Новые наблюдения центральной области Сверхновой 1987A

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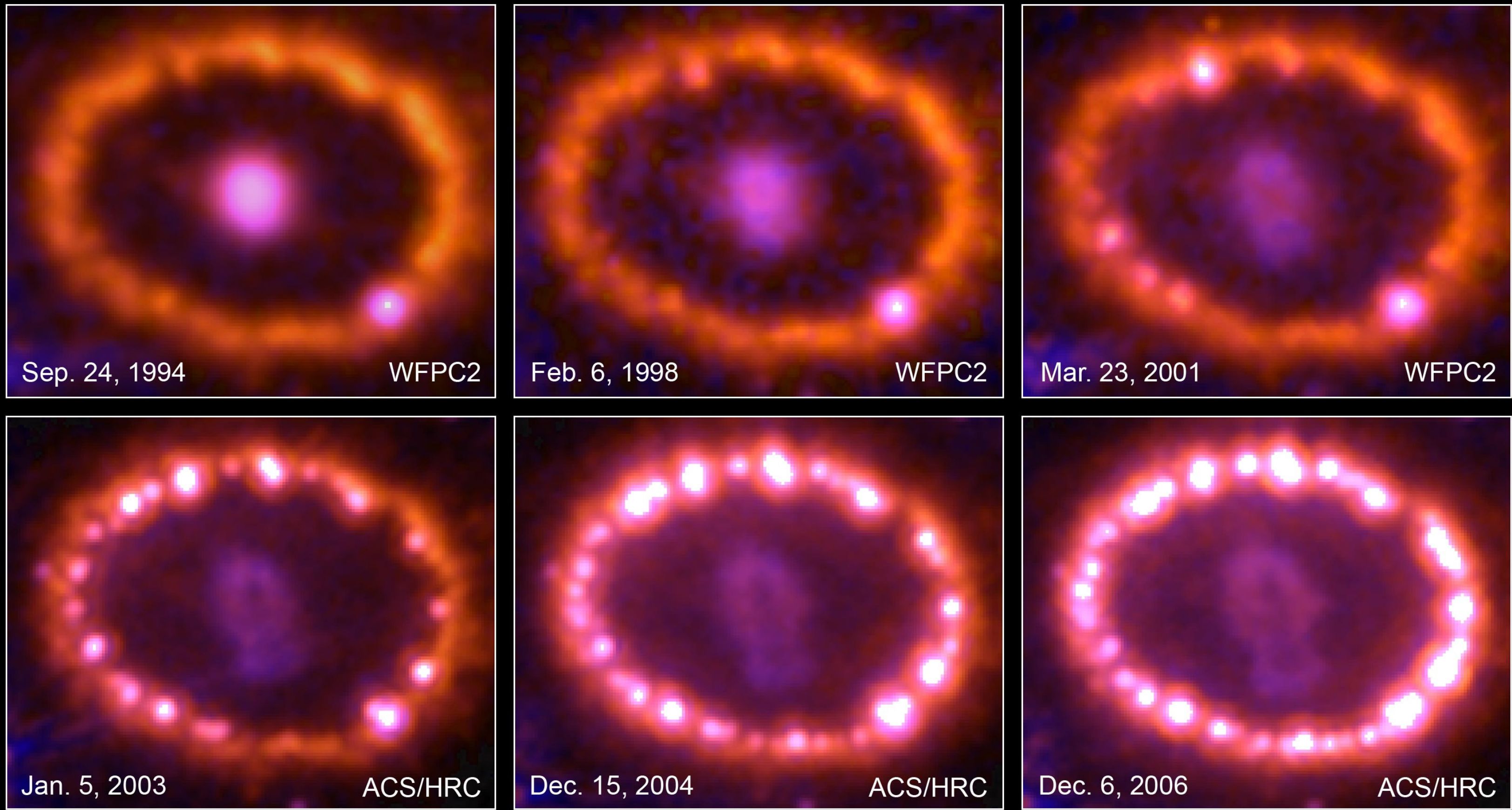
«ЗАЦЕПИНСКИЕ ЧТЕНИЯ»

25 мая 2012

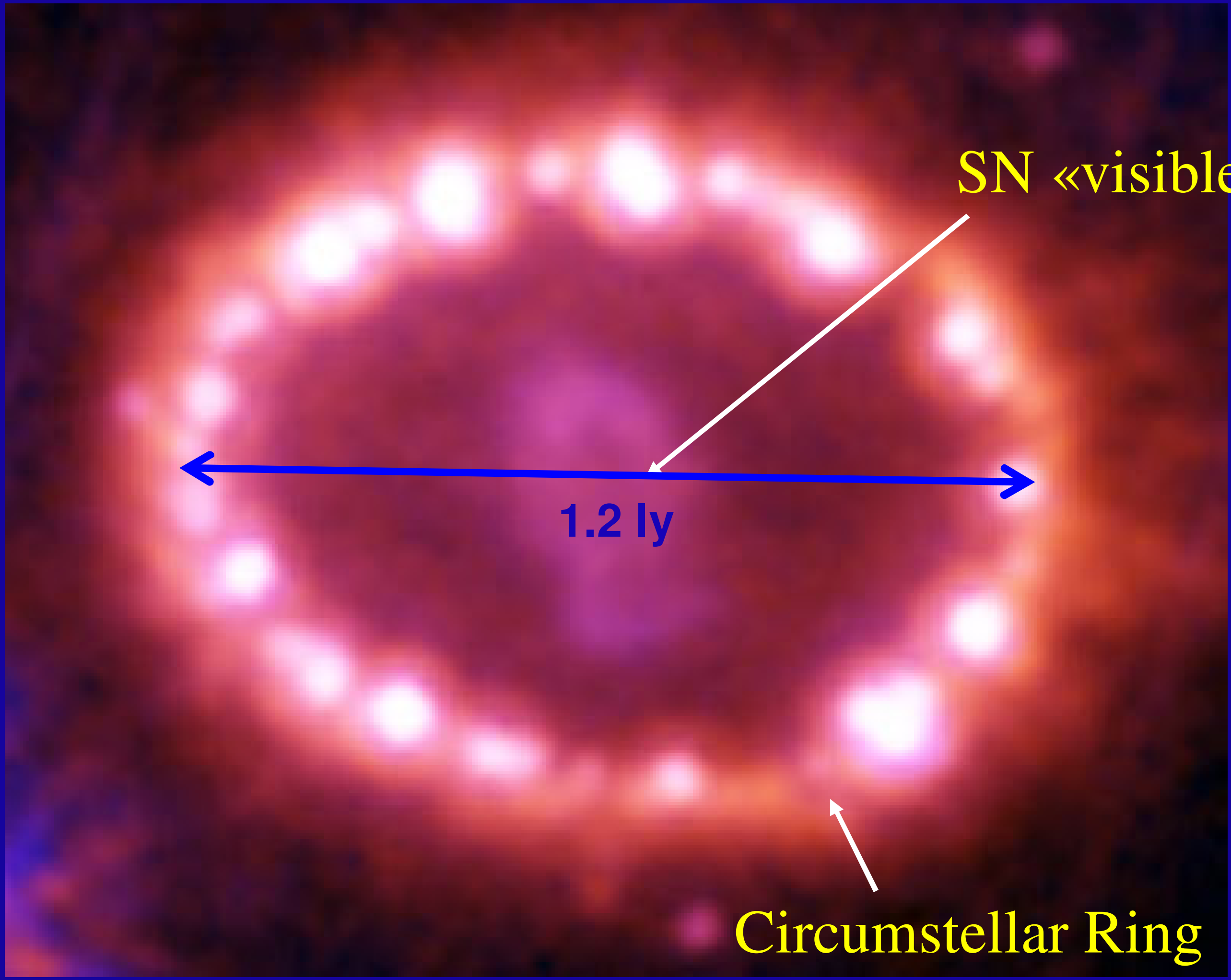


Supernova 1987A • 1994-2006

Hubble Space Telescope • WFPC2 • ACS

NASA, ESA, P. Challis, and R. Kirshner (Harvard-Smithsonian Center for Astrophysics)

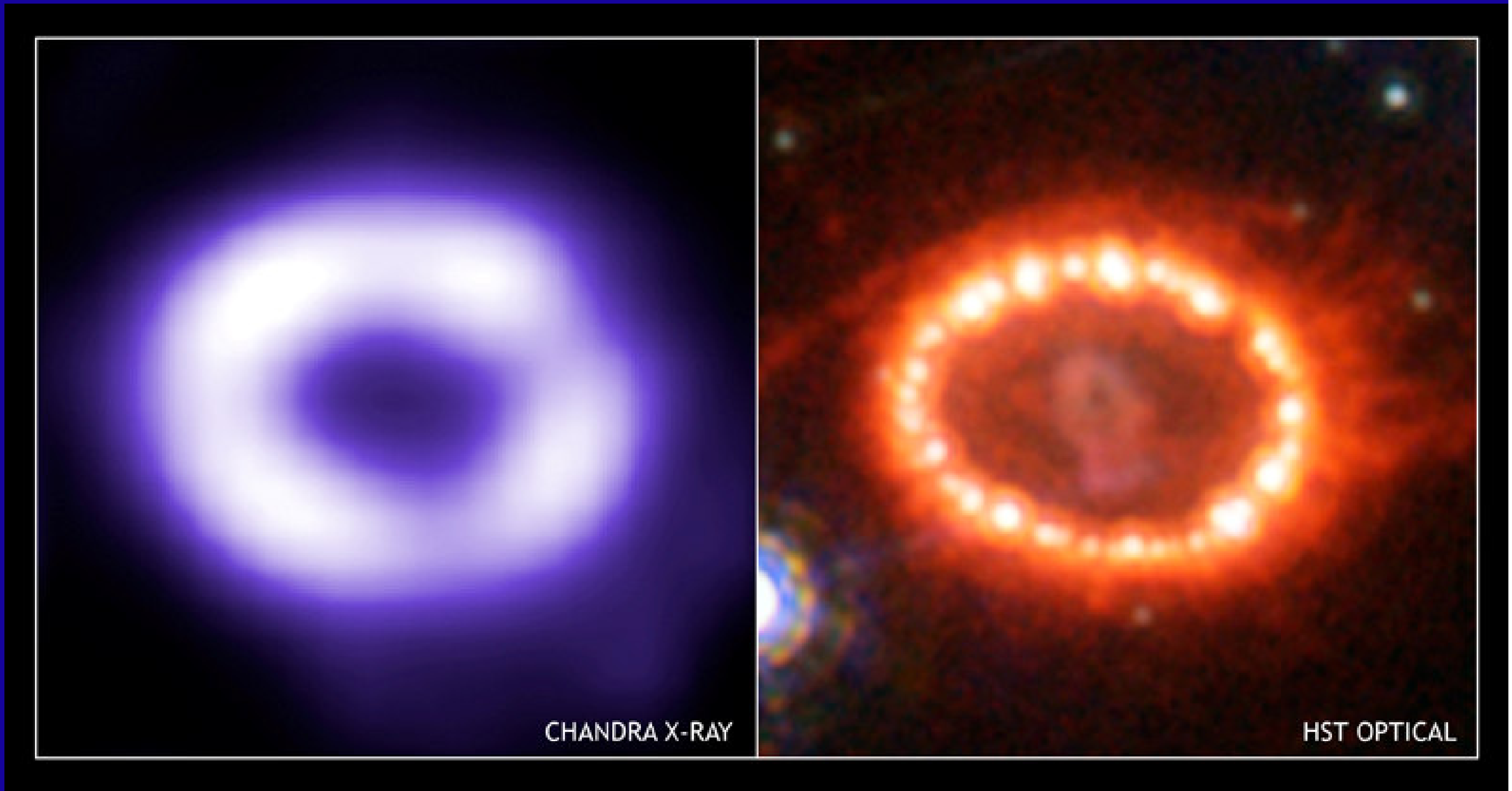
STScI-PRC07-10b



SN 1987A 16 years old (HST Nov. 28, 2003)

Interaction of shock wave with the circumstellar ring

January 2005



Chandra X-ray 0.4–0.7 keV
Observation Time 8 hours

HST Optical

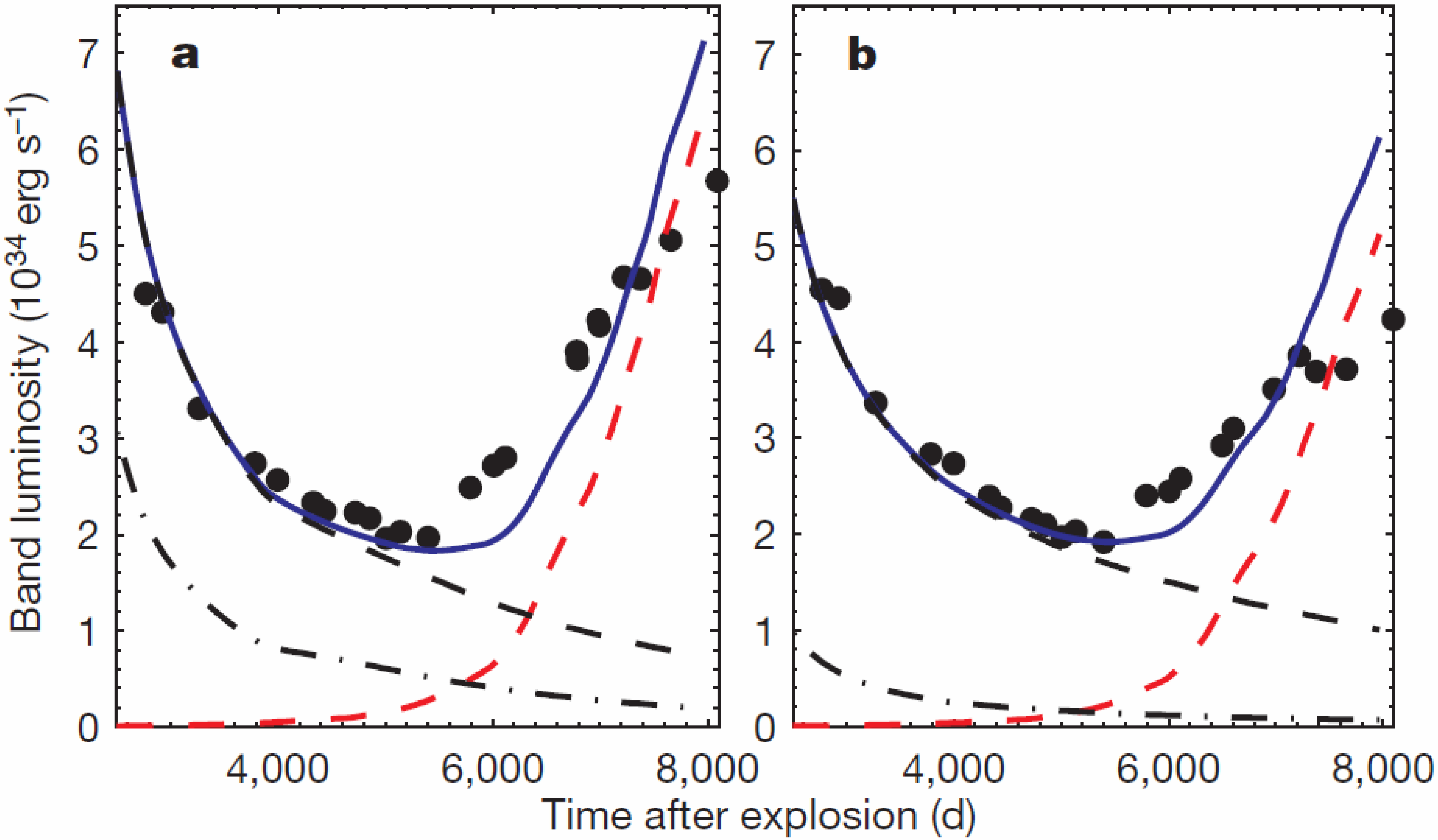


Figure 3 | Evolution of the luminosity from the ejecta in the R and B bands. **a**, R band; **b**, B band. The black dashed lines show a model with only radioactive input, mainly from ^{44}Ti. The ^{44}Ti mass used for the model is $1.4 \times 10^{-4} M_{\odot}$

J. Larsson et al. Nature, vol. **474**, p. 484, 23 June, 2011

The 3-D structure of SN 1987A's inner ejecta★

K. Kjær[1,2], B. Leibundgut[2,3], C. Fransson[4,5], A. Jerkstrand[4,5], and J. Spyromilio[2]

A&A 517, A51 (2010)

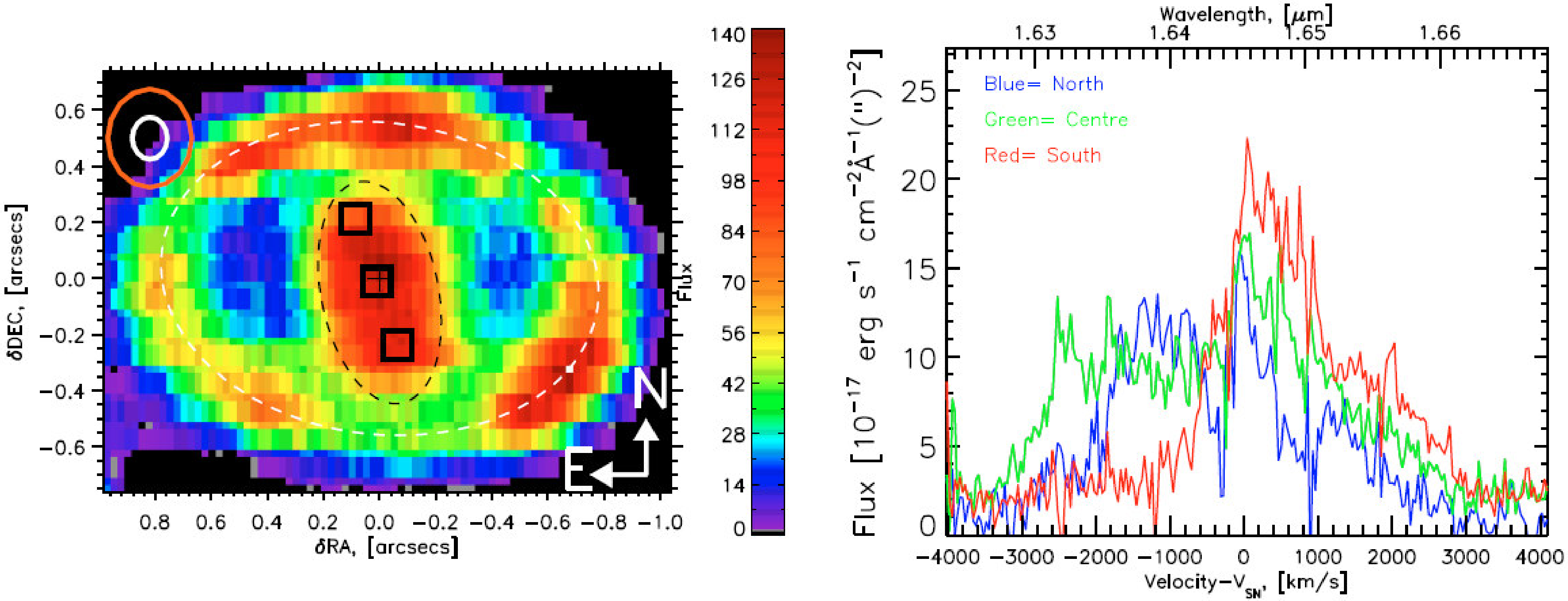


Fig. 3. *Left panel*: image of the 1.644 μm [Si I]+[Fe II] feature. The white dashed ellipse indicates the apparent shape of the inner ring, which is centred on (0, 0) marked with a cross. The ejecta shape is indicated by the black dashed ellipse. The ellipses in the top left corner show the 50% (80% in red) encircled energy area from a point source. The colour bar gives the flux intensity in 10^{-18} erg s^{-1} cm^{-2}. The right panel shows the line profile of the 1.644 μm feature extracted at three different positions shown in the left panel. The blue curve corresponds to the upper most extraction box, the green to the middle box, and the red curve to the bottom box.

image of the 1.644 μm [Si I]+[Fe II] feature observer →

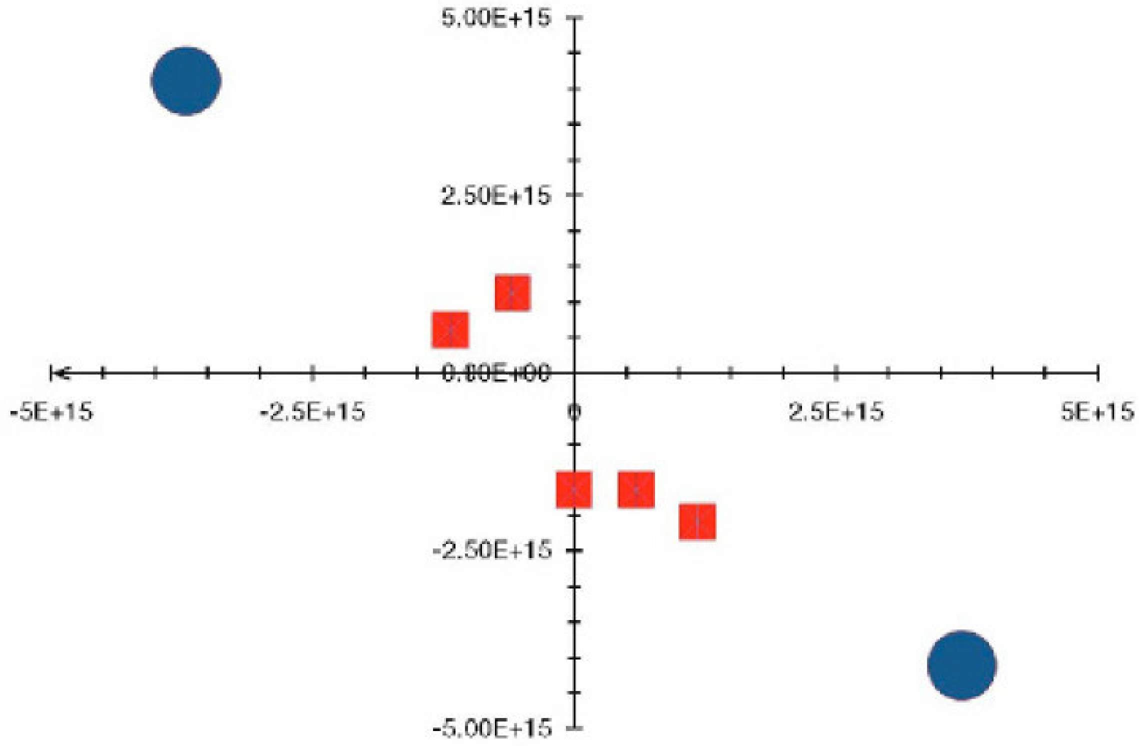
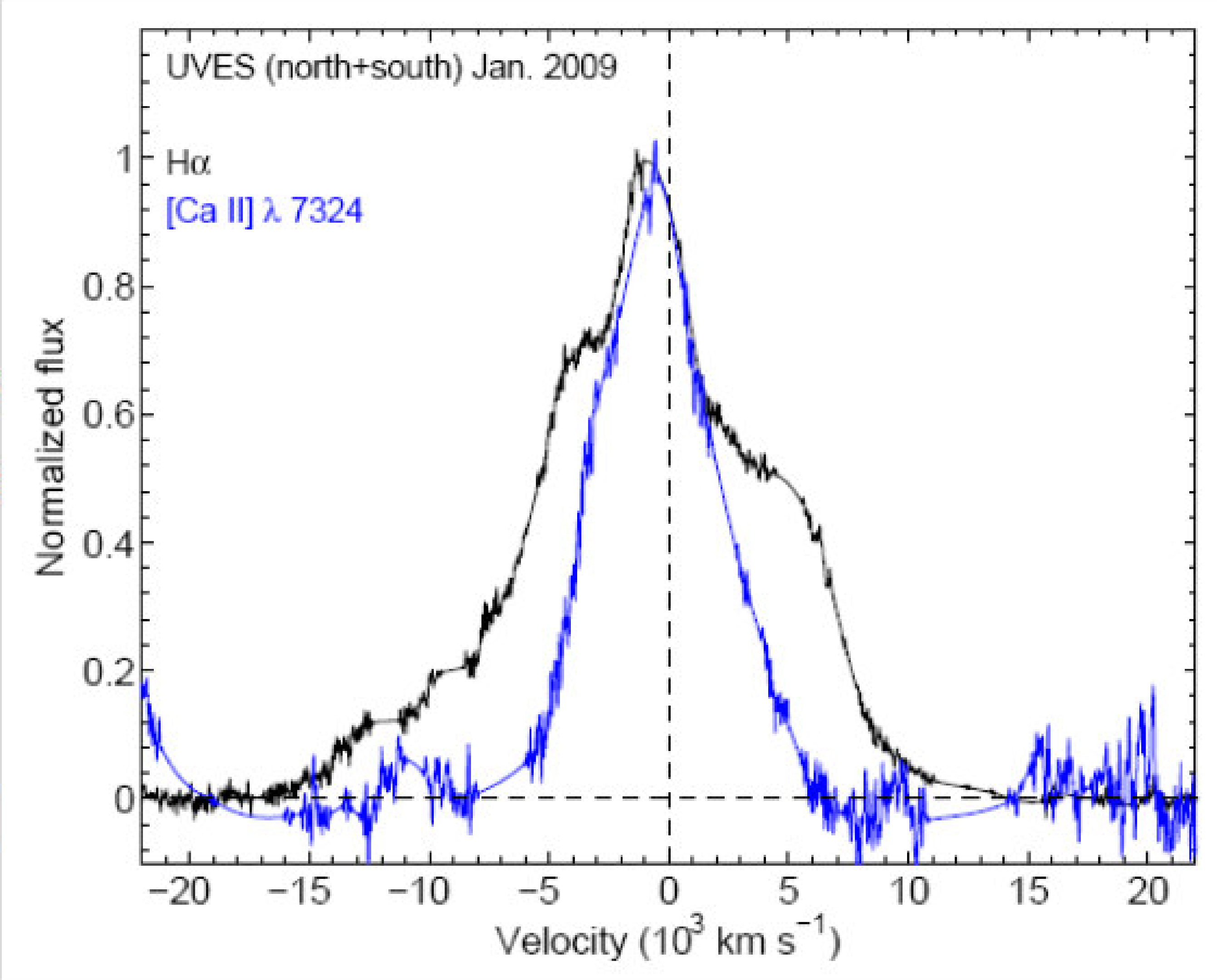


Fig. 9. Schematic view of the ejecta distribution of the ejecta relative to the the ring as seen in the 1.644 μm line. *Top*: the distances from the centre are given in meters, the observer is located on the left. This figure demonstrates that the ejecta mostly lie in the same plane as defined by the equatorial ring. The squares only give approximate emission centres. In reality the emission is more diffuse, see text for details.

Kjær et al. A&A 517, A51 (2010)



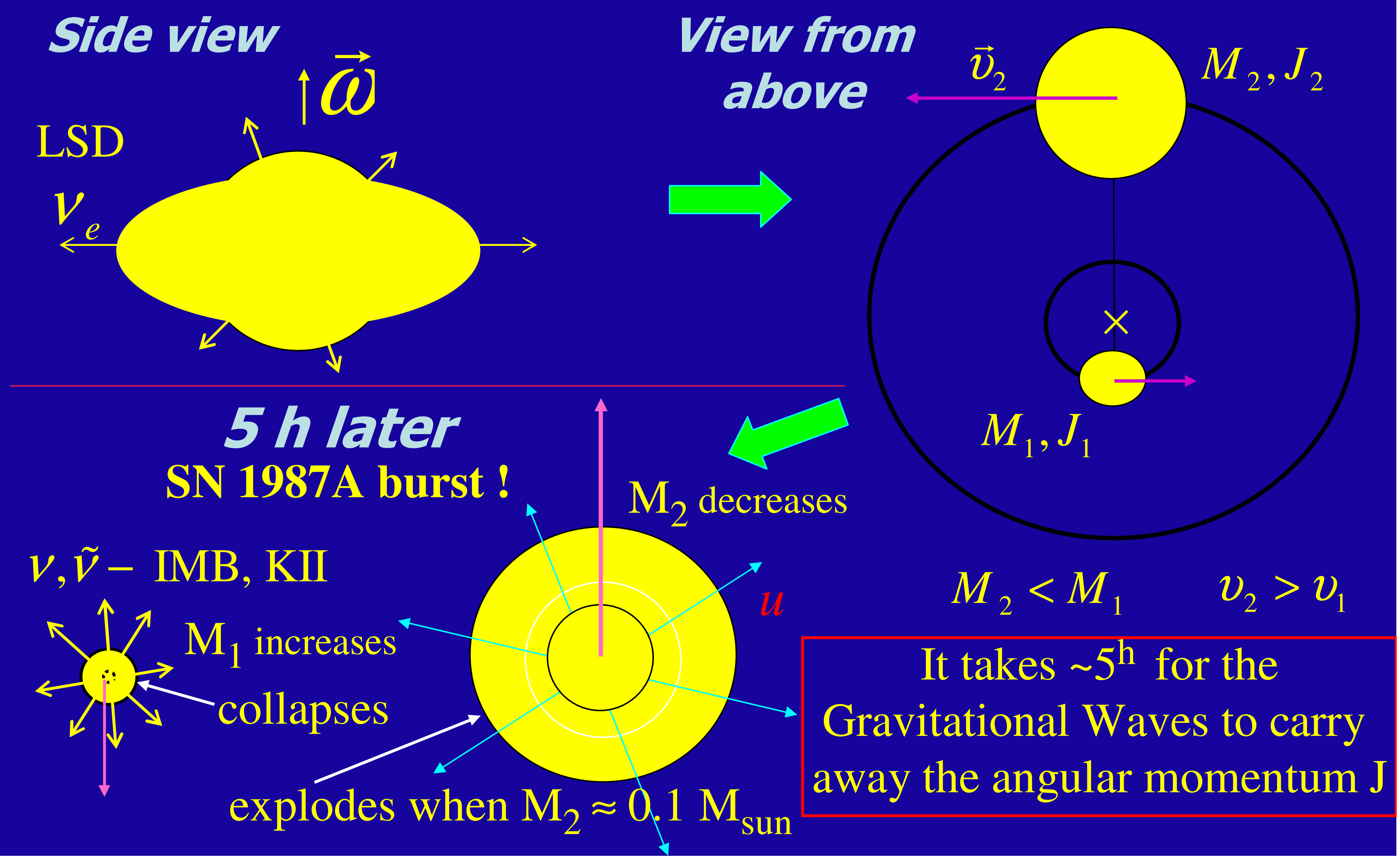
Fransson et al. 2012

B. Leibundgut 16th Workshop on Nuclear Astrophysics, Ringberg Castle, Germany, March 26-30, 2012
http://www.mpa-garching.mpg.de/Hydro/NucAstro/prog12.html

A rotating collapsar

The Two-Stage Gravitational Collapse Model

[Imshennik V.S., Space Sci Rev, **74**, 325-334 (1995)]



Conclusion

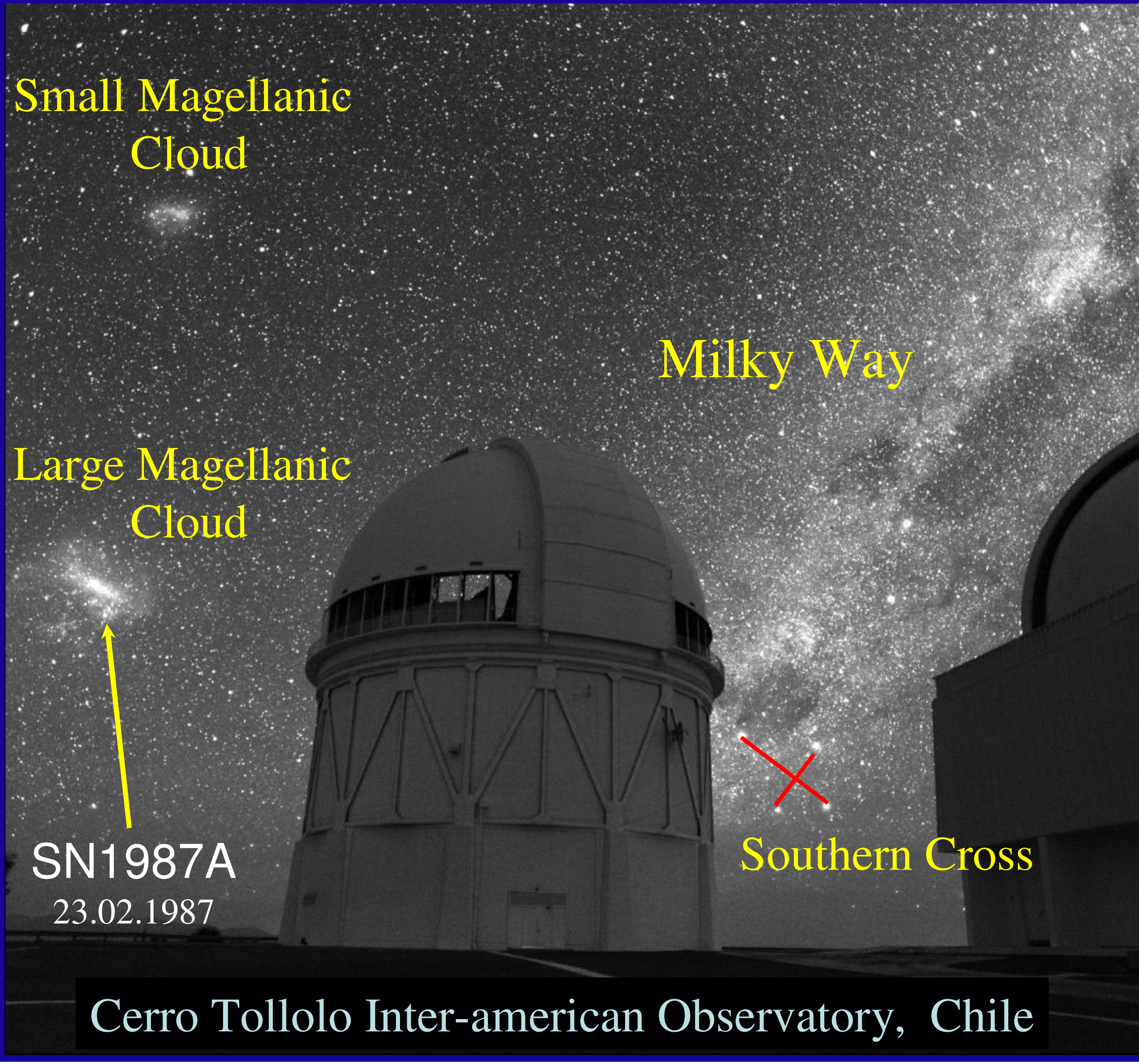
Central dust cloud has a form of a prolate ellipsoid with the axis ratio about 2.5.
The ellipsoid lays in the plane of equatorial ring and expands with the velocity of ~3000 km/s.

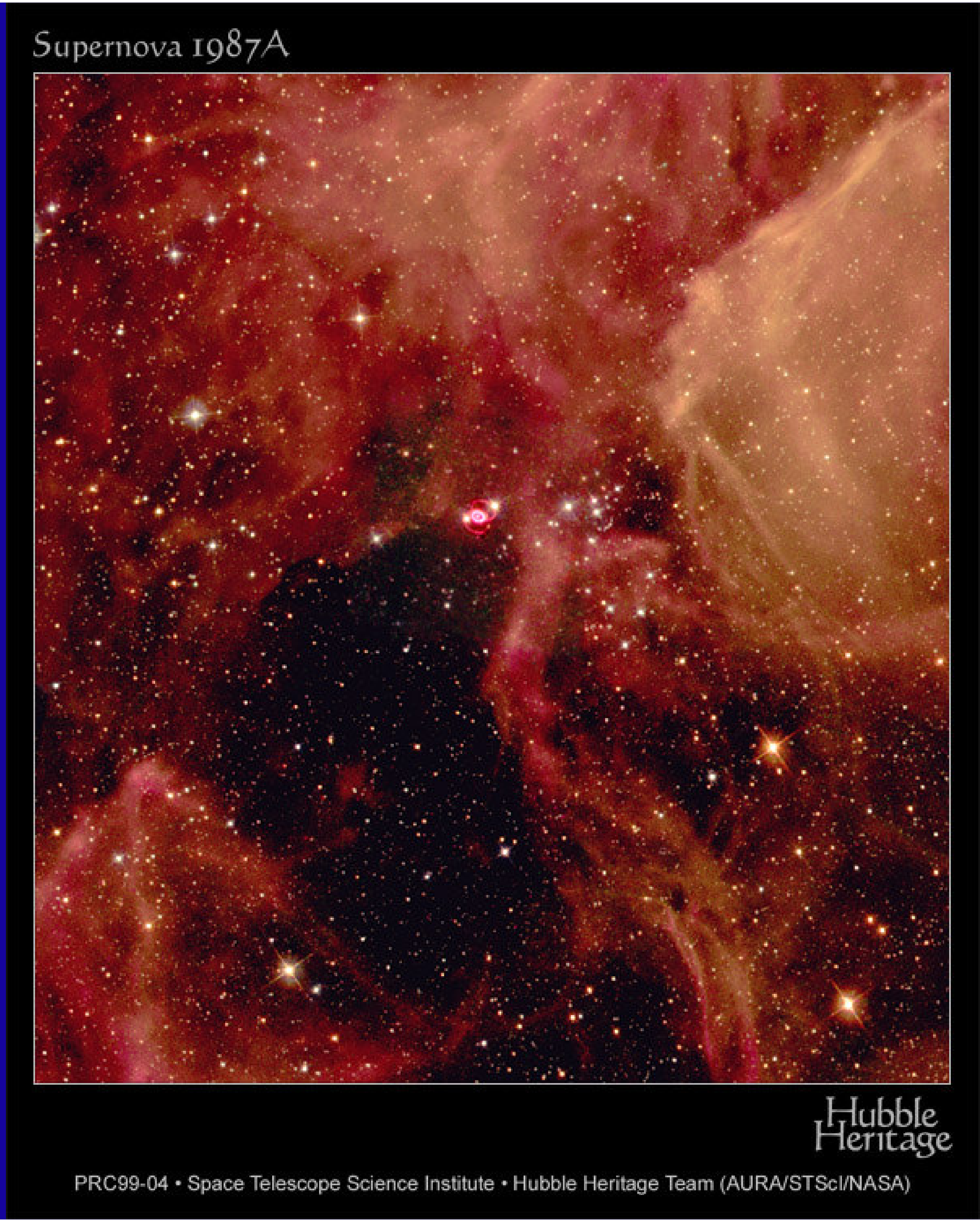
The dust is heated by X-rays from the ring and by the decay of Ti^{44} and radiates in far infrared.

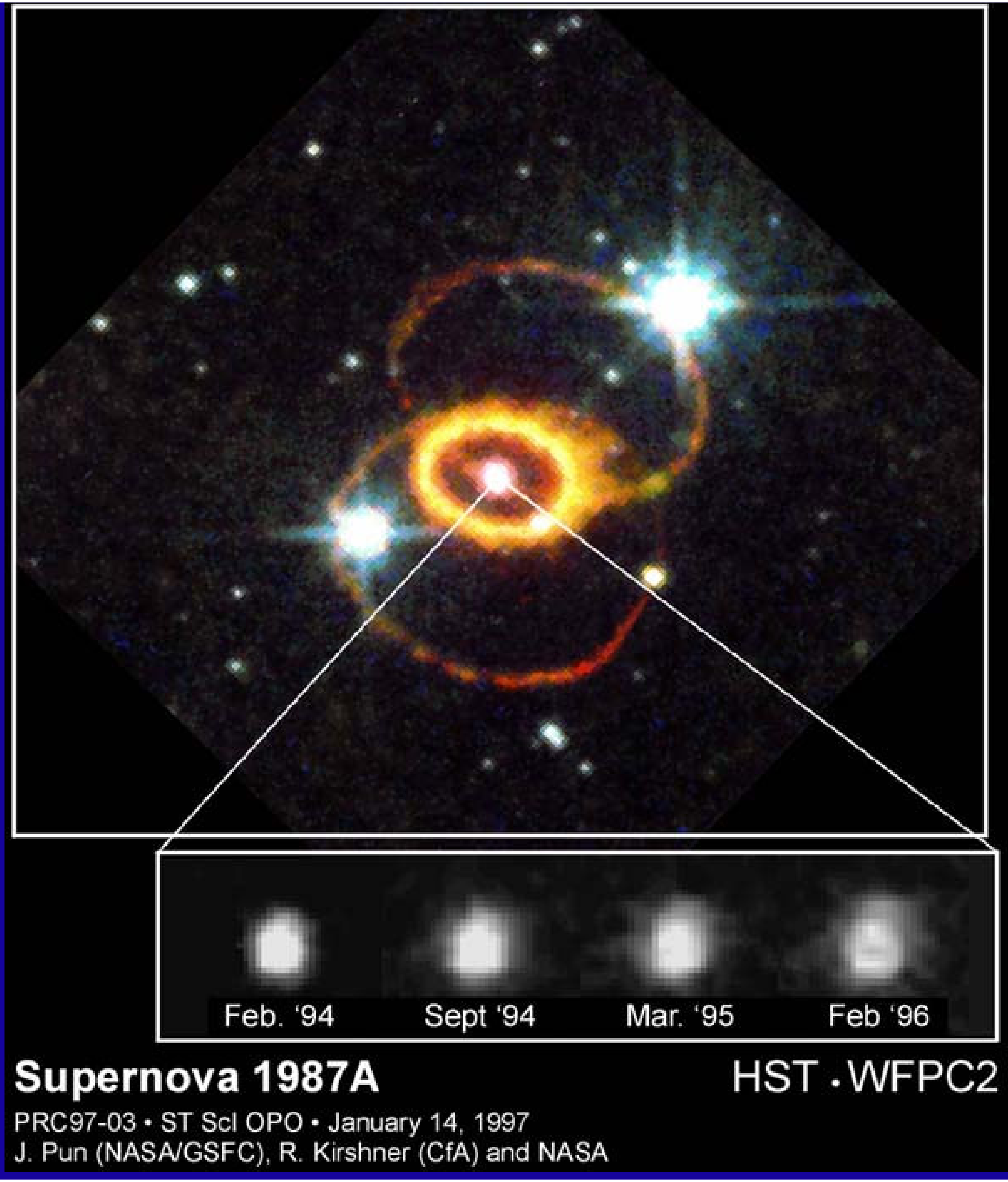
$$^{44}Ti \rightarrow {}^{44}Sc \rightarrow {}^{44}Ca \ \ (\tau = 78.2 \text{ y})$$

Central stellar remnant is not yet seen being screened by the dust.

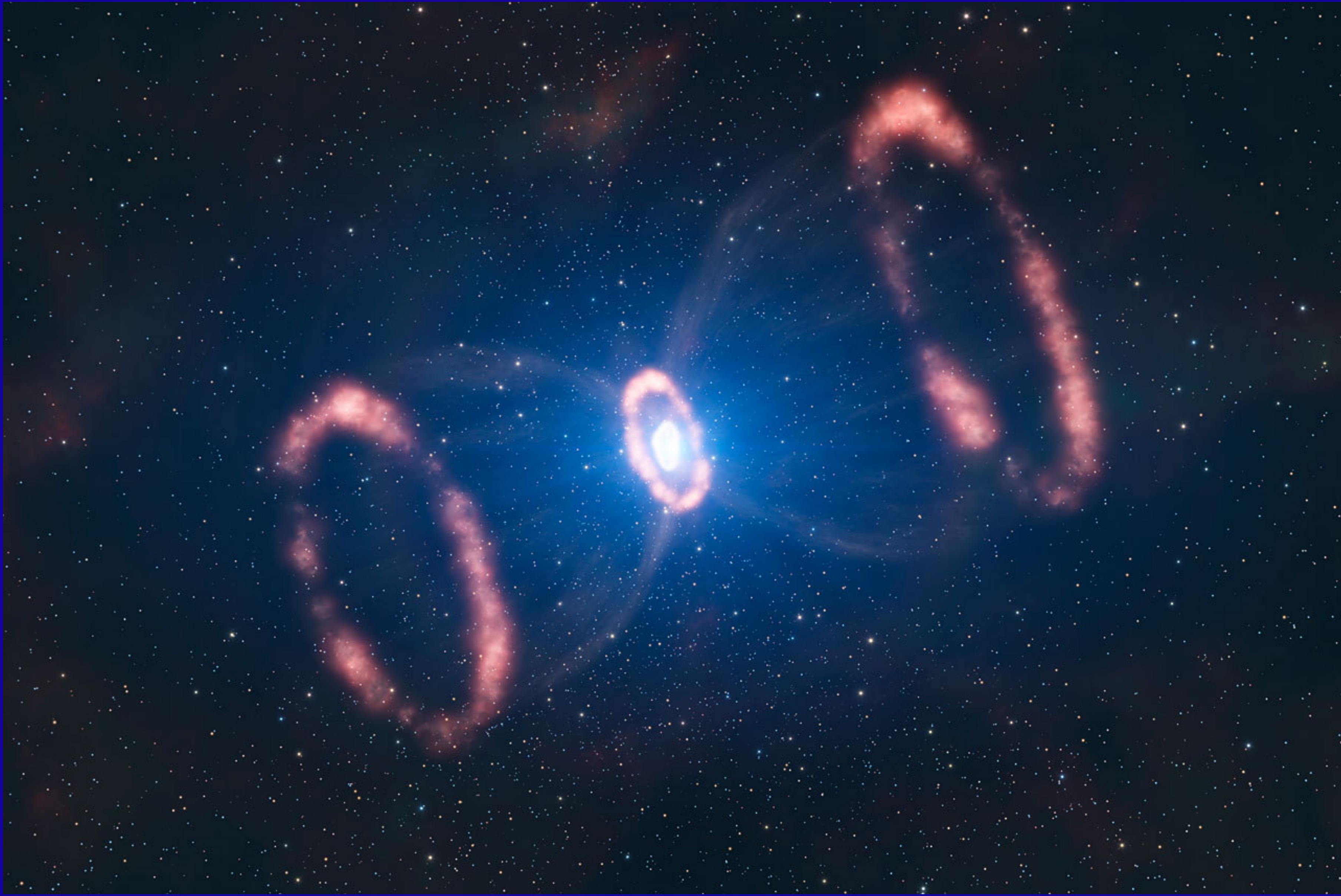
Спасибо!


Small Magellanic Cloud
Milky Way
Large Magellanic Cloud
SN1987A
23.02.1987
Southern Cross
Cerro Tollolo Inter-american Observatory, Chile

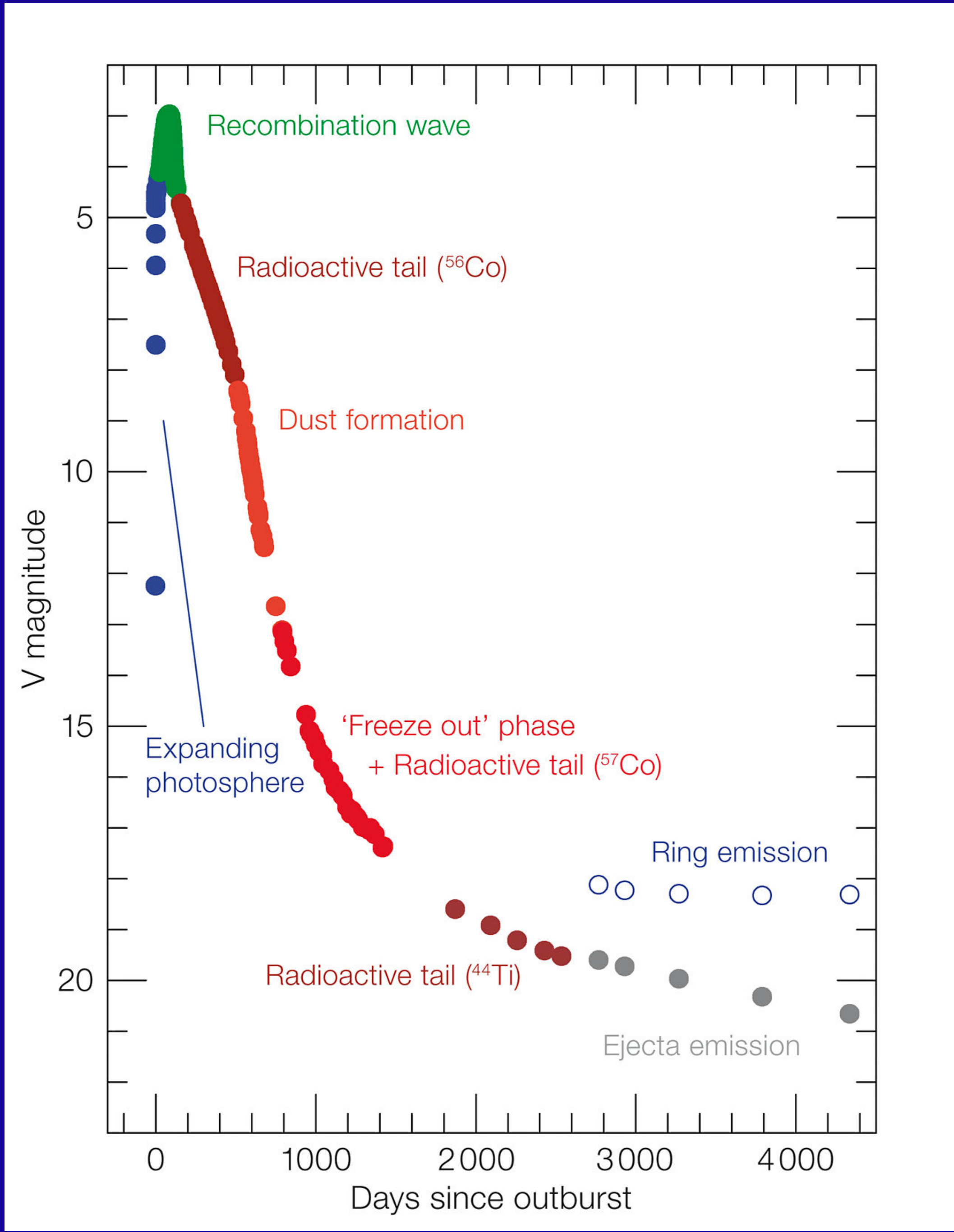

Supernova 1987A
Hubble Heritage
PRC99-04 • Space Telescope Science Institute • Hubble Heritage Team (AURA/STScI/NASA)


Feb. '94
Sept '94
Mar. '95
Feb '96
Supernova 1987A
HST • WFPC2
PRC97-03 • ST ScI OPO • January 14, 1997
J. Pun (NASA/GSFC), R. Kirshner (CfA) and NASA

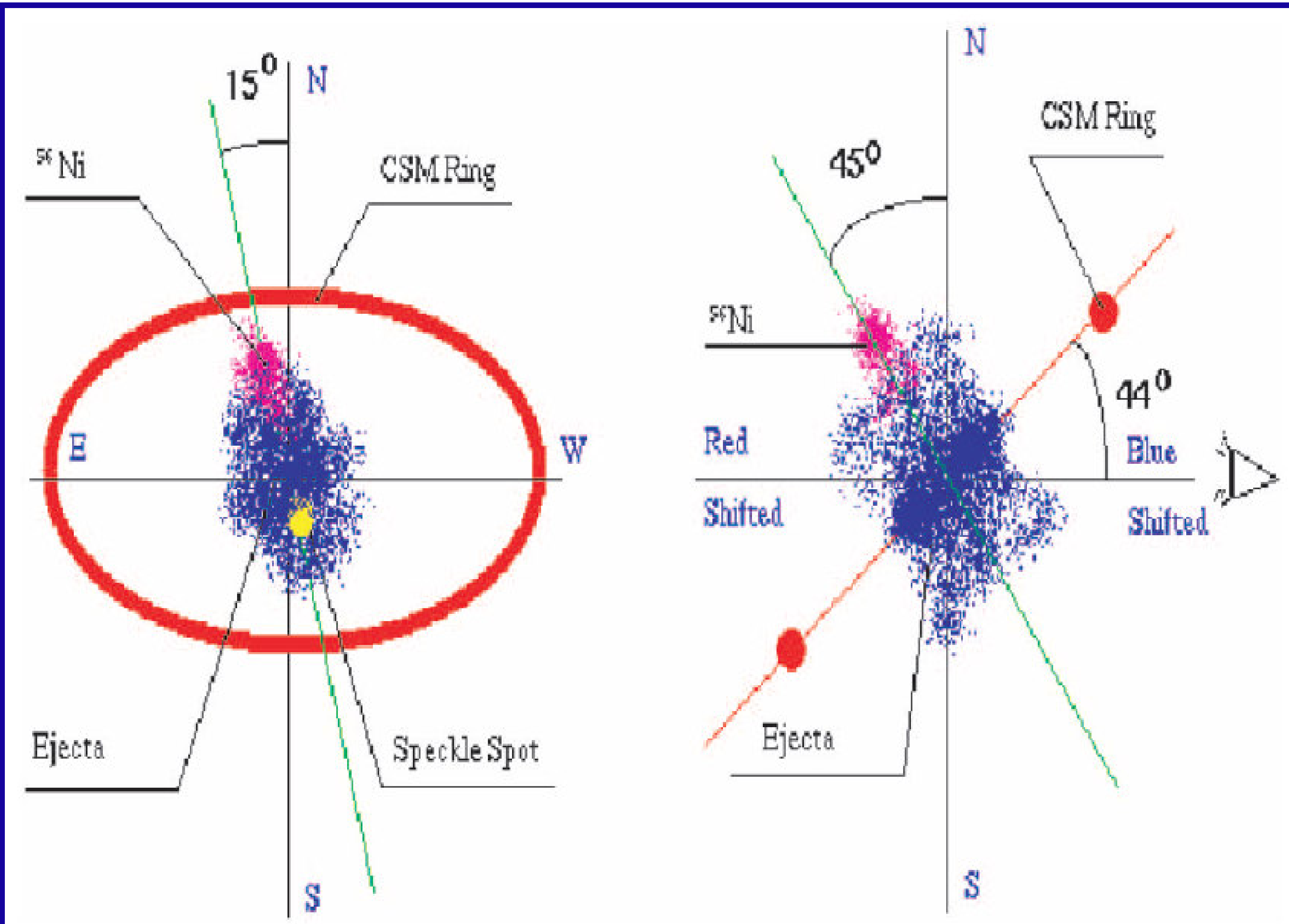
Bruno Leibundgut
ESO



eso1032a


Recombination wave
Radioactive tail (56Co)
Dust formation
'Freeze out' phase
+ Radioactive tail (57Co)
Expanding
photosphere
Ring emission
Radioactive tail (44Ti)
Ejecta emission
V magnitude
5
10
15
20
0
1000
2000
3000
4000
Days since outburst

eso0708c



L. Wang, J. Wheeler, P. Höflich *et al.* ApJ **579**, 671 (2002)

Jet-like ejection of ^{56}Ni: $M_{\mathrm{Ni}} \approx 10^{-4} M_{\odot}$; $u \geq 5000$ km/s

N. Chugai, Astron. Lett. **17**, 942 (1991)

Core-collapse SNe (all other Types but Ia)

The SN outburst is triggered by the gravitational collapse of the "iron" core of a mass M_{Fe}=(1.2–2) $M_{\odot}$ into a neutron star. About (10–15)% $M_{Fe}c^2$ is radiated in the form of neutrinos and antineutrinos of all the flavors (e, μ, τ):

$$E_{\nu\tilde{\nu}} = (3-5)\times 10^{53}\,\text{erg}$$

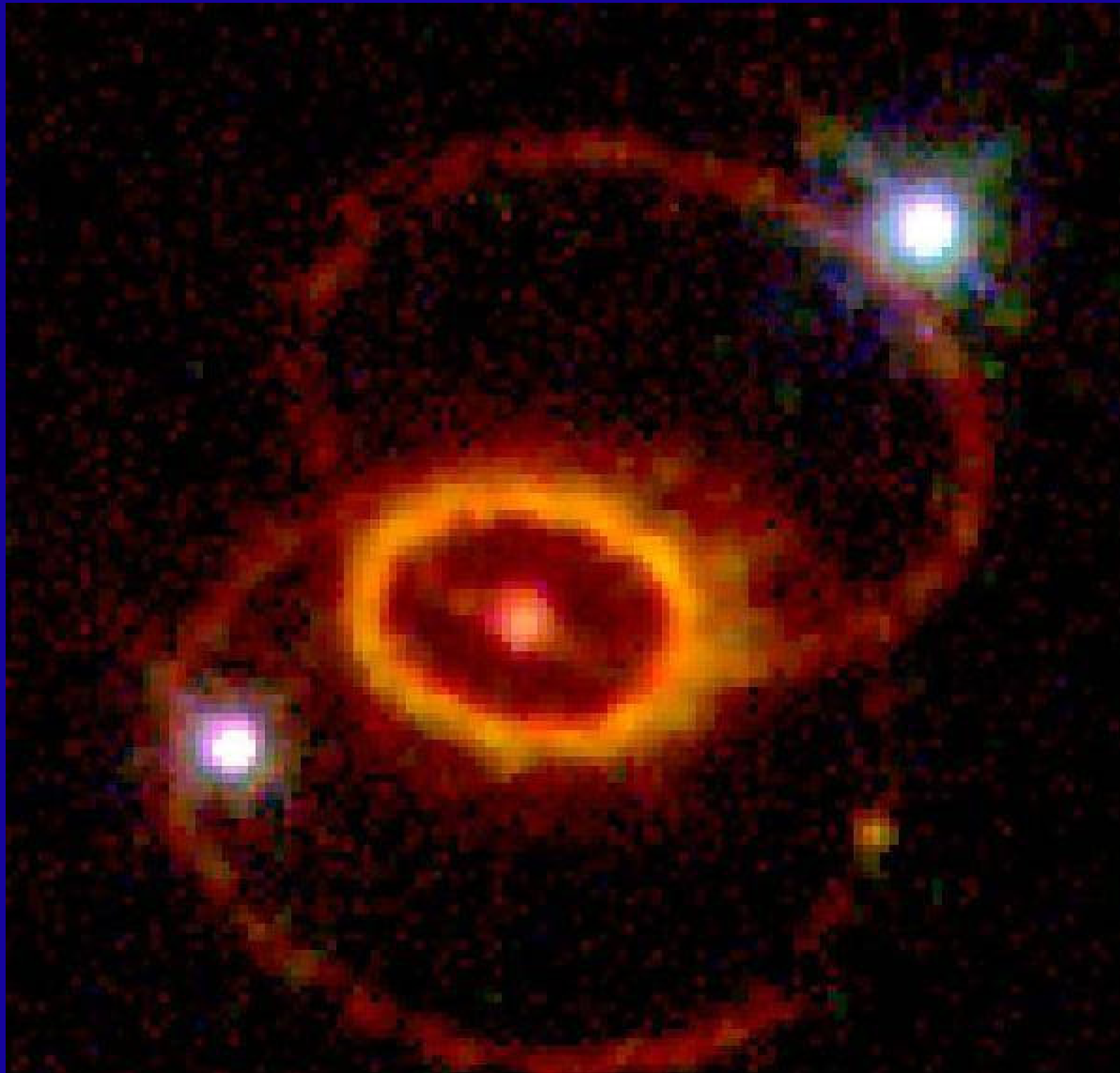
The explosion energy (kinetic energy of the envelope expansion):

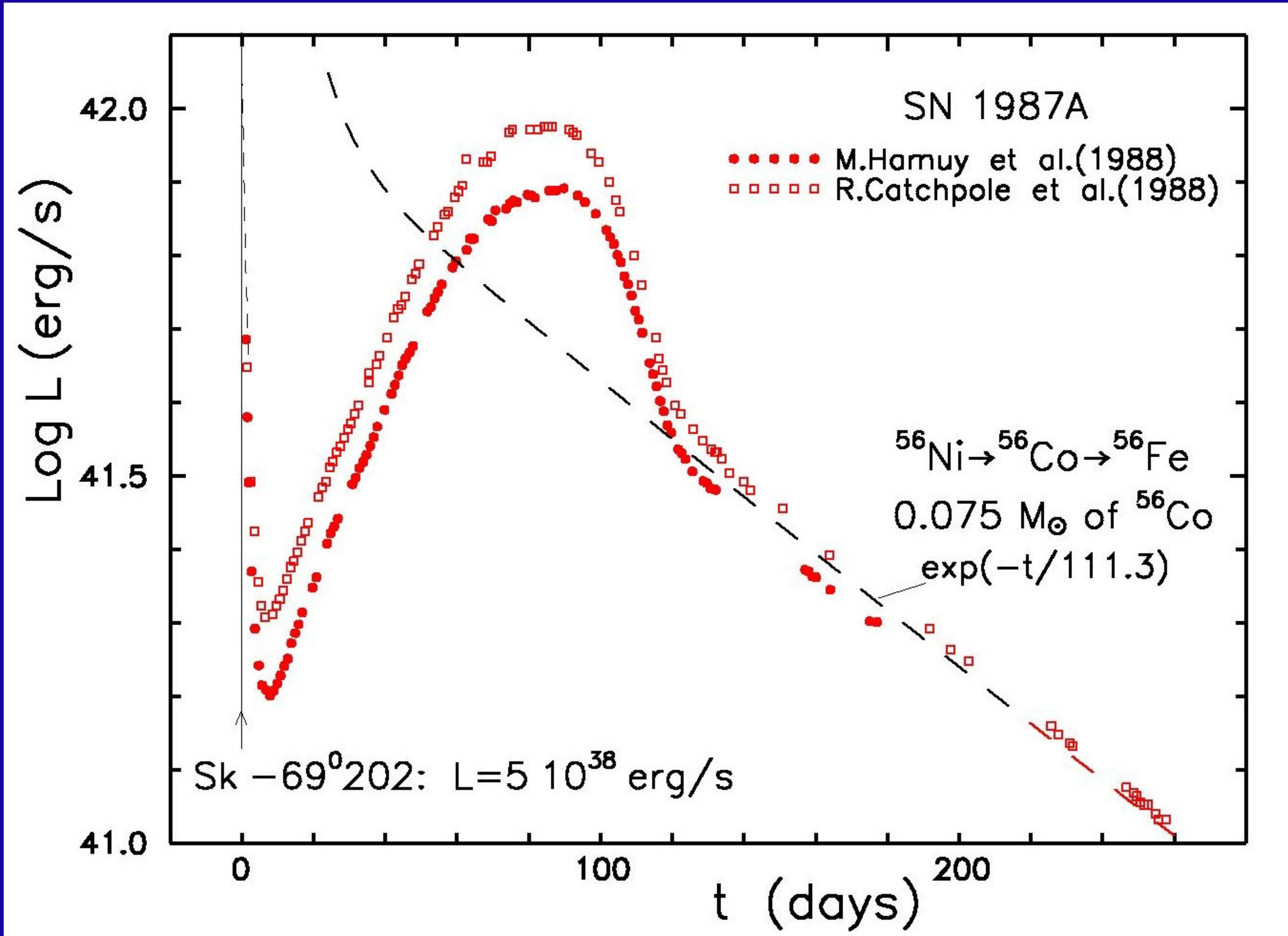
$$E_{exp} = (0.5\text{–}2)\times 10^{51}\,\text{erg}$$

it comes from the shock wave created at the boundary between a new-born neutron star and the envelope to be expelled.

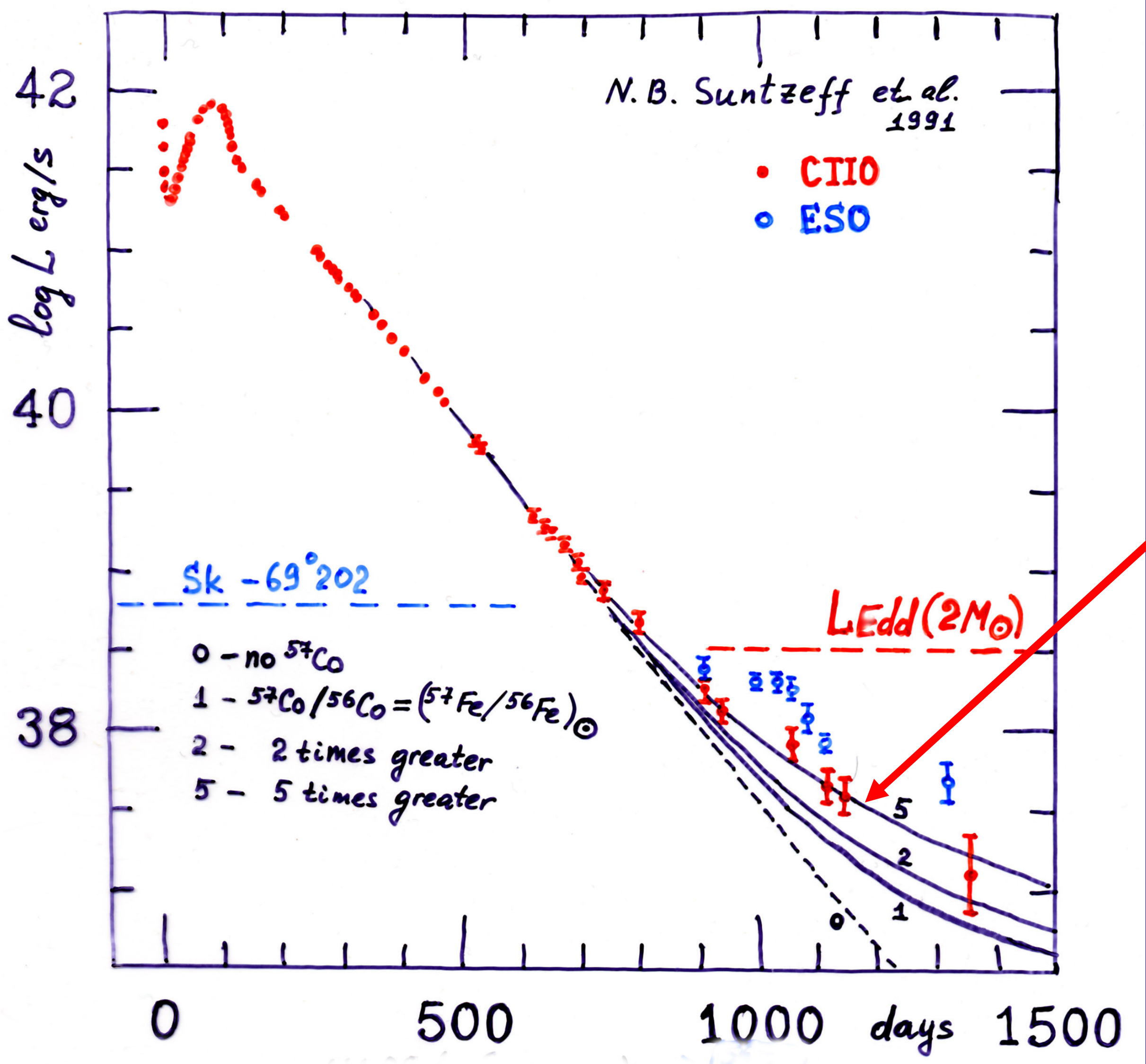
$$E_{exp}/E_{\nu\tilde{\nu}} \sim 3\times 10^{-3}\ !!$$

Rich nucleosynthesis — from neutrino-induced creation of light element in C-O and He shells through synthesis of heavy nuclides by neutron capture at the bottom of expelled envelope





The Bolometric Light Curve of SN 1987A



N. Suntzeff *et al*. Astron. J. **102**, 1118 (1991)

$^{56}\text{Ni} \rightarrow {}^{56}\text{Co}$ (τ=8.8 d)

$^{56}\text{Co} \rightarrow {}^{56}\text{Fe}$ (τ=111.26 d)

$^{57}\text{Co} \rightarrow {}^{57}\text{Fe}$ (τ=391 d)

$^{44}\text{Ti} \rightarrow {}^{44}\text{Sc} \rightarrow {}^{44}\text{Ca}$ (τ=78.2 y)

Curve 5 is a mixture of 0.075 $M_\odot$ ^{56}Ni and of some ^{57}Co + ^{44}Ti