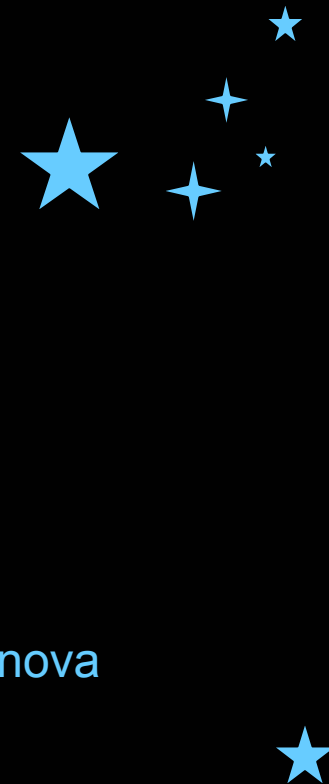


Evolicija ostataka supernova
i veza
supernova – ostatak supernove

SADRŽAJ

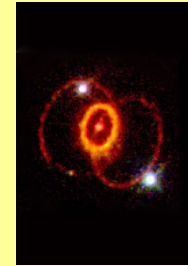
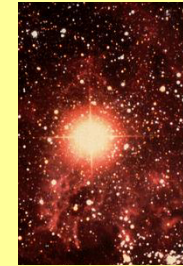
- SUPERNOVE
 - istorijske supernove, klasifikacija
 - evolucija zvezda: supernova
 - fizika supernova eksplozija
- OSTACI SUPERNOVA
 - evolucija ostataka supernova:
 - hidrodinamička evolucija
 - radio evolucija, $\Sigma - D$ relacija
 - optička i X posmatranja ostataka supernova
 - klasifikacija
- Veza: supernova – ostatak supernove





SUPERNOVE

supernova = nova zvezda



Tycho Brahe
(1546 – 1601)



Johannes Kepler
(1571 – 1630)

-De Stella Nova (1573)

-De Stella Nova in Pede Serpentarii (1606)

ISTORIJSKE SUPERNOVE:

DATUM	ZAPIS	SAZVEŽĐE	OSTATAK
AD 185?	kineske hronike	Kentaur?	G315.4-2.3 ?
AD 1006	kaluđeri u Švajcarskoj i Italiji	Vuk	G327.6+14.6
AD 1054	kineske hronike, arapski astronomi	Bik	Crab
AD 1181	kineske hronike	Kasiopeja	3C58
AD 1572	Tycho	Kasiopeja	G120.1+2.1
AD 1604	Kepler	Zmija	G4.5+6.8
AD 1680?	Flamsteed ?	Kasiopeja	Cas A

SN 1987 A



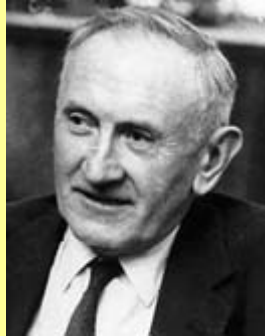
pre



posle



Walter Baade
(1893-1960)



Fritz Zwicky
(1898-1974)

KLASIFIKACIJA SUPERNOVA:

Dva tipa + podtipovi (prema optičkom spektru):

1. SN I – nema Balmerovih linija
 - a) SN Ia – Si II, $\lambda = 615.0$ nm
 - b) SN Ib – He I, $\lambda = 587.6$ nm
 - c) SN Ic – nema (ili slabe) linije He

2. SN II – Balmerove linije
 - nehomogena klasa (SN IIL, IIP, IIb, IIn, ...)

-On Super-novae (1934)

KRIVE SJAJA
(maksimum):

SN Ia :

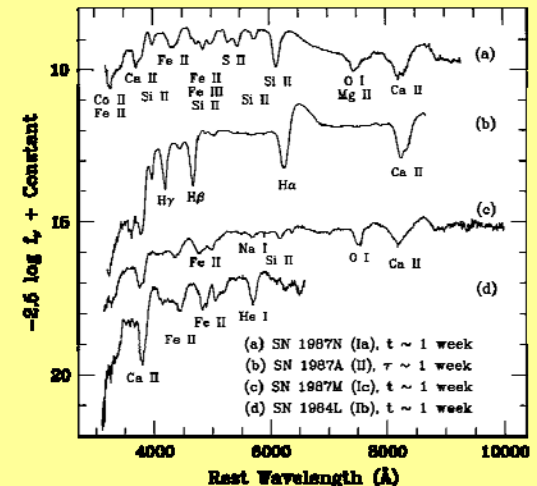
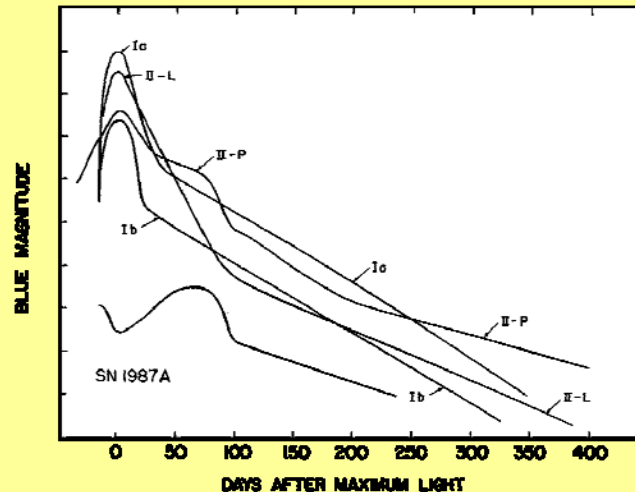
$M_B \approx -19$

SN Ib :

$M_B \approx -(18-18.5)$

SN II :

$M_B \leq -18.5$



FIZIKA SUPERNOVA EKSPLOZIJA

supernova = kraj evolucije ili “umiranje” zvezde

PROGENITORI (zvezde roditelji)
i MEHANIZAM EKSPLOZIJE:

SN Ia :

- populacija II
- deflagracija (detonacija) belog patuljka u TDS

$$M = M_{Ch} = 1.4 M_{\odot}$$

SN II :

- gravitacioni kolaps B zvezde (H omotač)
- neutronska zvezda (pulsar)

$$M = 8 - 18 M_{\odot}$$

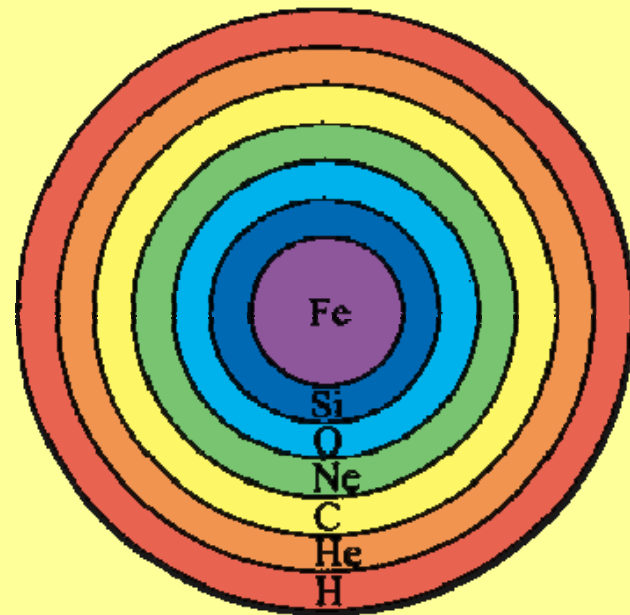
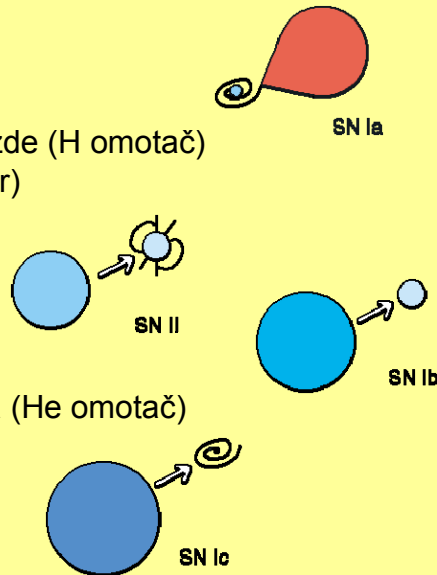
SN Ib :

- populacija I
- eksplozija O, W-R zvezda (He omotač)

$$M > 18 M_{\odot}$$

SN Ic :

- hipernova (crna rupa)



OSTACI SUPERNOVA

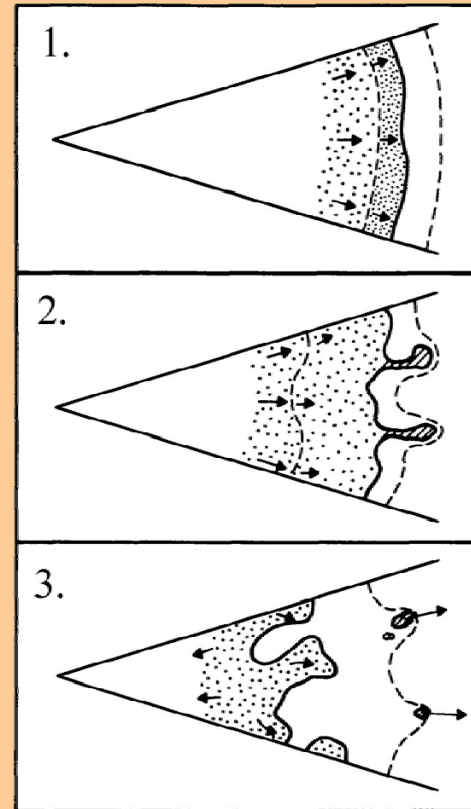
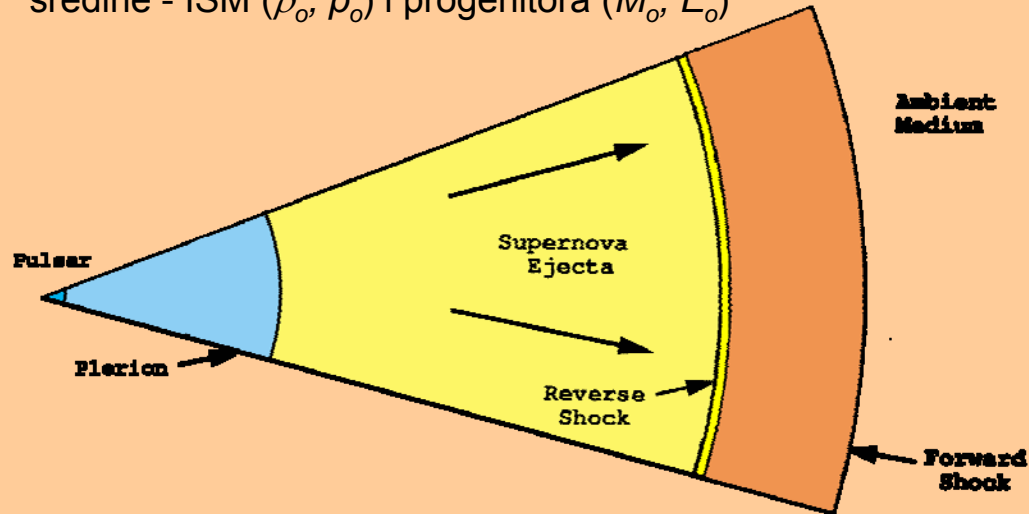
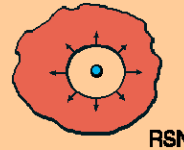
supernova = rađanje novih zvezda

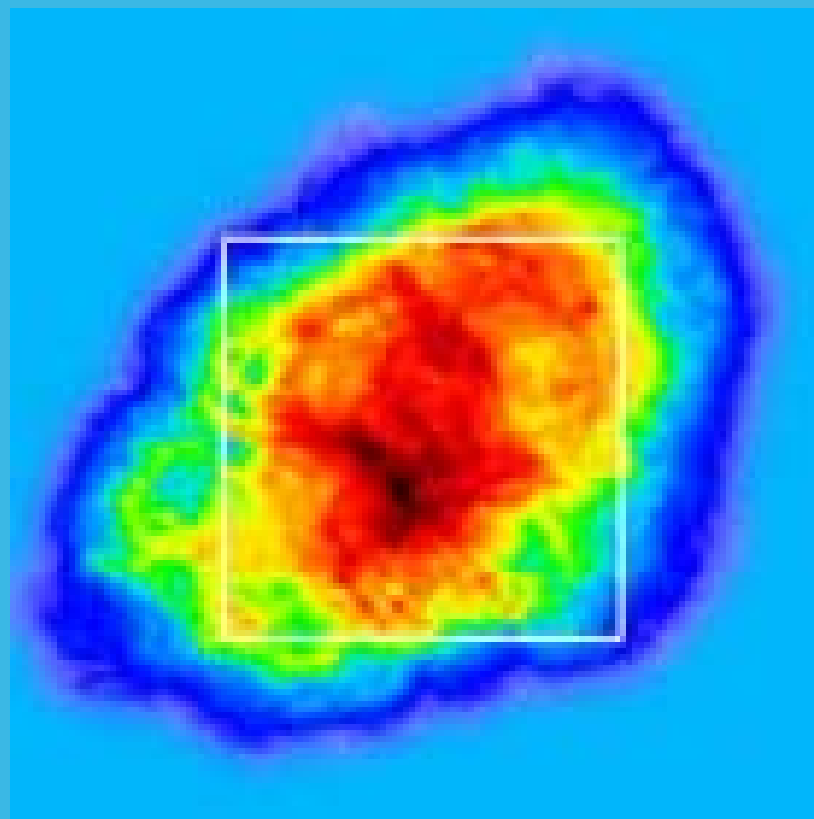
- prelazna faza - CSM: RADIO-SUPERNOVA

- ostatak supernove (SNR) – 100000 god.

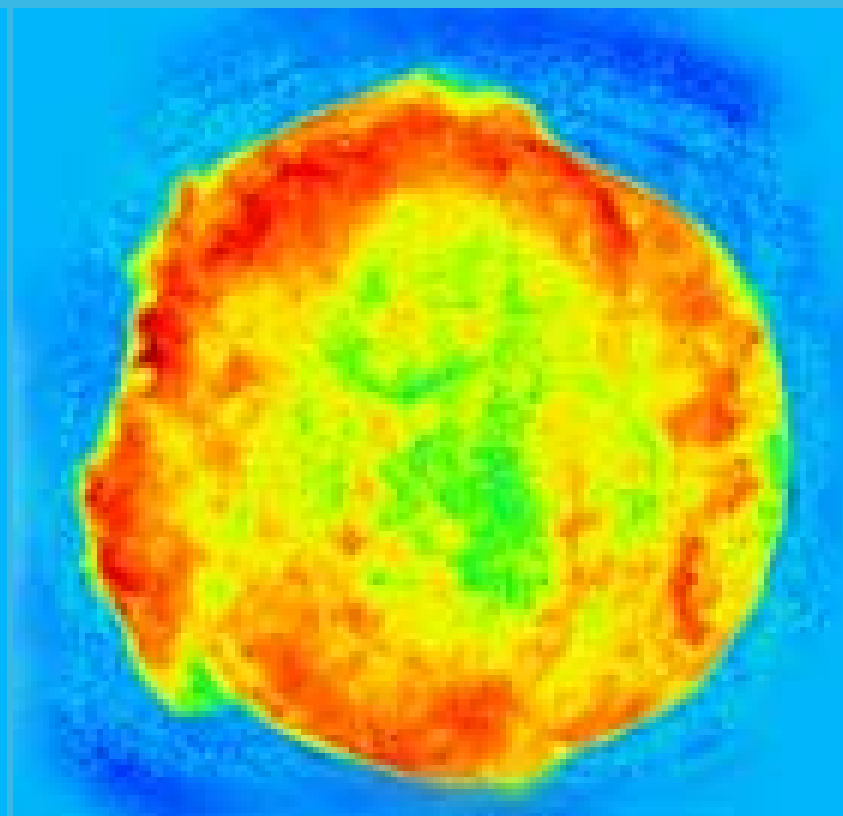
- udarni talasi, kosmicko zračenje, magnetno polje, sinhrotronski mehanizam

- tipovi (*shell, plerions*), faza, karakteristike okolne sredine - ISM (ρ_o, p_o) i progenitora (M_o, E_o)





Crab

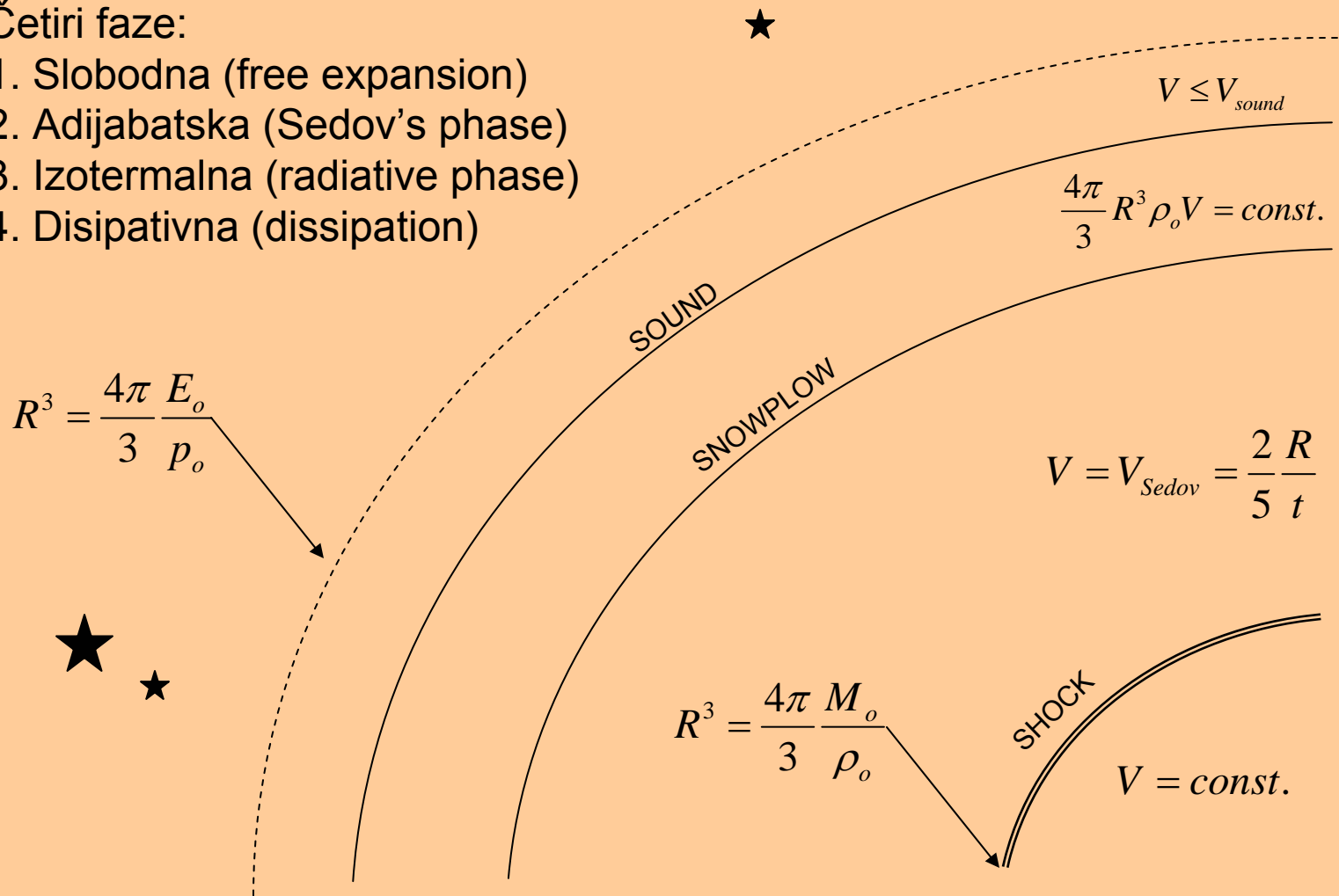


Tycho

HIDRODINAMIČKA EVOLUCIJA OSTATAKA SUPERNOVA

Četiri faze:

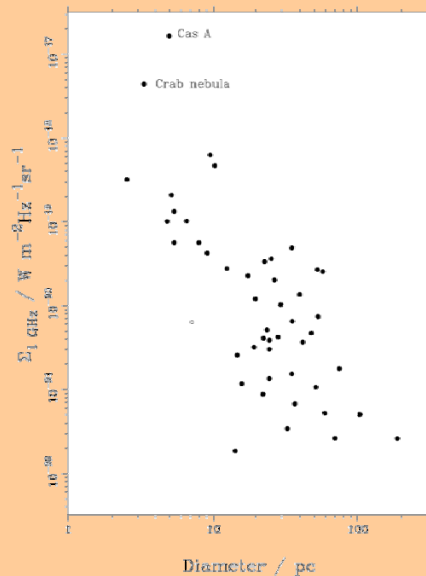
1. Slobodna (free expansion)
2. Adijabatska (Sedov's phase)
3. Izotermalna (radiative phase)
4. Disipativna (dissipation)



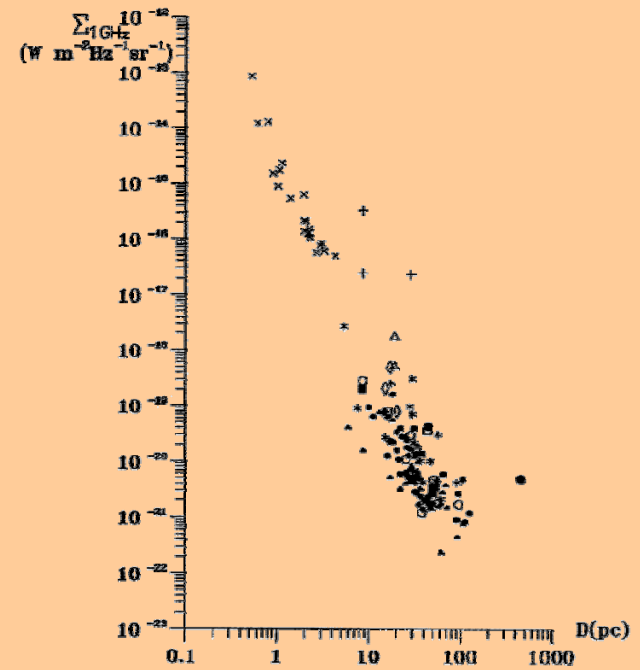
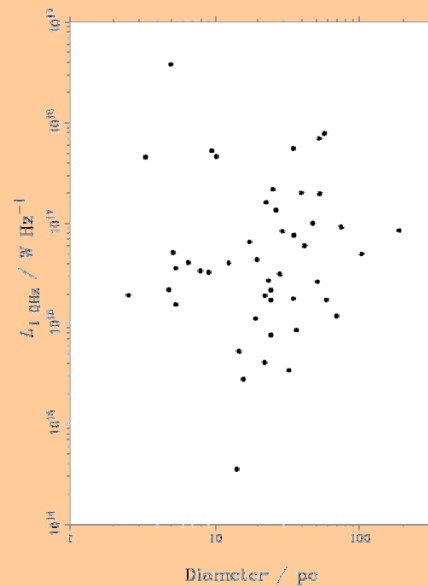
RADIO EVOLUCIJA OSTATAKA SUPERNOVA

$$\Sigma - D \text{ relacija: } \Sigma_{\nu} = A D^{-\beta} \quad [\text{W m}^{-2} \text{Hz}^{-1} \text{sr}^{-1}]$$

- teorijska: Duric & Seaquist (1986), Berezhko & Völk (2004)
- empirijska: Case & Bhattacharya (1998), Urošević et al. (2005)
- problem daljina
- parametri: ρ_0 , M_0 , E_0 , B_0



Green (2005)



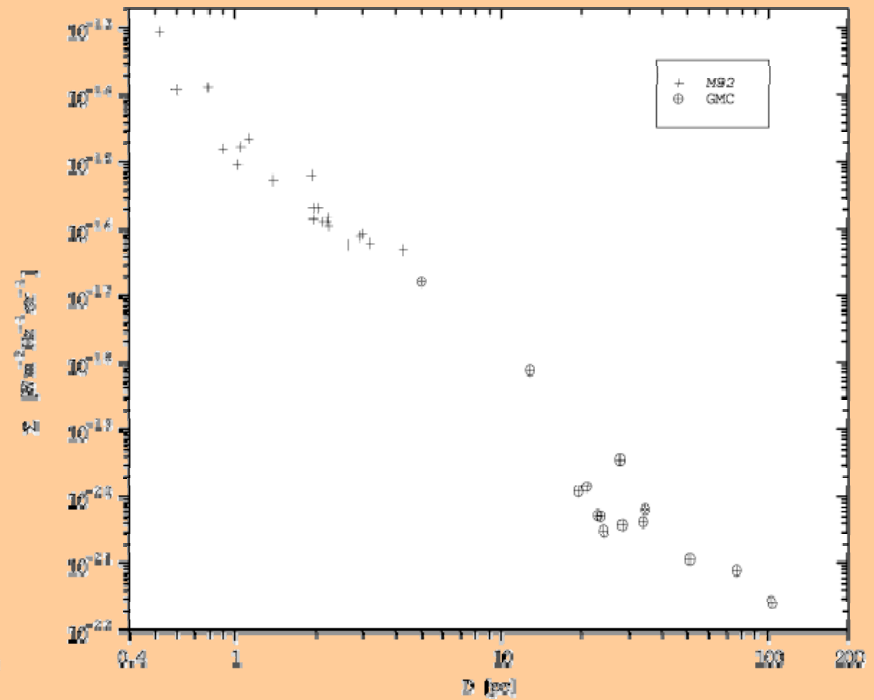
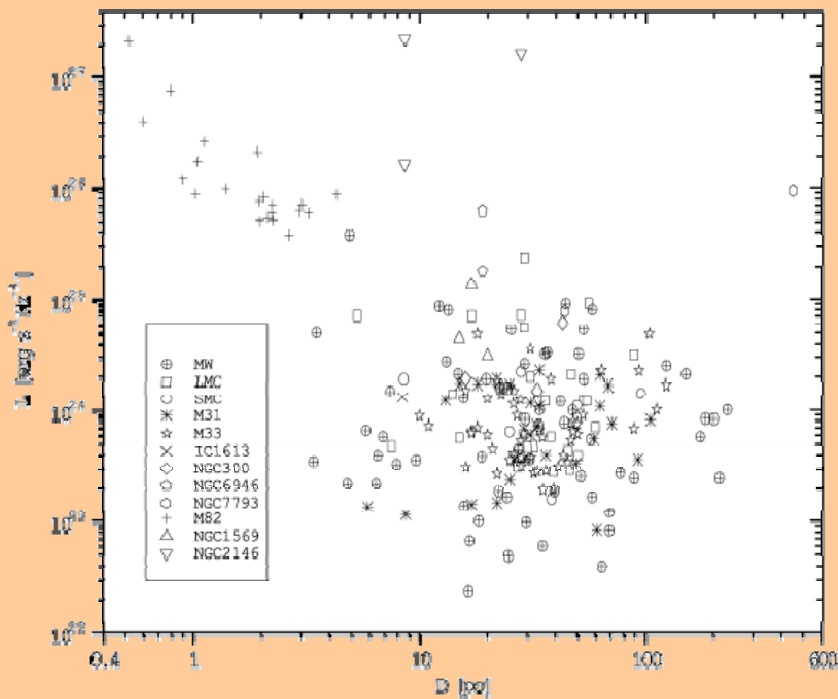
Urošević et al. (2005)

$L - D$ korelacija:

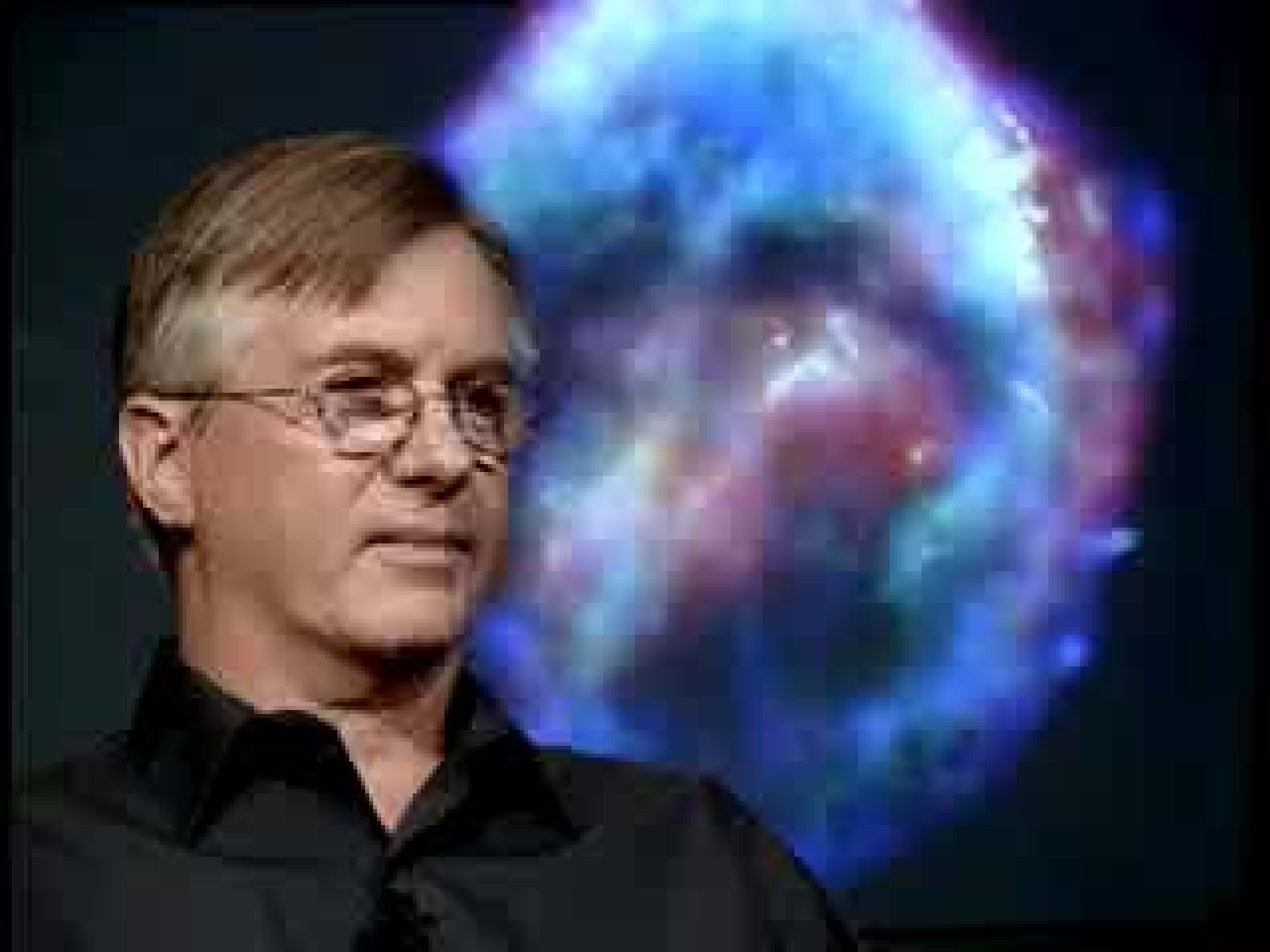
$$\Sigma_v \propto S_v \theta^{-2} \propto L_v D^{-2}$$



- statistička studija: Arbutina et al. (2004)
- M82 (Huang et al. 1994) i GMC SNRs (Huang & Thaddeus 1985)
- potreba za klasifikacijom (diferencijacijom)
- *multiwavelength observations*



Arbutina et al. (2004)



OPTIČKA I X POSMATRANJA OSTATAKA SUPERNOVA

Optička posmatranja:

- Ostaci u Magelanovim oblacima: [Mathewson et al. \(1983\)](#)

- optička klasifikacija-četiri klase:

1. *Balmer-dominated (4+3) – $H\alpha$*
2. *oxygen-rich (2+3) – O*
3. *plerionic/composite*
4. *evolved*

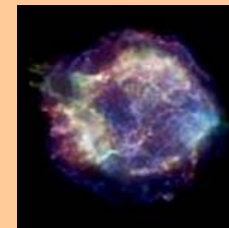
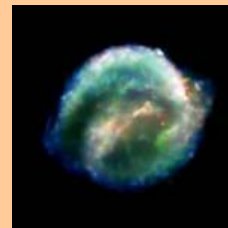
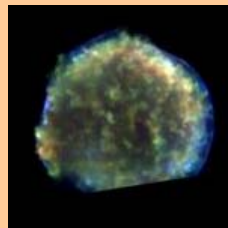
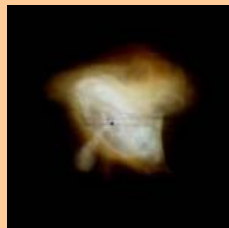
- *Hubble Space Telescope*



IC posmatranja: *Spitzer*

X posmatranja:

- *Einstein, ROSAT, ASCA, Chandra, XMM-Newton*

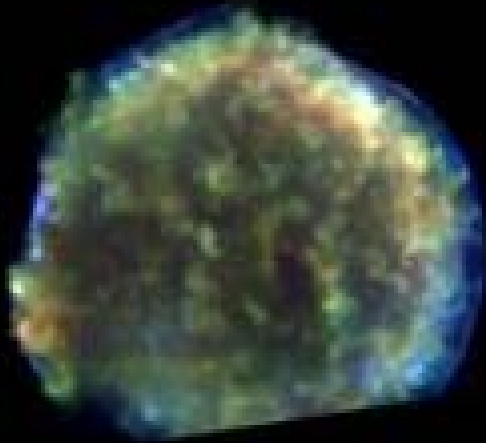




Crab



Cas A



Tycho



Kepler

VEZA SUPERNOVA – OSTATAK SUPERNOVE

- Na osnovu optičke klasifikacije: [van den Bergh \(1988\)](#)

1. *SN Ia* \Rightarrow *Balmer-dominated SNR*
2. *SN Ib* \Rightarrow *oxygen-rich SNR*
3. *SN II* \Rightarrow *plerionic/composite SNR*



- *Balmer-dominated* - high velocity, nonradiative, collisionless shocks, ISM
Tycho, Kepler, SN1006, +LMC(4) +SMC(1)

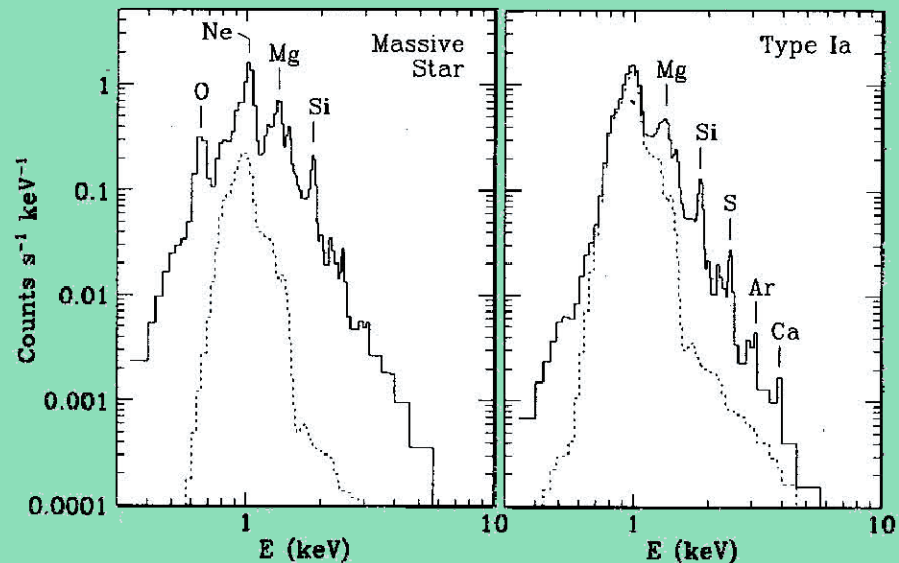
- *oxygen-rich* – CSM, HII, mol. clouds

Cas A, Pup A, G292.0+1.8, +LMC(2) +SMC(1)+NGC 4449(1)

- X posmatranja: trag eksplozije SN

- *SN Ia*: **LMC (1)**
- *SN Ib*, *oxygen-rich*: **SMC(1)**

(Hughes et al. 1995)



$\Sigma - D$ relacija:

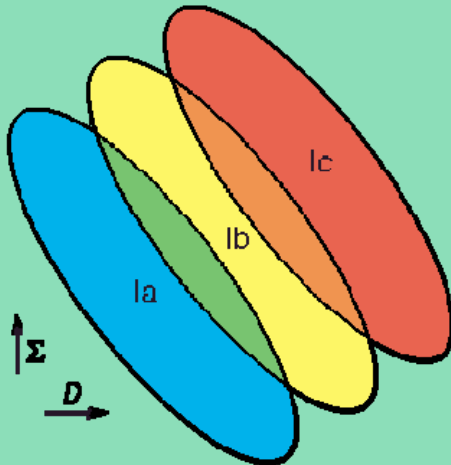
- parametri: $M_o = 1 - 10 M_\odot$
 $E_o = 10^{51} (10^{52}) \text{ ergs}$
 $\rho_o = 10^{-3} - 10^3 \text{ g cm}^{-3}$



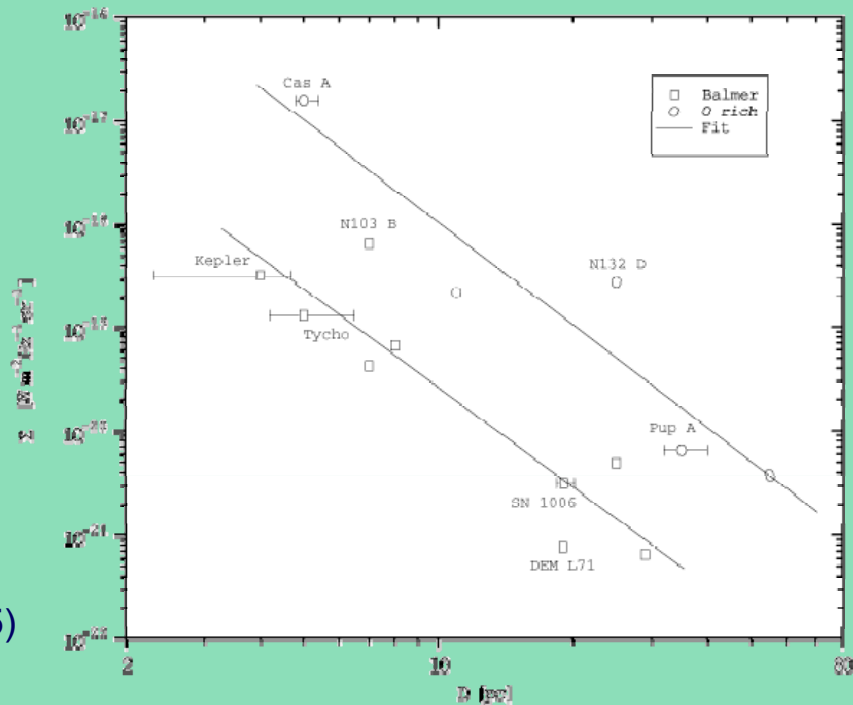
- značaj gustine ISM (CSM):
veća gustina \Rightarrow masivnije zvezde \Rightarrow SN Ib (II) \Rightarrow oxygen-rich (Ib) ostaci (6)
manja gustina \Rightarrow zvezde manje mase \Rightarrow SN Ia \Rightarrow Balmer-dominated (Ia) ostaci (9)

(4. SN Ic \Rightarrow HNR)

- studija Balmer-dominated ostataka:
 Tuohy et al. (1982)



(Arbutina & Urošević 2005)



PREDLOG:

- Ostaci u retkoj sredini – bolji uzorak (*high-z*, *loops*, *la*)
- Ostaci u gustoj sredini – *lb* (M81, M82, M83)
- *la* i *lb* ostaci – teorija sinhrotronskog mehanizma i radio evolucija



LITERATURA

(za čitanje)

Chevalier R.A., 1977, ARA&A, **15**, 175

Woosley S.E., Weaver T.A., 1986, ARA&A, **24**, 205

Weiler K.W., Sramek R.A., 1988, ARA&A, **26**, 295

van den Bergh S., Tammann G.A., 1991, ARA&A, **29**, 363

Filippenko A.V., 1997, ARA&A, **35**, 309







SEMINAR KATEDRE ZA ASTRONOMIJU
15.03.2005.

Bojan Arbutina

Evolucija ostataka supernova i veza supernova – ostatak supernove

Deo korišćenog materijala preuzet je sa:

<http://chandra.harvard.edu>



Smithsonian

CXC



KONTAKT:

barbutina@aob.bg.ac.yu

<http://www.aob.bg.ac.yu/~barbutina>