ANALISI DI SEGNALI DI NEUTRINO DALLA SN1987A

Pagliaroli Giulia

In collaborazione con M.L.Costantini, A.Ianni e F.Vissani

IFAE 2007 NAPOLI

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- Collapse Model and neutrino emission
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The SN1987A

February 23,1987

LSD
Scintillator
0.09Kt
UT = 2:52:37
5 events

BAKSAN
Scintillator
0.2Kt
UT = 7:36:06
5 events

IMB
Water
Cerenkov
6.8Kt
UT = 7:35:41
8 events

KII
Water
Cerenkov
2.14Kt
UT = 7:35:35
12+4 events

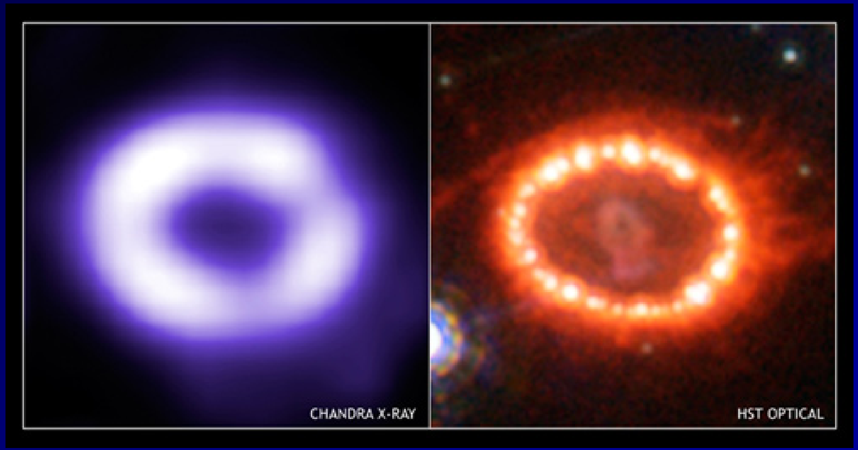
The SN1987A

SN1987A Progenitor :
Sanduleak -69°202
Blue Giant in the Large Magellanic Cloud

$D \cong 50 Kpc \qquad M \approx 20 M_{\odot}$

SN1987A Slam:
Generates Ring-shaned Remnant

SN1987A Remnant:
Core of Supernova Goes Missing

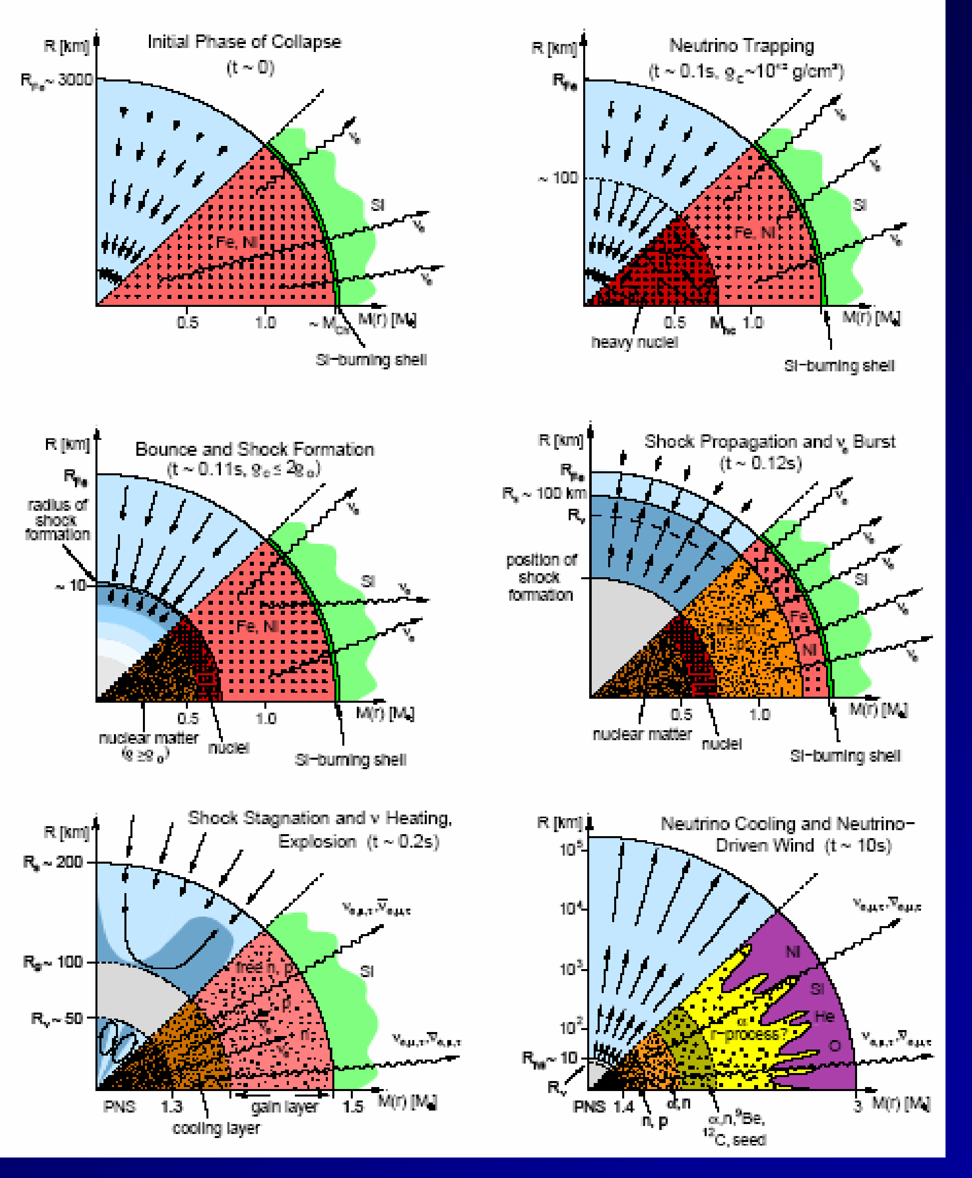


Standard Core Collapse SN

1. Collapse
2. Bounce
3. Shock Propagation
4. Shock Stagnation
5. Accretion ➡ 10%
6. Cooling PNS ➡ 90%

$$N_\nu \approx 10^{58}$$

$$< E_\nu >= 10 - 20 MeV$$



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The Neutrino Events

DATA

$$t_1, t_2, \ldots, t_{N_{ev}}$$
$$\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_{N_{ev}}$$
$$\delta\varepsilon_1, \delta\varepsilon_2, \ldots, \delta\varepsilon_{N_{ev}}$$

$N_{ev} = 29$ ⇒

KII + IMB + BAKSAN

Detector Efficiency Functions

$$\eta(\varepsilon)$$

Background Spectrum Rate

$$B(\varepsilon)$$

ASSUMPTIONS

Standard Collapse {
- Non-rotating star
- Spherically symmetric

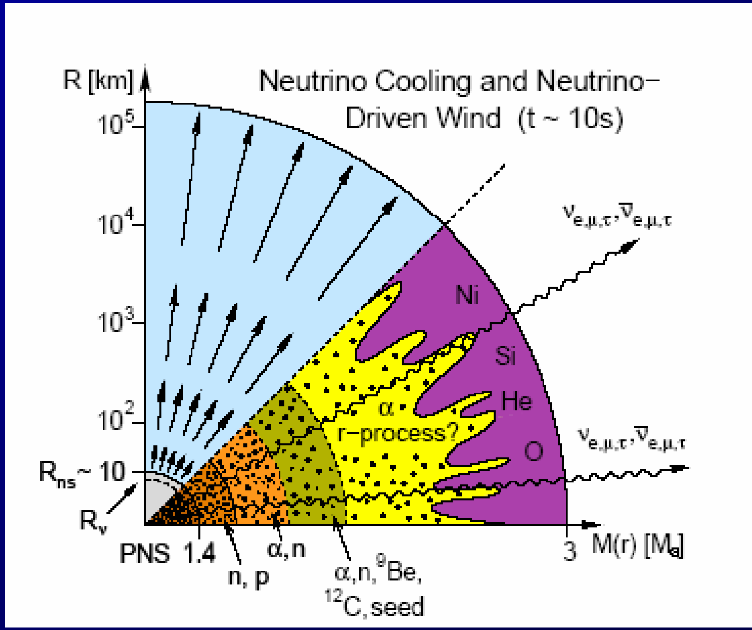
⇒ Isotropic neutrino emission

$$p_n = \frac{\bar{n}^n}{n!} e^{-\bar{n}}$$

$\bar{\nu}_e + p \rightarrow e^+ + n$ ***(IBD)***

$$R(E_\nu, t) = \sigma_{\nu p}(E_\nu) N_b \Phi_{\nu_e}(E_\nu, t)$$

Emission Model: Cooling



$$\Phi^0_{\bar{\nu}_e}(E_\nu, t^{em}) \propto R_C^{\,2} f_{FD}(E_\nu, T(t^{em}))$$

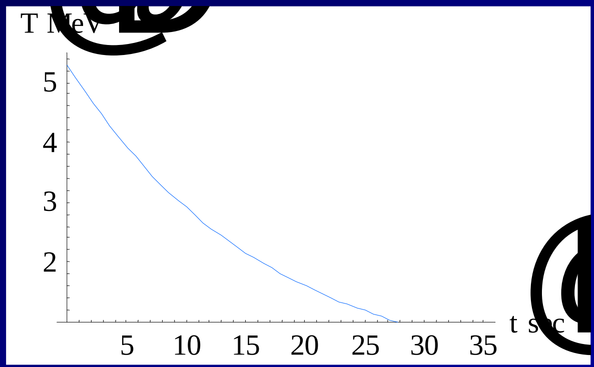
Neutrinosphere Radius

Thermal Phase Emission

$$\Phi_{\bar{\nu}_e}(E_\nu, t^{em}) = P_{ee}\Phi^0_{\bar{\nu}_e}(E_\nu, t^{em}) + (1 - P_{ee})\Phi^0_{\bar{\nu}_\mu}(E_\nu, t^{em})$$

$$P_{ee} = cos^2(\vartheta_{12})$$

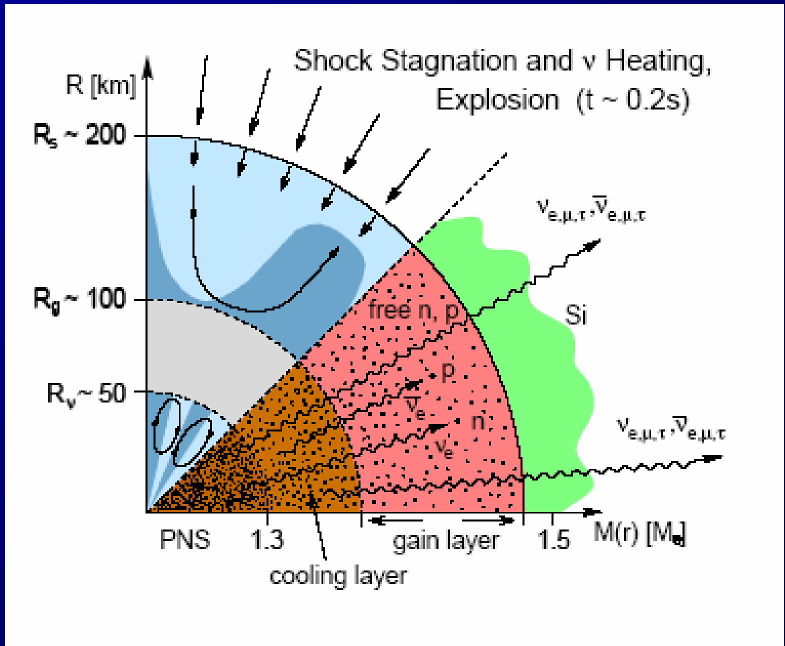
$$T(t^{em}) = T_C e^{-\frac{t^{em}}{4\tau_C}}$$



Model Parameters

$$R_C \quad T_C \quad \tau_C + 3 \cdot t^{off} \Rightarrow \boxed{6}$$

Emission Model: Accretion



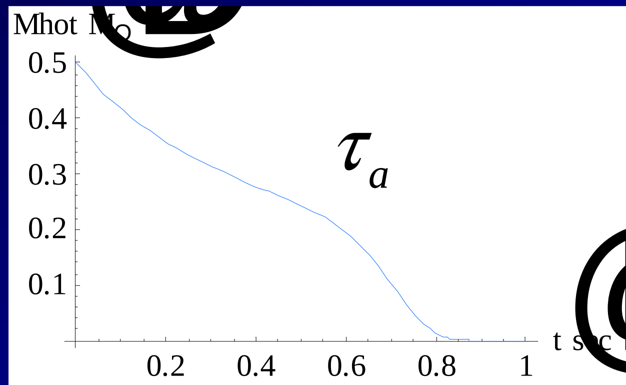
$$n + e^{+} \rightarrow p + \overline{\nu}_e$$

Non thermal spectrum

$$\Phi_{\overline{\nu}_e}(E_\nu, t^{em}) \propto M_{hot}(t^{em}) \frac{E_\nu^{\;4}}{1 + e^{\left(\frac{E_\nu}{T_a}\right)}}$$

$$M_{hot}(t^{em}) = M_{MAX} \cdot g(t^{em})$$

$0.5 M_{\odot}$



τ_a

New Model Parameters

$$\tau_a \quad T_a$$

Total Parameters

6+2

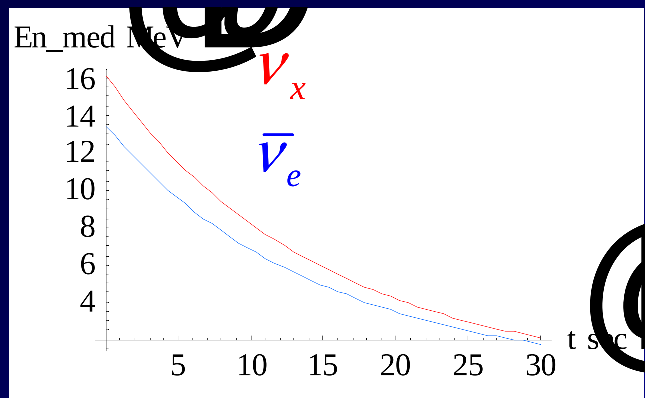
Cooling Results

COOLING + OSCILLATIONS ➡ ***EQUIPARTITION +*** $T_C^{\bar{\nu}_x} = 1.2 \cdot T_C^{\bar{\nu}_e}$

$T_C\,(MeV)$	$R_C\,(km)$	$\tau_C\,(\mathrm{sec})$	t_{KII}^{off}	t_{IMB}^{off}	t_{BAK}^{off}
$4.26_{-0.91}^{+1.26}$	31_{-16}^{+32}	$3.69_{-1.57}^{+2.42}$	$0.^{+0.89}$	$0.^{+0.44}$	$(2\cdot 10^{-6})^{+4.5}$

$$< E_{\bar{\nu}_x} >= 12.1 MeV$$

$$< E_{\bar{\nu}_e} >= 10.1 MeV$$



$$E_b = 3.87 \cdot 10^{53} erg$$

Cooling + Accretion Results

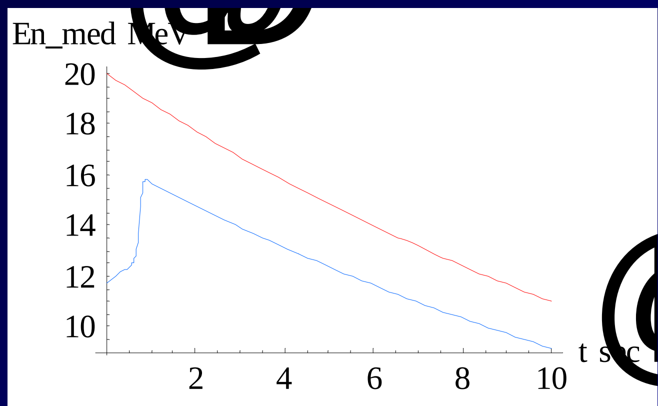
COOLING + OSCILLATIONS + ACCRETION ➡ ***EQUIPARTITION*** **+** $T_C^{\bar{\nu}_x} = 1.2 \cdot T_C^{\bar{\nu}_e}$

T_C (MeV)	R_C (km)	τ_C (sec)	T_a (MeV)	τ_a (sec)	t^{off}_{KII}	t^{off}_{IMB}	t^{off}_{BAK}
$5.29^{+2.14}_{-1.38}$	$12.6^{+18}_{-7.7}$	$4.18^{+3.6}_{-1.88}$	$2.03^{+0.22}_{-1.37}$	$0.73^{+1.35}_{-0.29}$	$0.^{+0.17}$	$0.^{+0.69}$	$0.^{+0.59}$

$< E_{\bar{\nu}_e} >^{accr} = 10.3 MeV$

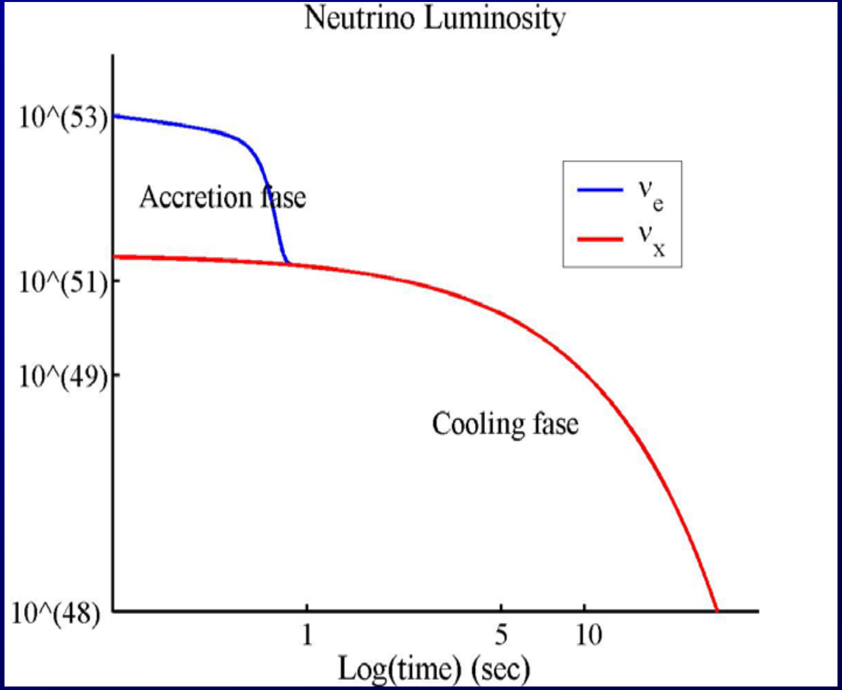
$< E_{\bar{\nu}_e} >^{cool} = 12.6 MeV$

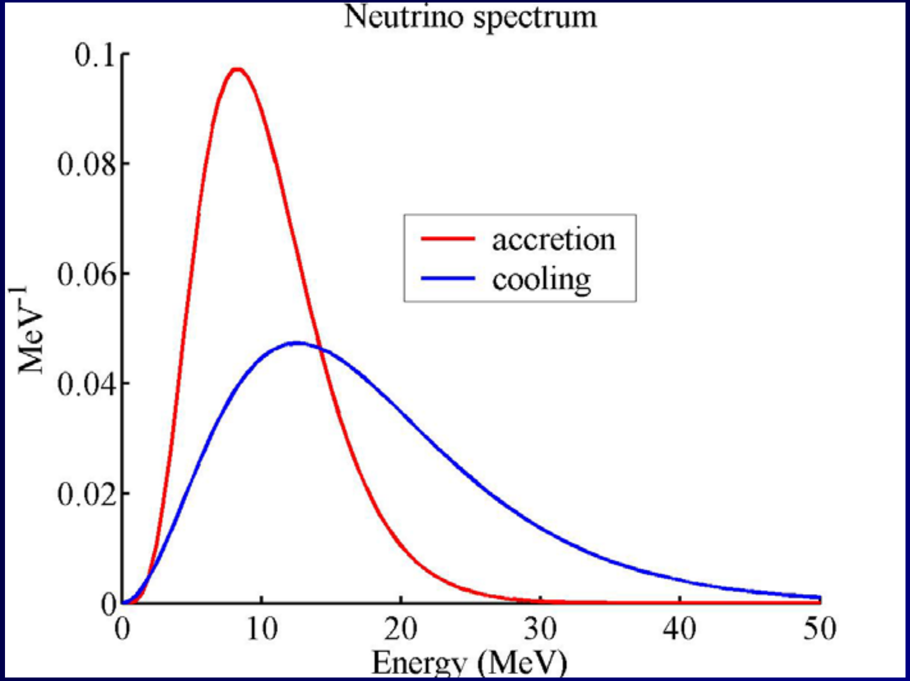
$< E_{\bar{\nu}_x} > = 15.1 MeV$



$E_b^{accr} = 6.3 \cdot 10^{52} erg$ **+** $E_b^{cool} = 1.76 \cdot 10^{53} erg$ **=** $E_b = 2.4 \cdot 10^{53} erg$

Results





LIKELIHOOD RATIO TEST

$$LR = \frac{L^{cool}}{L^{accr+cool}} = 0.0011 \Rightarrow \quad \alpha = 0.9989 \; > 3\sigma$$

Discussion

ANALYSIS UPGRADES:

- *New cross section for IBD*
- *Modified Likelihood*
- *Neutrino oscillations*

↓

- ***AGREEMENT WITH LAMB & LOREDO***
- ***ACCRETION PHASE EVIDENCE***
- ***ACCRETION ENERGY*** $E_b^{accr} = 26\% E_b$

Referenze

- Janka et al. astro-ph/0612072
- Lamb & Loredo PRD65,063002
- Koshiba et al. PRD38,2
- Strumia & Vissani PLB564,42-54
- Alexeyev et al. PLB205,2