Neutrinos from SN1987A: temperature models for two neutrinos bursts

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SN1987A

SN1987A - characteristics

What is this?

SN → Type II supernovae → Core Collapses

February 23rd, 1987.

Luminosity ~10^8 $L_\odot$ ($L_\odot$ ~3.9×10^{33} ergs/s)

Distance ~ 50Mpc ~168000 light years

Progenitor: Sanduleak -69°202 (SK -69°202).

Arnett et al. 1989; Parthasarathy et al. 2006, Fransson et al. 2007.

SN1987A - Motivation

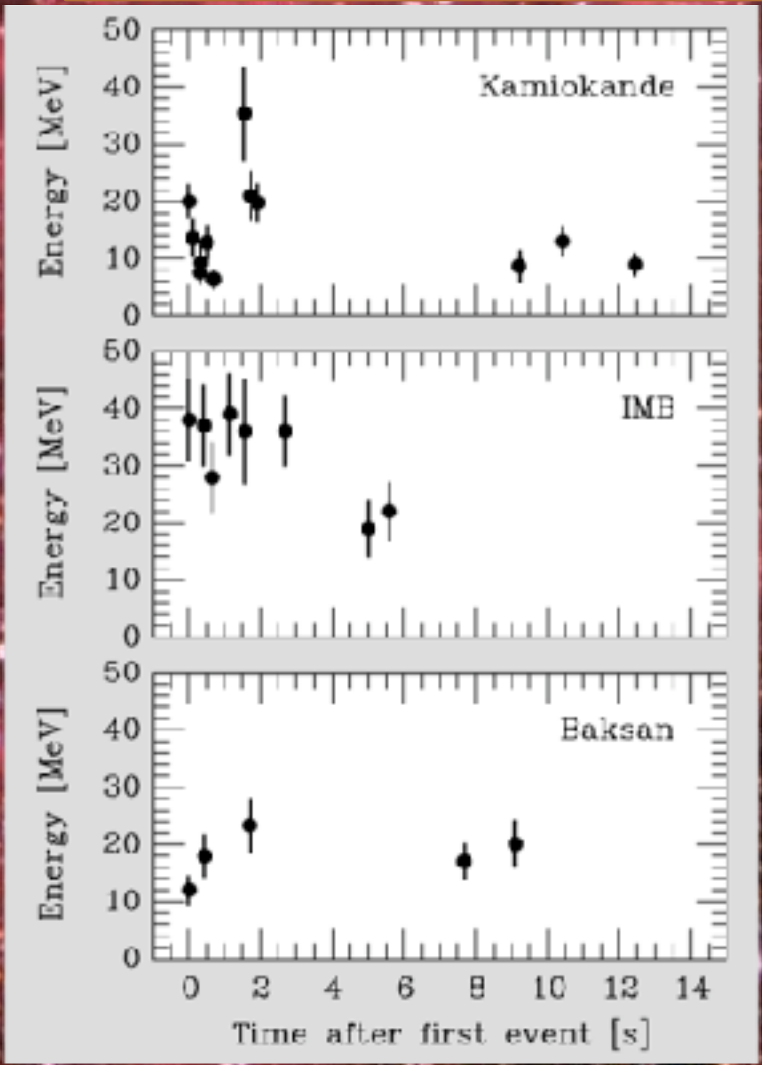
The scenario with two temperatures burst was proposed by Benvenuto and Horvath 1989 (Phys. Rev. Let., vol 63, no. 7, 1989).

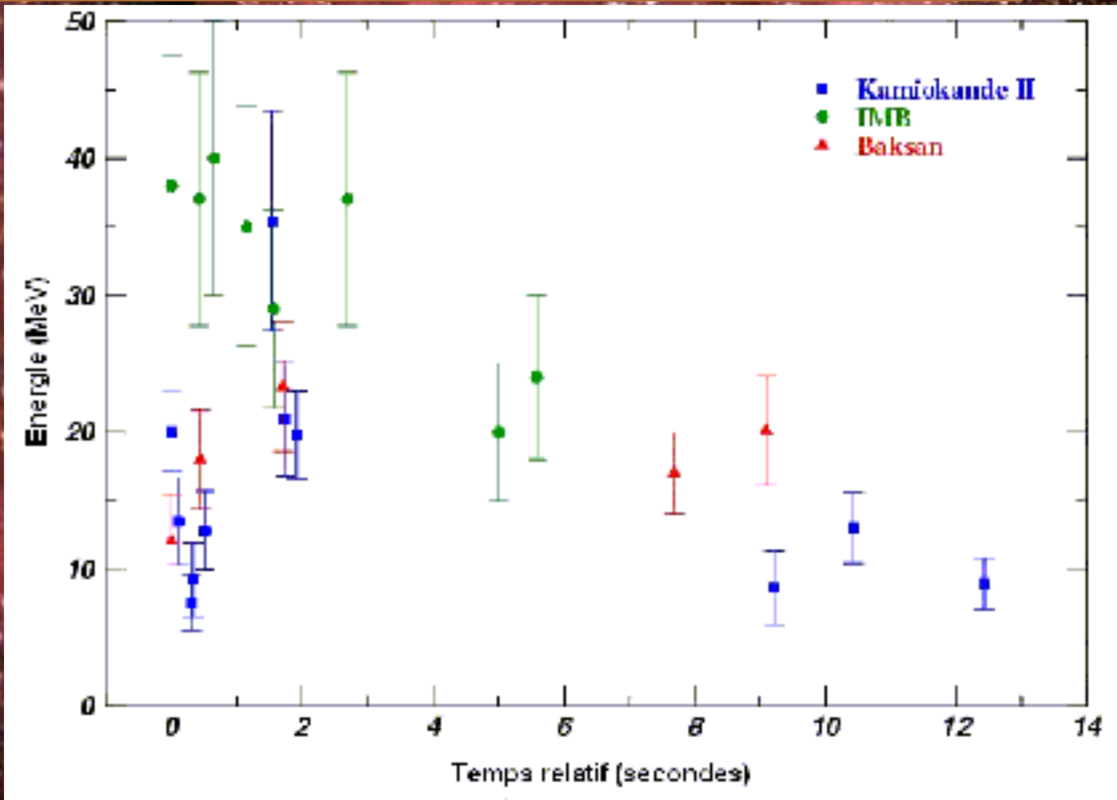
Two temperatures the idea is:

Conversion to SQM follows the “normal” burst!

$e^{-} + e^{+} \rightarrow v_e +$ anti - v_e – carry the binding energy and both cases!

Neutrinos from Supernovae





One or two bursts?

SN1987A - Bayes' Theorem for the Analysis of the neutrinos burst(s)

Bayes' theorem

$$P(M_i|D) = \frac{P(D|\theta, M_i)P(\theta_i|M_i)}{P(D)}.$$

Likelihood

Prior distribution

Posteriori distribution

Loredo & Lamb 2001, Valentim et al. 2011.

SNA1987A - Likelihood

- The likelihood function is built through this principle:

$$L(\theta|D,M) = \left[\prod_i^N p(m_i|D,M)\right] \prod_j p(m_j|D,M).$$

Likelihood

What it measured!

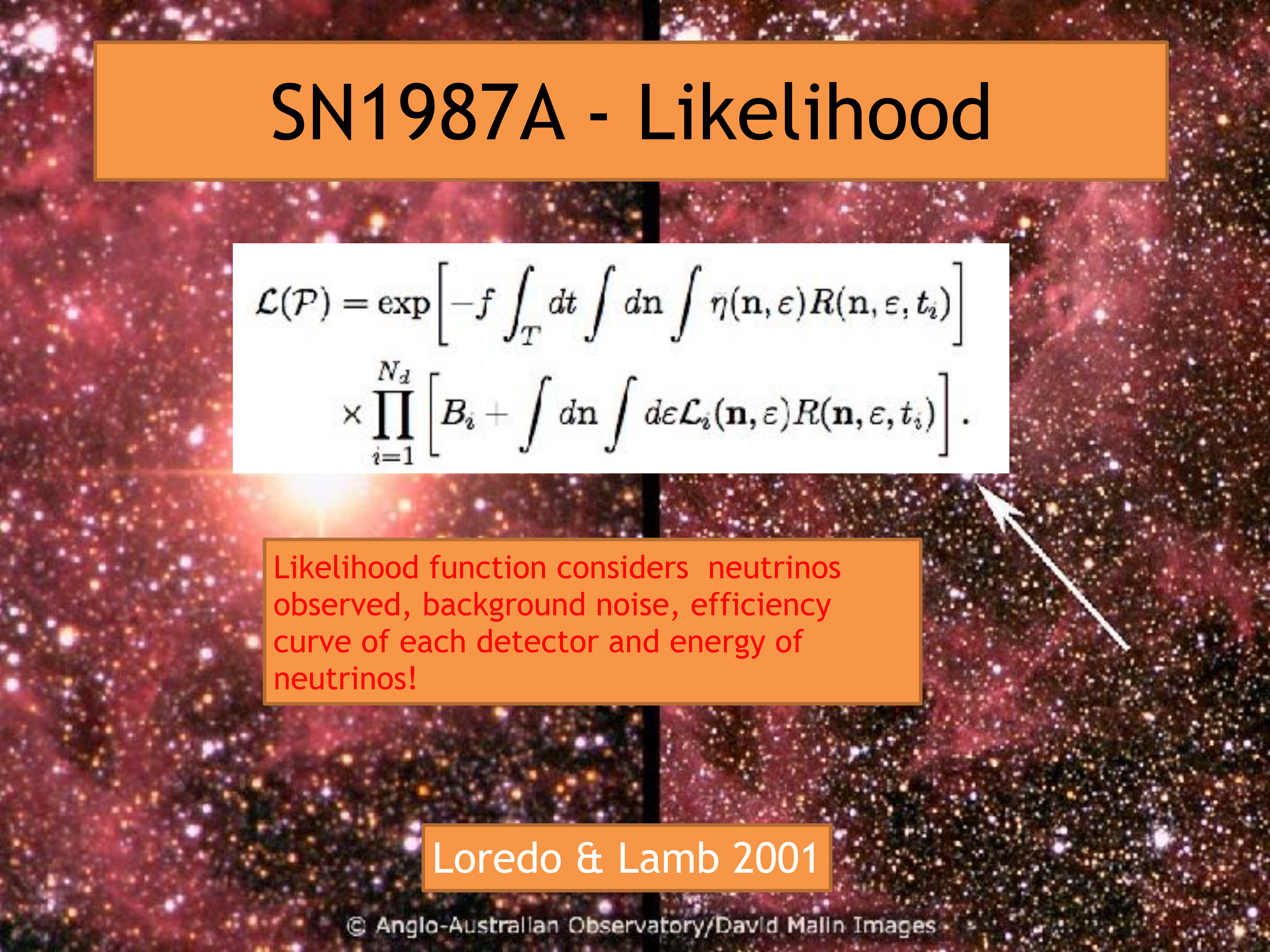
What it is expected to be measured!

SN1987A - Likelihood

$$\mathcal{L}(\mathcal{P}) = \exp\left[-f\int_T dt \int d\mathbf{n} \int \eta(\mathbf{n},\varepsilon) R(\mathbf{n},\varepsilon,t_i)\right] \times \prod_{i=1}^{N_d}\left[B_i + \int d\mathbf{n}\int d\varepsilon \mathcal{L}_i(\mathbf{n},\varepsilon) R(\mathbf{n},\varepsilon,t_i)\right].$$

Likelihood function considers neutrinos observed, background noise, efficiency curve of each detector and energy of neutrinos!

Loredo & Lamb 2001



SN1987A -Bayesian tools for analysis

Bayesian Information Criterion (BIC)

$$\ln B_{ij} = \ln\left[\mathcal{L}_i(\theta,\phi)/\mathcal{L}_j(\theta)\right] - \frac{1}{2} m_\phi \ln N.$$

- **Interpretation of Bayes Factor**

$\ln(B_{ij})$	B_{ij}	Evidence against H_j
0 to 1	1 to 3	Not worth more than a bare mention
1 to 3	3 to 20	Positive
3 to 5	20 to 150	Strong
> 5	> 150	Very Strong

Models of neutrinos' bursts

Two uniform temperatures (TUT)

Max. Likehood Parameter: 7.28071e-65;
alpha 1.50 .
Radius of neutrinosphere 15km;
T1 3.30 MeV —> first burst;
T2 0.33 MeV —> second burst;
Tp 3.00s temporal gap between peaks.
Percentage amplitude between the two peaks is: 10%;
Tau 1 0.10s —> time duration of the first peak;
Tau 2 28.00s —> time duration of the second peak.

Models of neutrinos' bursts

Two exponential temperatures (TEXT)

Max Likehood Parameter:1.30737e-53;
alpha 2.90.
Radius of neutrinosphere 29km;
T1 3.90 MeV —> first burst;
T2 3.12 MeV —> second burst;
Tp 5.00s temporal gap between peaks.
Percentage amplitude between the two peaks is: 80%;
Tau 1 9.10s —> time duration of the first peak;
Tau 2 20.10s —> time duration of the second peak.

Models of neutrinos' bursts

Two step temperatures (TST)

Max Likehood Parameter: 1.85255e-52;

alpha 3.10.

Radius of neutrinosphere 31km;

T1 3.60 MeV —> first burst;

T2 2.52 MeV —> second burst;

Tp 4.50s temporal gap between peaks.

Percentage amplitude between the two peaks: 70%;

Tau 1 2.70s —> time duration of the first peak;

Tau 2 8.00s —> time duration of the second peak.

Results

Bayesian Information Criterion

Model	Likelihood	BIC Models comparative	Analysis
TUT	7.28071e-65	TEXT/TUT = 25.91381	*strong evidence in favor*
TEXT	1.30737e-53	TST/TUT = 28.56494	*strong evidence in favor*
TST	1.85255e-52	TST/TEXT = 2.651131	*weak evidence in favor*

SN1987A - Conclusions and Perspectives

- Improving this model.
- Suggesting new models!
- Using new statistical tools!
- Detections of new neutrinos from SNe on DUNE, IceCube, etc.

SN1987A - Acknowledgements

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We would like to invite!

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