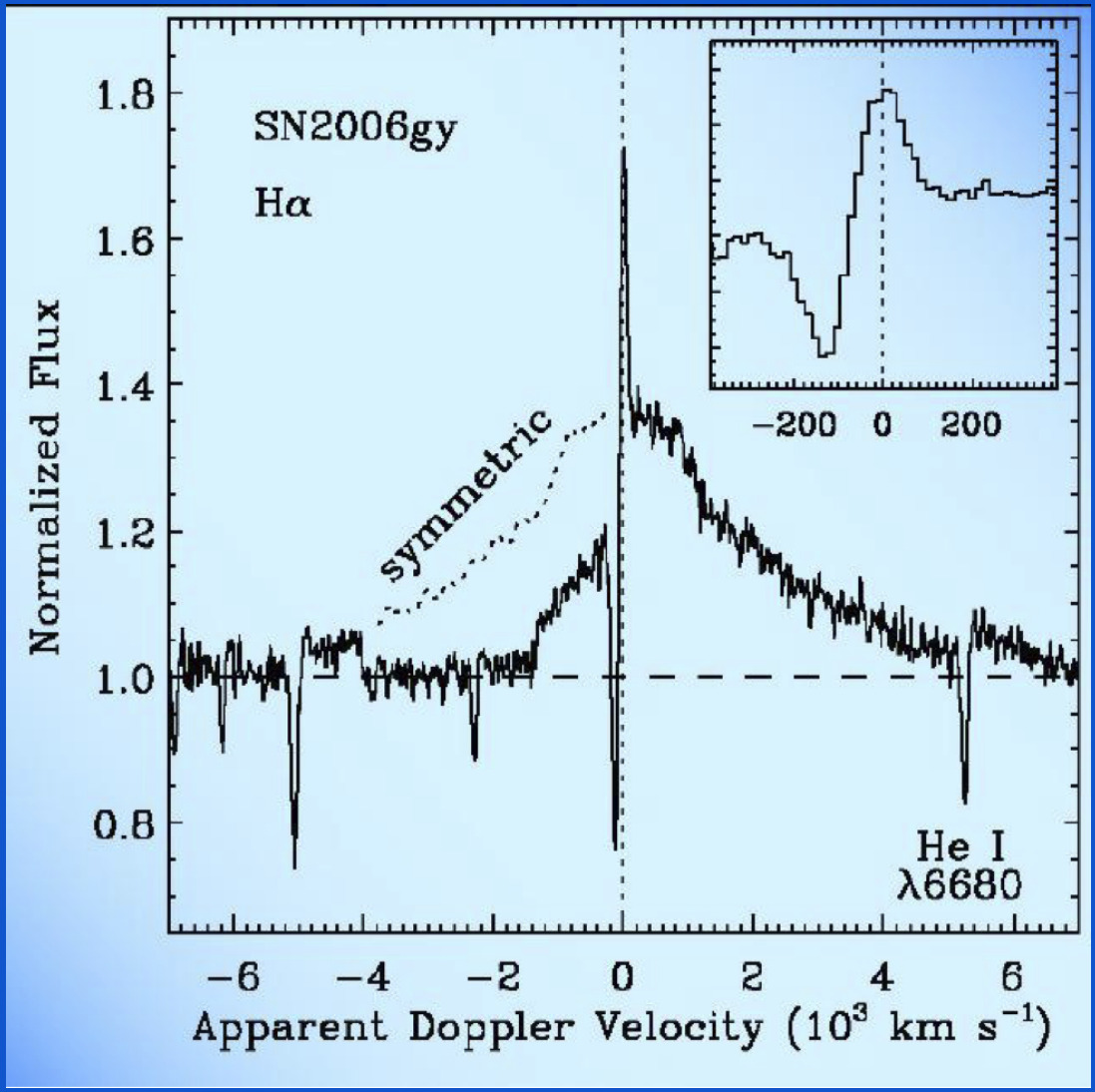
N. Smith, et al. Astrophys. J. 666, 1116 (2007)

SN 2006gy spectra



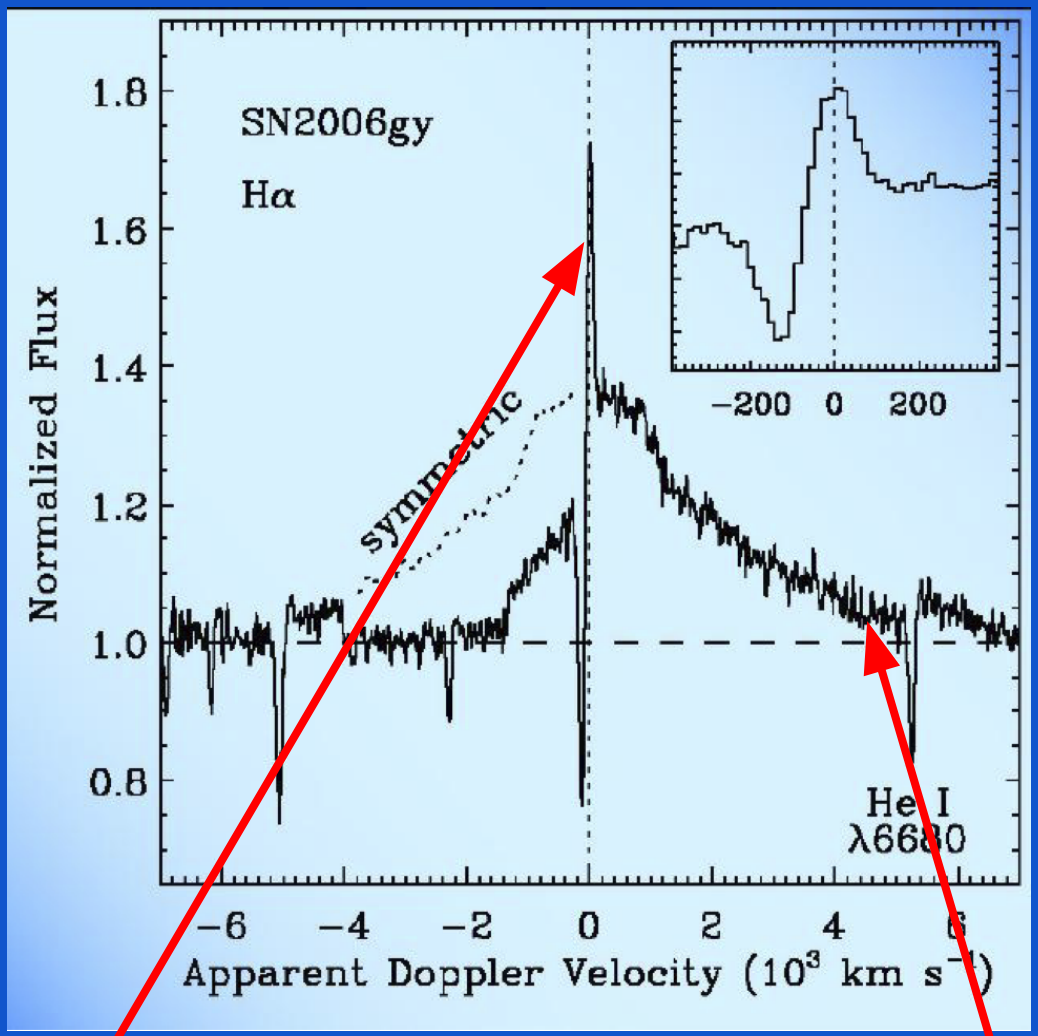
Circumstellar material (CSM)

SN 2006gy Hα profile



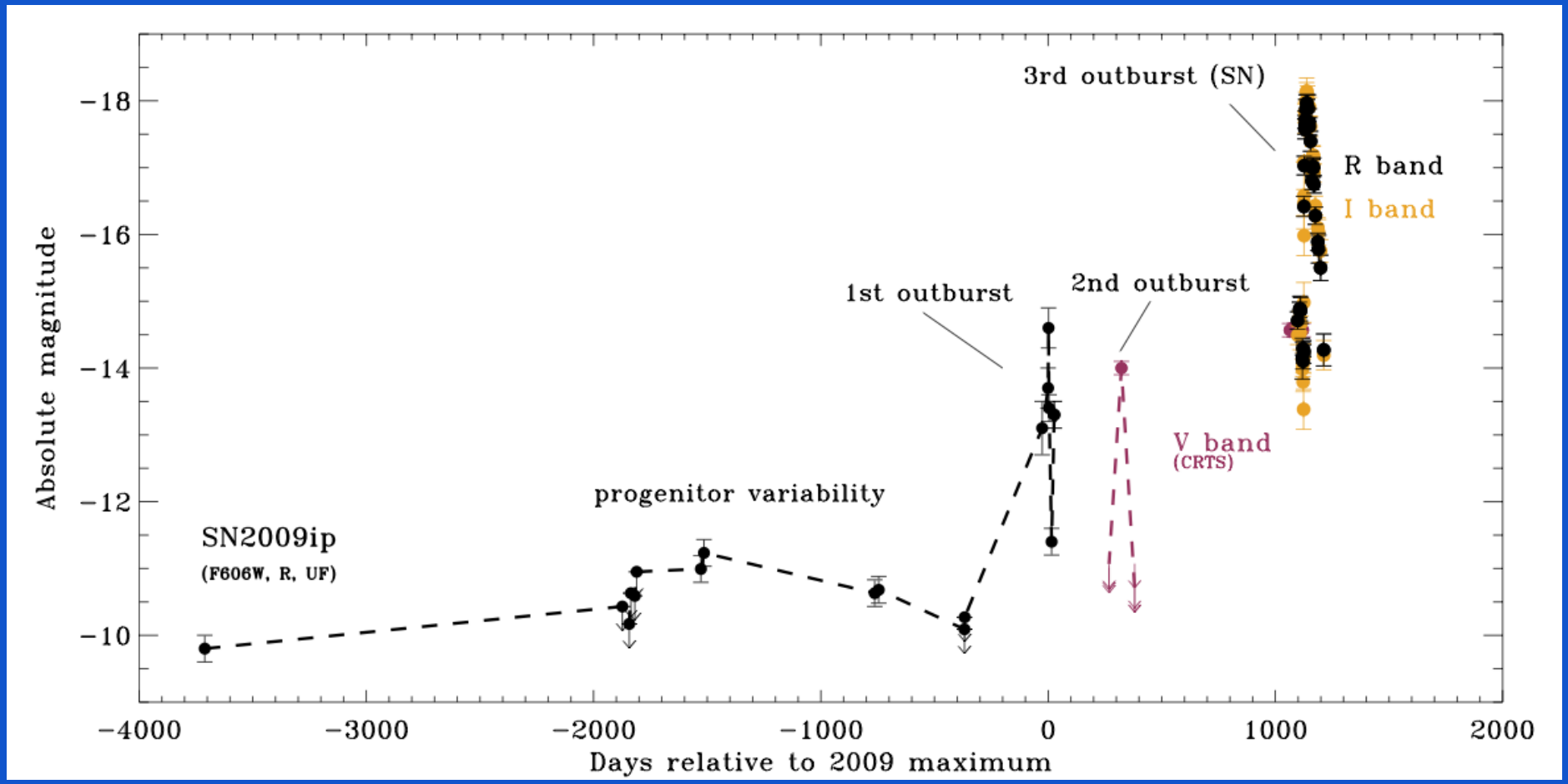
N. Smith, et al. Astrophys. J. 666, 1116 (2007)

SN 2006gy Hα profile



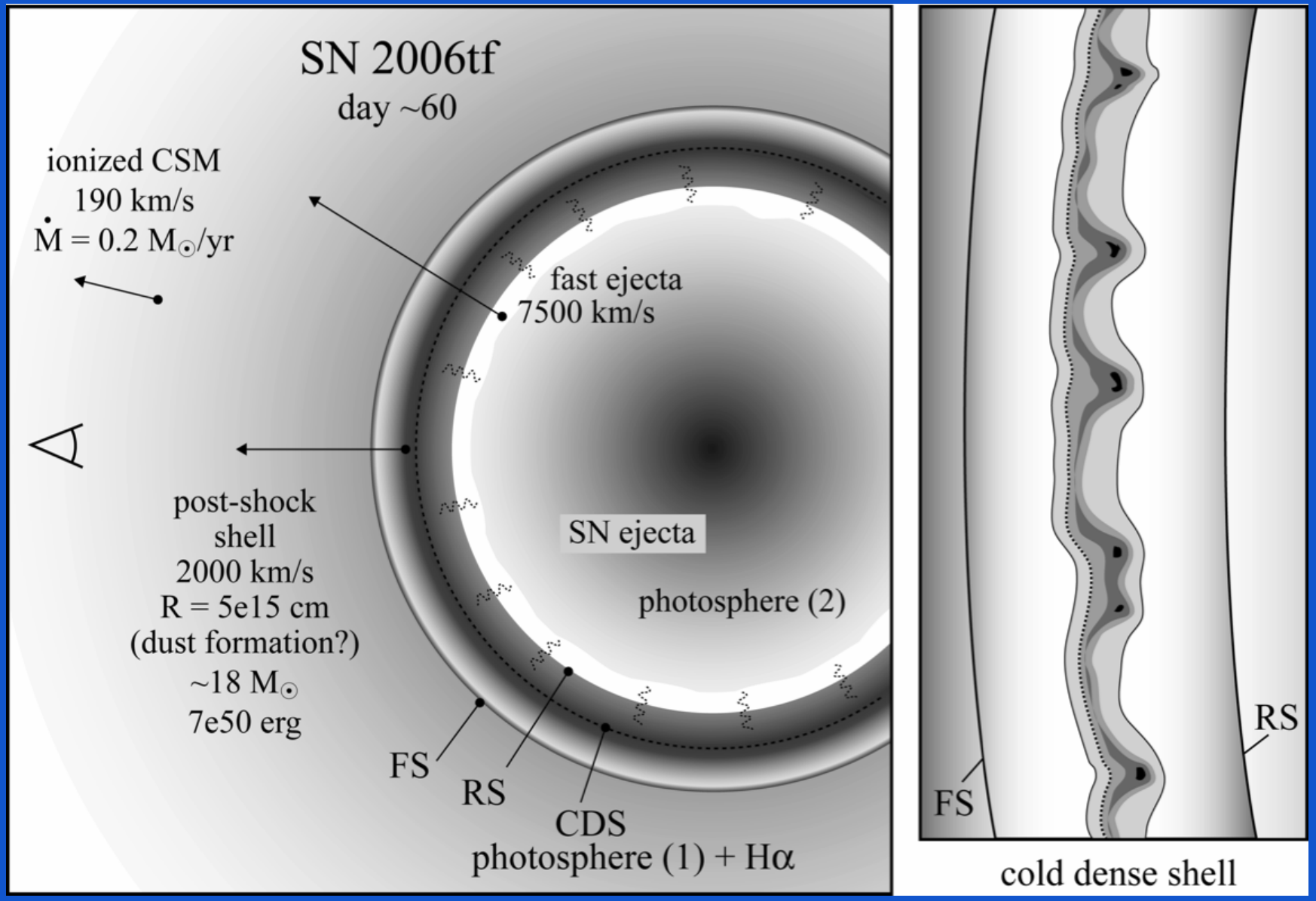
narrow $v \sim 200\mathrm{km/s}$ **wide** $v \sim 5000\mathrm{km/s}$

SN 2009ip LC

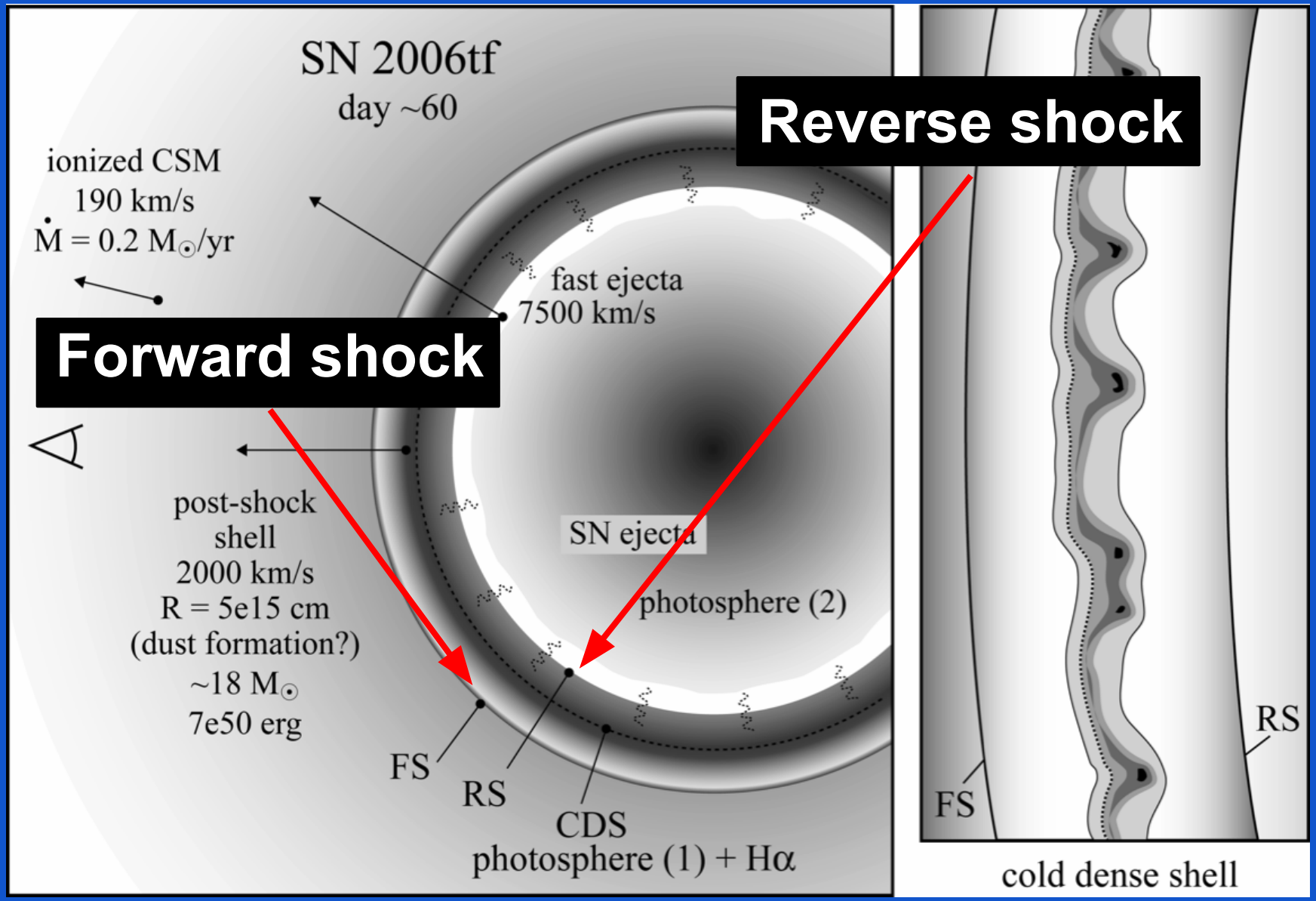


J. Mauerhan, et al. MNRAS 430, 1801 (2013)

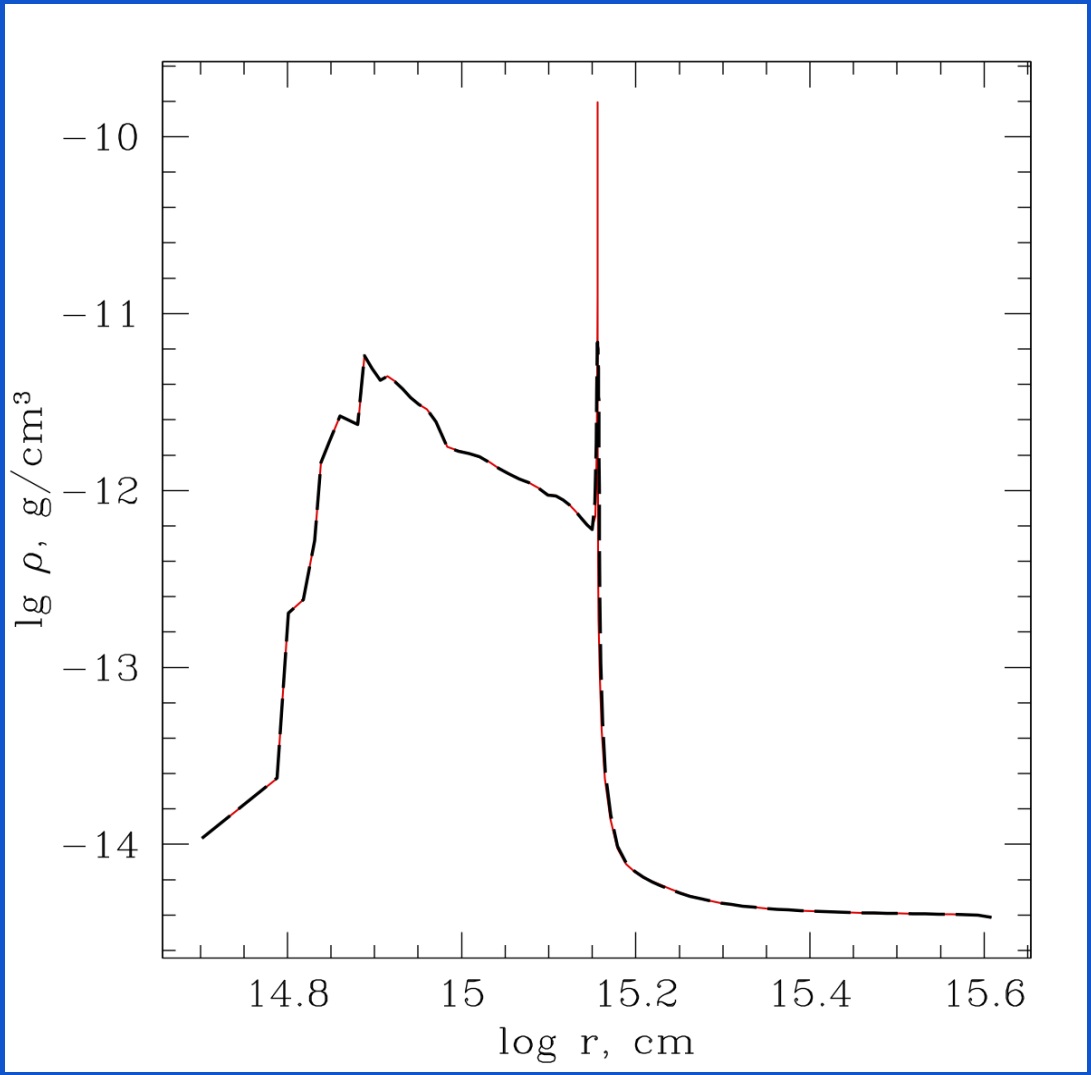
N. Smith, et al. Astrophys. J. 686, 467 (2008)



N. Smith, et al. Astrophys. J. 686, 467 (2008)

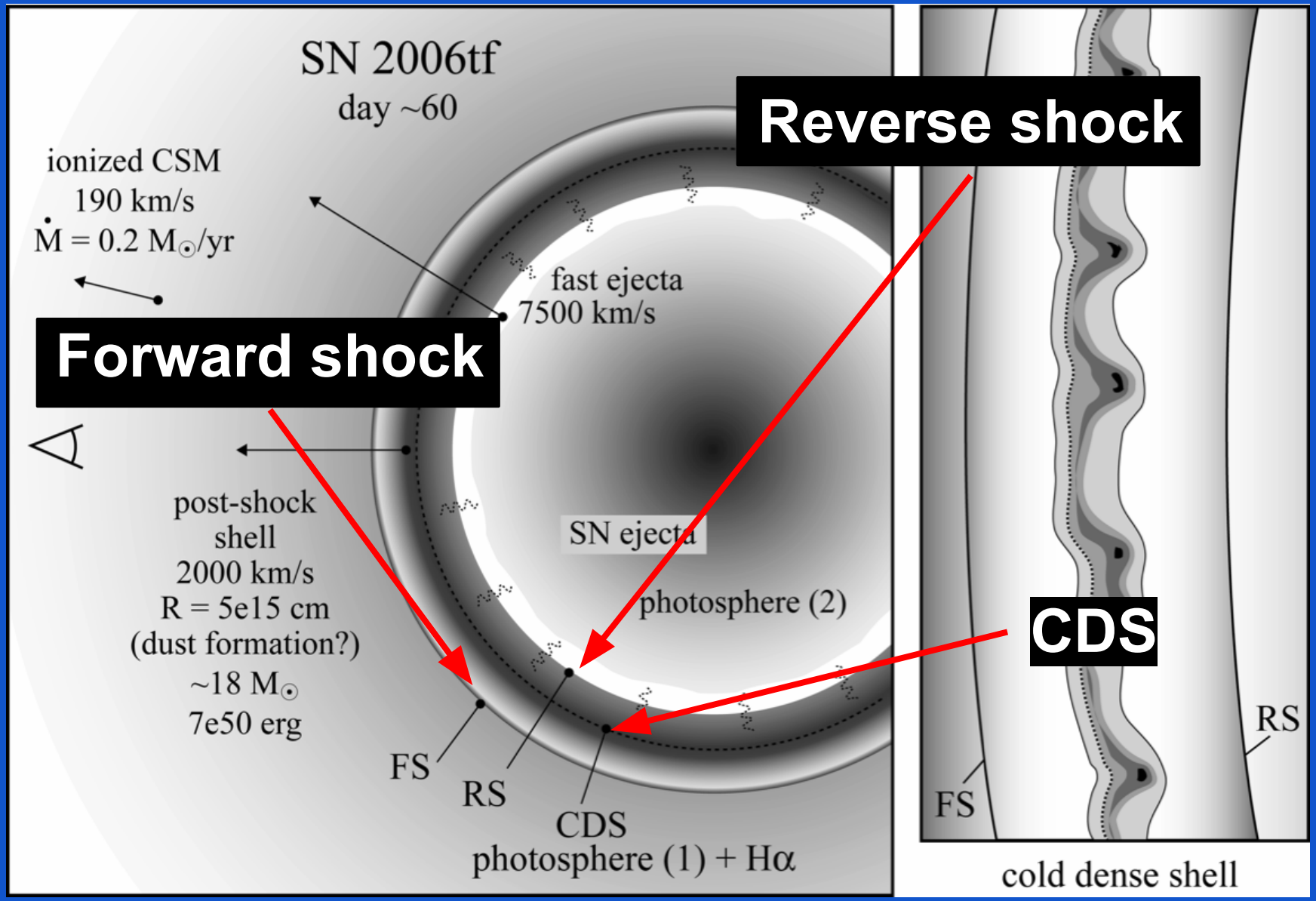


Shocks in SNe IIn



N. Chugai, et al. MNRAS 352, 1213 (2004)

N. Smith, et al. Astrophys. J. 686, 467 (2008)



DSM

Measure wide line components

$$v_{ph} = dR_{ph}/dt = v_{cds}$$

$$dR_{ph} = v_{ph}dt$$

DSM

Measure wide line components

$$dR_{ph} = v_{ph} dt$$

R_0 **initial radius**

$$R_i \equiv R_0 + \Delta R_i$$

$$i = 1, 2, 3, \ldots$$

DSM

$$F_{\nu i} = \zeta_{\nu i}^2 R_i^2 \pi B_\nu (T_{c\nu i}) / D^2$$

ζ correction factor

T_c color temperature

B black-body intensity

D sought-for distance

DSM

$$F_{\nu i} = \zeta_{\nu i}^2 R_i^2 \pi B_\nu (T_{c\nu i}) / D^2$$

$\zeta = 1$ OK for the growing LC part

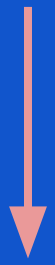
T_c color temperature

B black-body intensity

D sought-for distance

DSM

$$F_{\nu i} = \zeta_{\nu i}^2 R_i^2 \pi B_\nu(T_{c\nu i}) / D^2$$



$$\zeta_{\nu i}(R_0 + \Delta R_i)\sqrt{\pi B_\nu(T_{c\nu i})} = 10^{0.2A_\nu} D\sqrt{F_{\nu i}}$$

DSM

$$\zeta_{\nu i}(R_0 + \Delta R_i)\sqrt{\pi B_\nu(T_{c\nu i})} = 10^{0.2A_\nu} D\sqrt{F_{\nu i}}$$

from model

$$\zeta$$

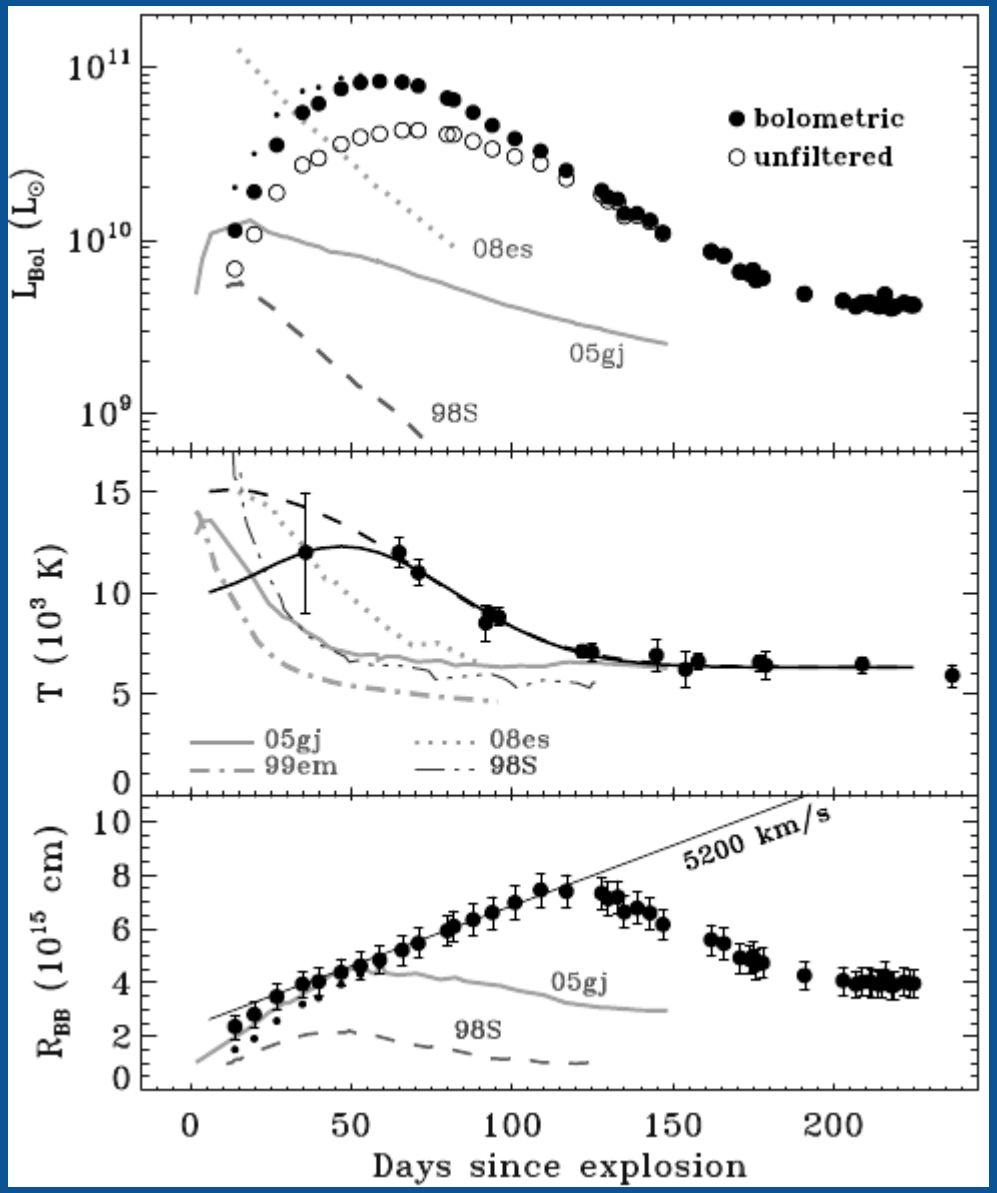
astronomical observations

$$T_c \quad A$$

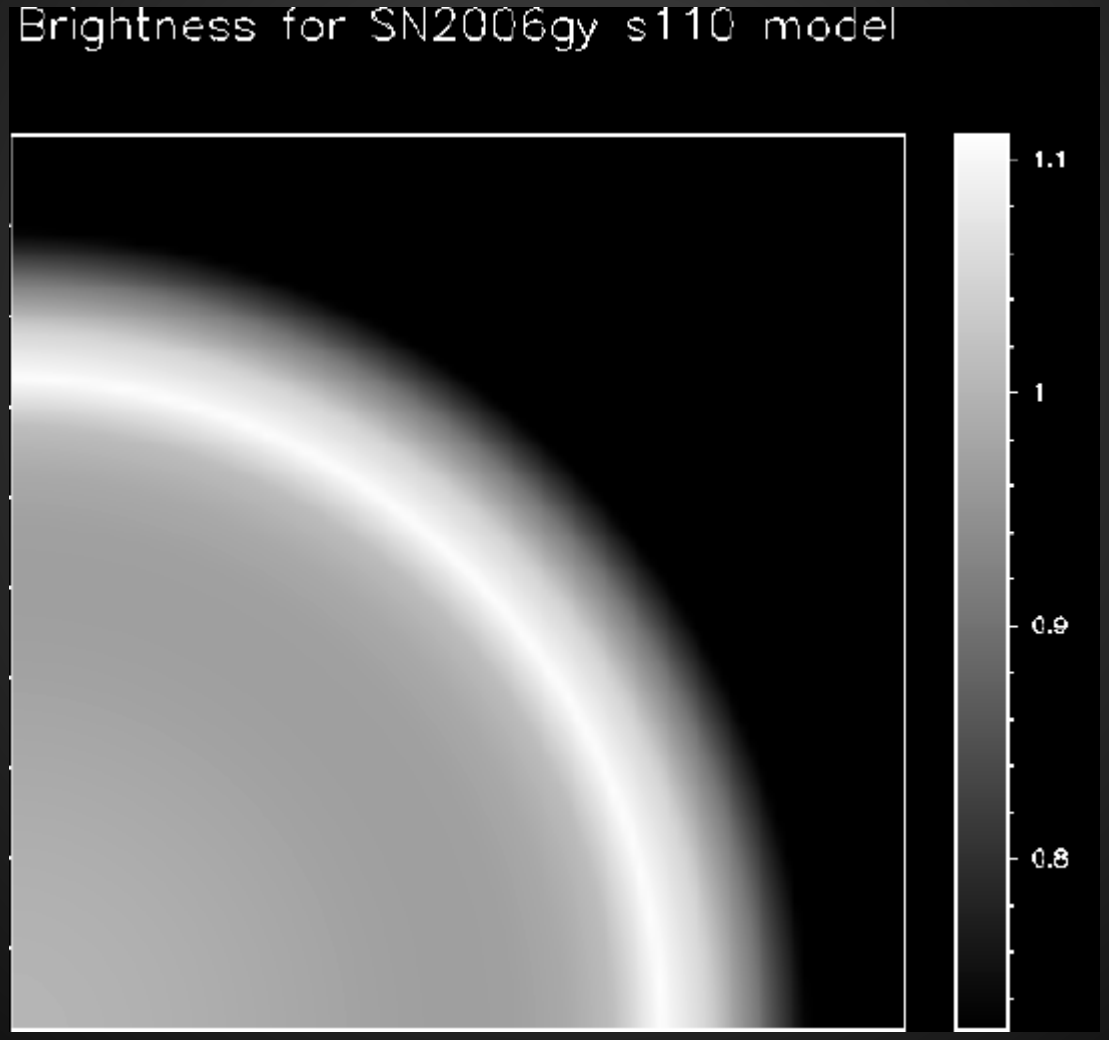
measuring

$$F \quad \Delta R$$

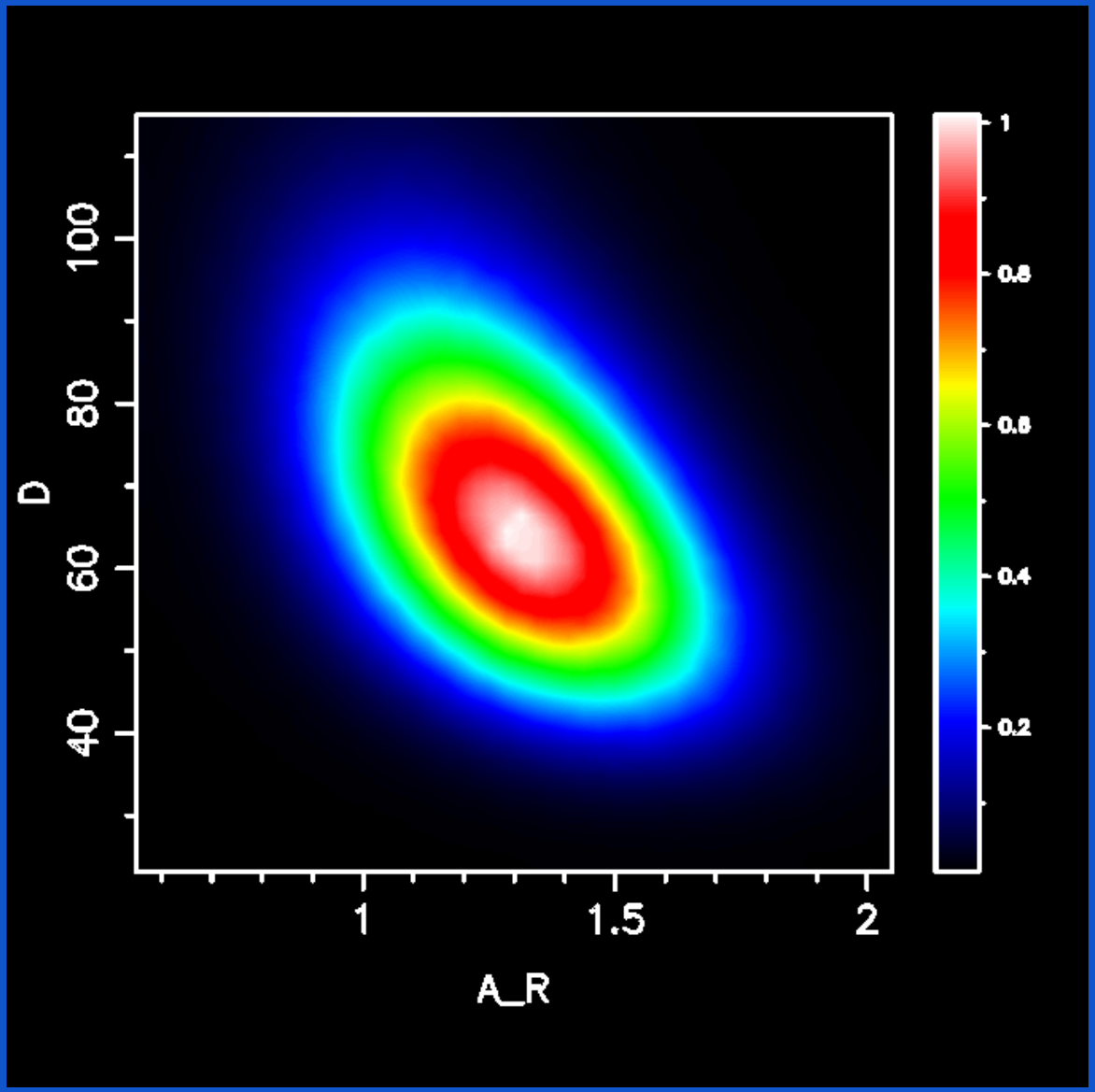
Observed *L, T, R(t)* of SN2006gy



‘Visible’ disk of SNIIn on declining LC stage



SN 2006gy



SN 2006gy

$$D \approx 68^{+19}_{-15}(68\%\mathrm{CL})\ \mathrm{Mpc}$$

standard value $71\ \mathrm{Mpc}$

SN 2009ip

$$D \approx 20.1 \pm 0.8 \ (68\% \ \mathrm{CL}) \ \mathrm{Mpc}$$

standard value $20.4 \ \mathrm{Mpc}$

Hubble parameter

$$H_0 \approx 79^{+23}_{-17}(68\%\mathrm{CL})\ \mathrm{km/s/Mpc}$$

Hubble parameter

$$H_0 \approx 79^{+23}_{-17}(68\%\mathrm{CL})\ \mathrm{km/s/Mpc}$$

Latest SN value

A. Riess, et al. ApJ 730, 119 (2011)

$$H_0 = 73 \pm 2.4\ \mathrm{km/s/Mpc}$$

New PLANCK value

$$H_0 = 67.3 \pm 1.2\ \mathrm{km/s/Mpc}$$

Conclusions

- SN IIn - may be primary distance indicators in cosmology
- We need more good observations and models (also in 3D)
- SEAM-like models are needed, not black-body