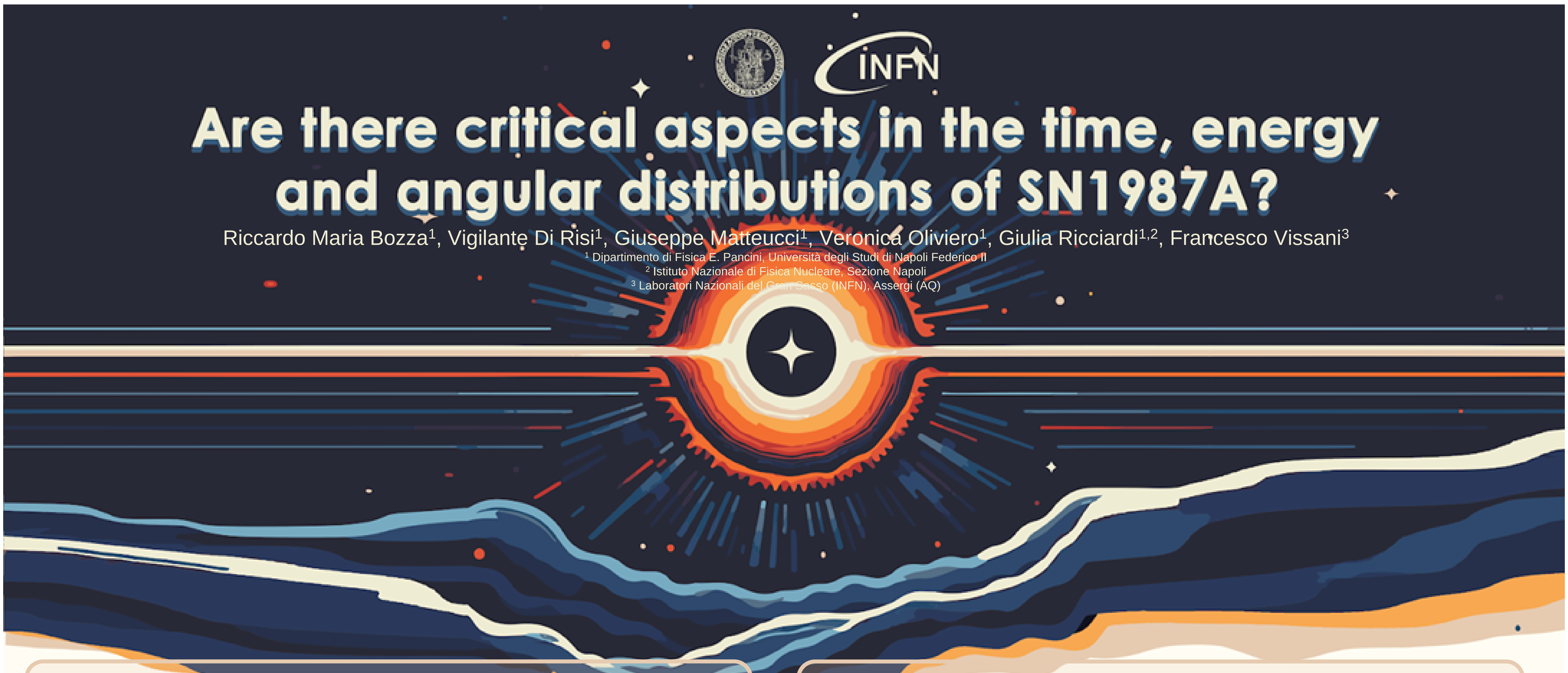

Are there critical aspects in the time, energy and angular distributions of SN1987A?

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Study of SN1987A reveals secrets of the cosmos

Supernova 1987A (SN1987A) is a type II event that occurred in 1987 in the Large Magellanic Cloud, at 168,000 light years from Earth.

The associated neutrino emission was observed: three experiments, Kamiokande-II, IMB and Baksan, detected a total of 29 events in a time span of about 30 seconds. This provided general support for theoretical expectations, which predict neutrinos as the main source of energy release in a core-collapse supernova event.

SN1987A continues to be a key object of study, as it is the only such phenomenon observed to date.

In this analysis, we analyse SN1987A data with the help of a new and more accurate modelling of the neutrino flux, which includes parameters describing the physics of the event.

SN1987A viewed by the James Webb Space Telescope NIRCam.

The new analysis

A recently proposed model [Symmetry 2021, 13(10), 1851] describes the time- and energy-dependent flow of anti-neutron electrons by including its two main components: accretion and cooling. The former is an initial volume and very bright phase due to positron-neutron interactions around the nascent neutron star; the latter is a surface emission.

We calculated the differential interaction rate for Kamiokande-II, Baksan and IMB, also taking the background into account.

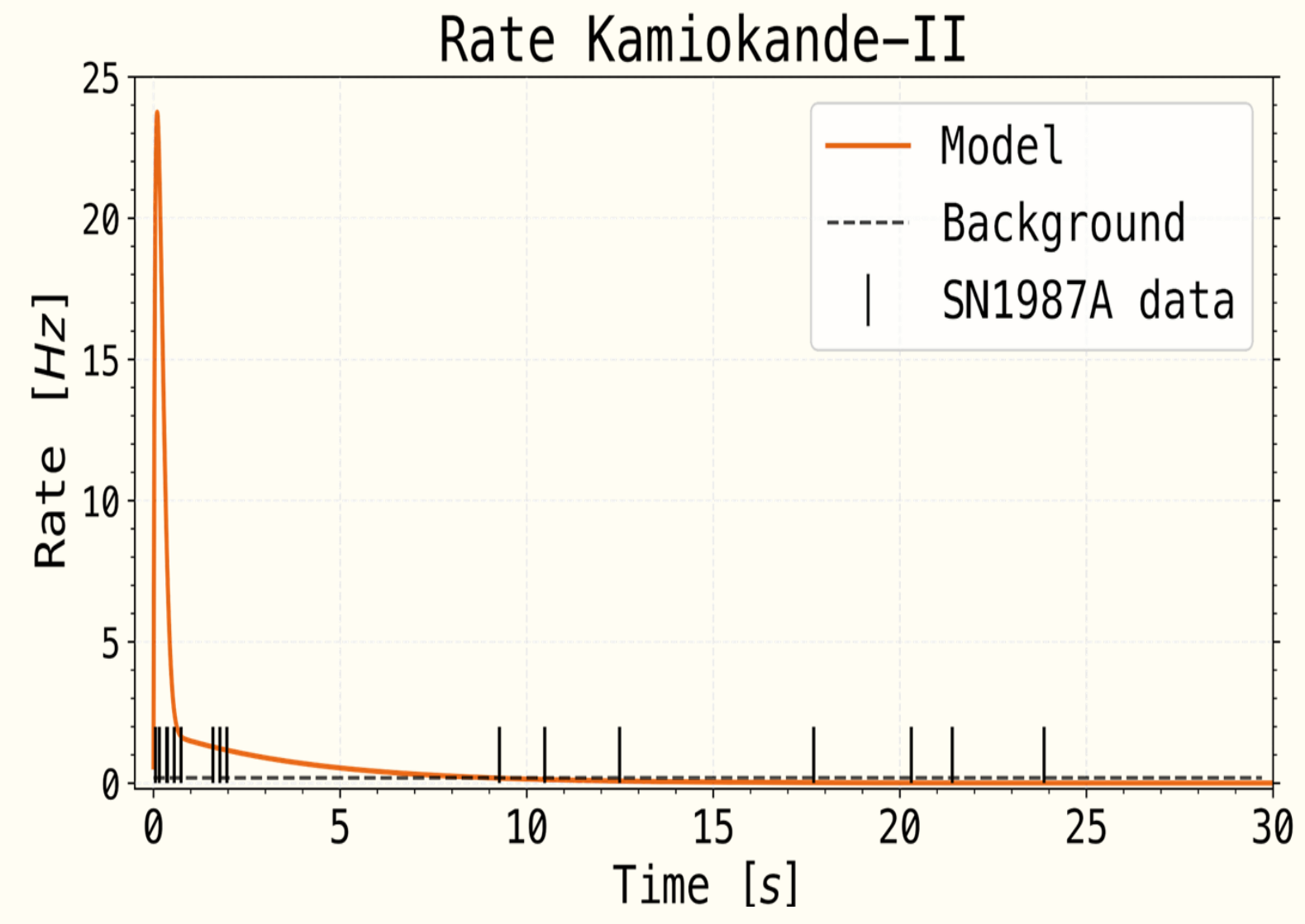
In this poster, we present the first two steps of our analysis:

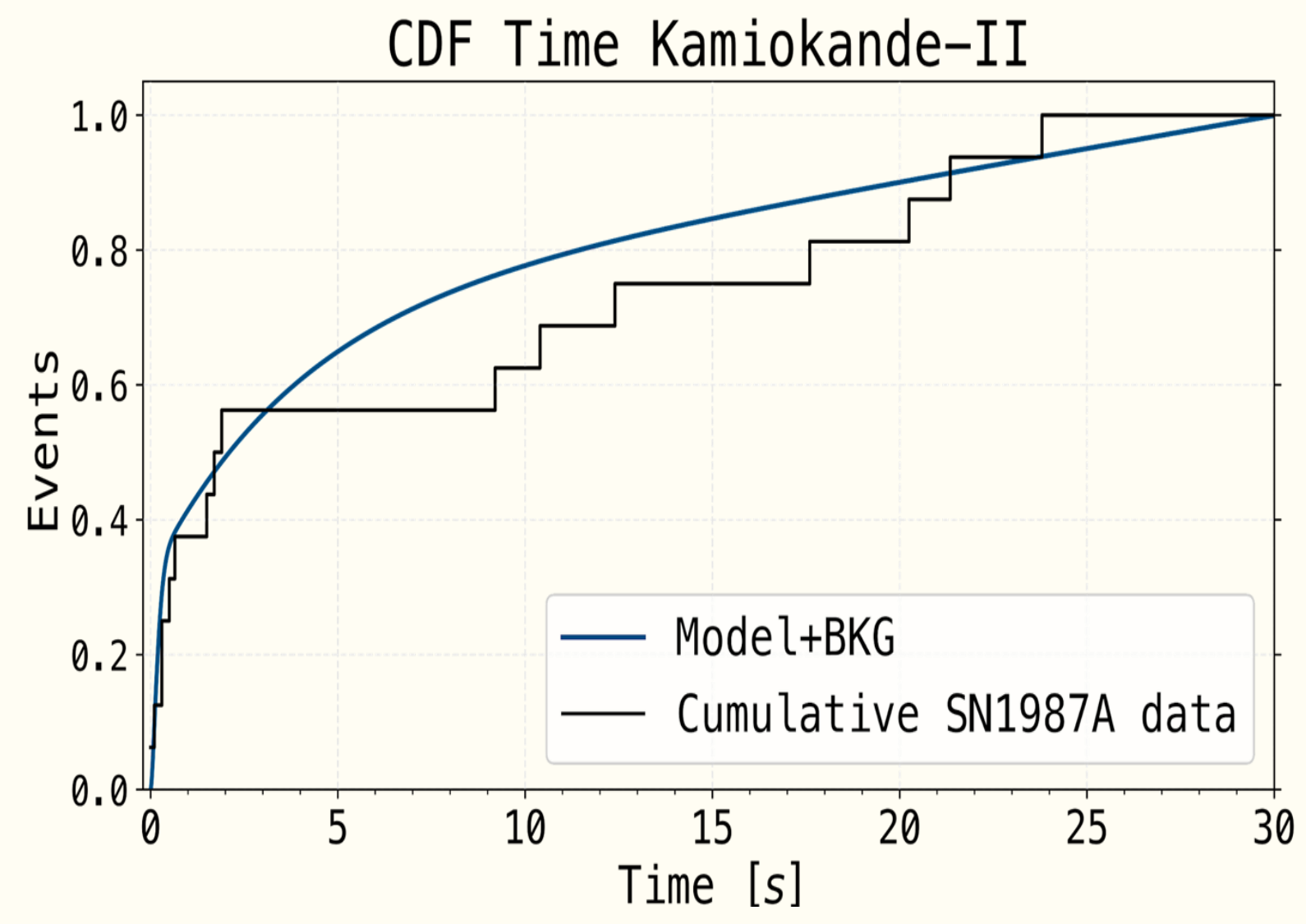
1) Verification of the goodness of fit of the model: reference values for the parameters were chosen in accordance with the literature and Cramer's g.o.f. test was performed on the data.

2) Best-fit analysis: to assess the most likely parameters of our model and their ranges, we maximised the likelihood function, both for the single experiment and by combining all experiments.

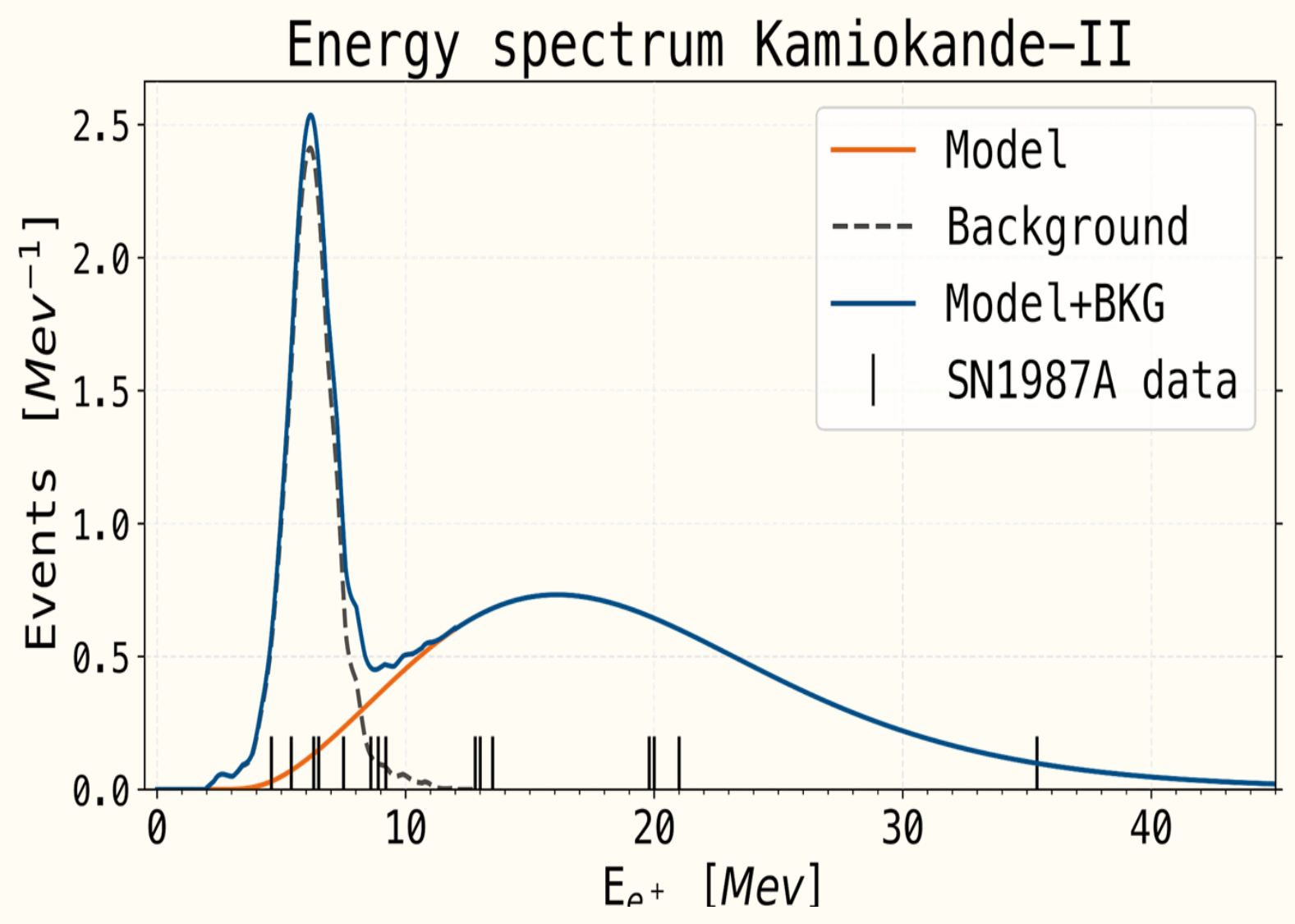
The Data and the New Model

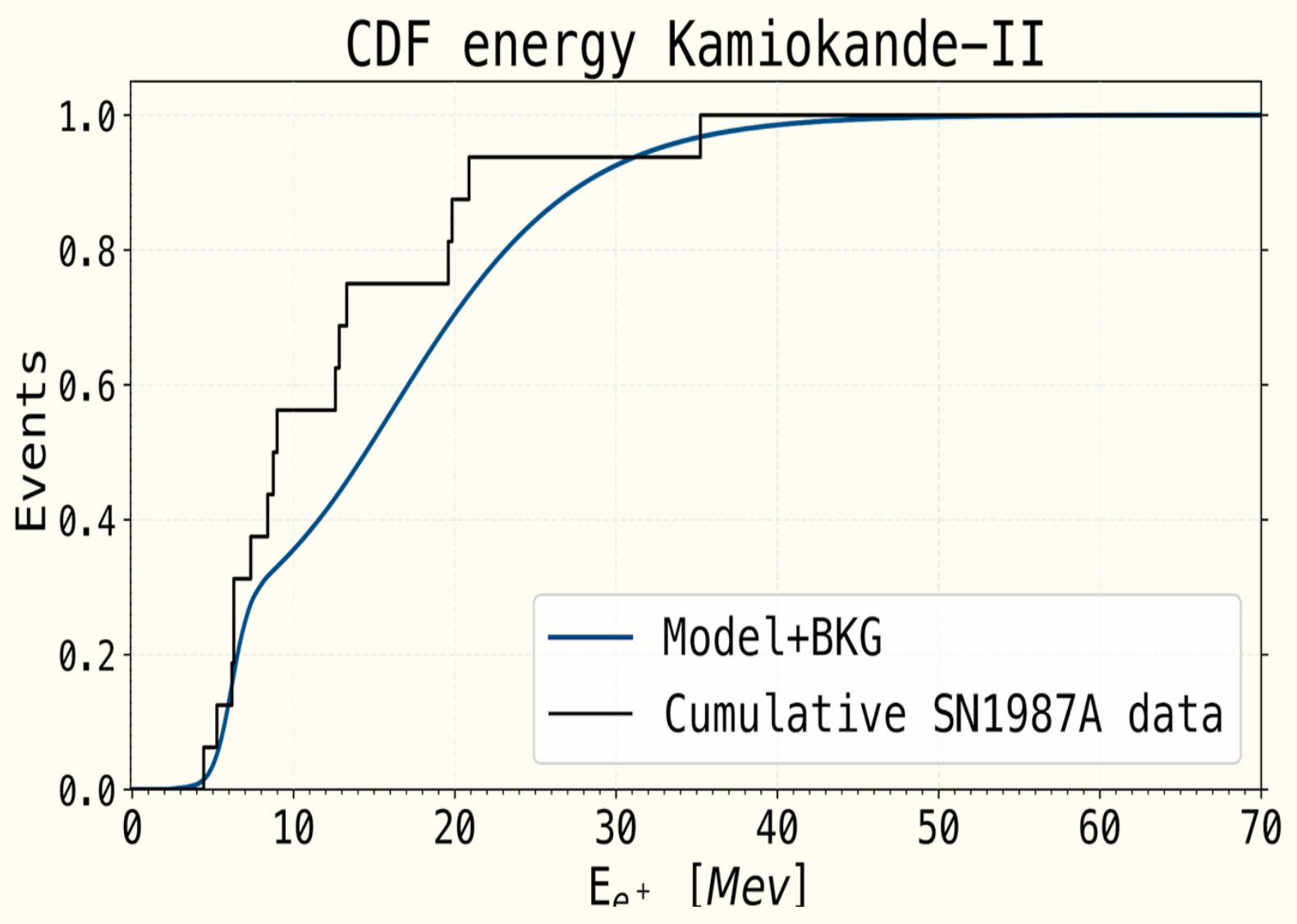
TIME



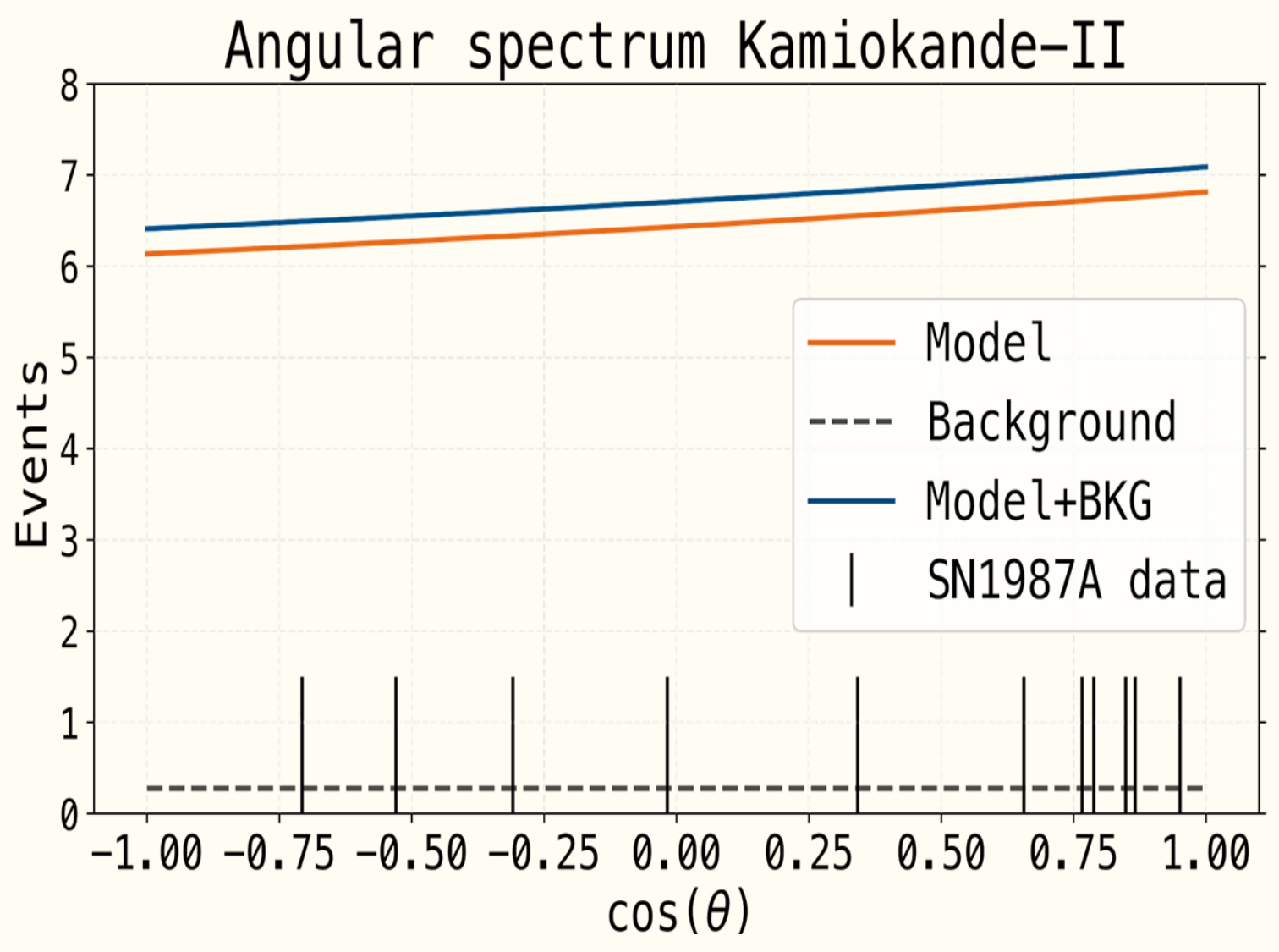


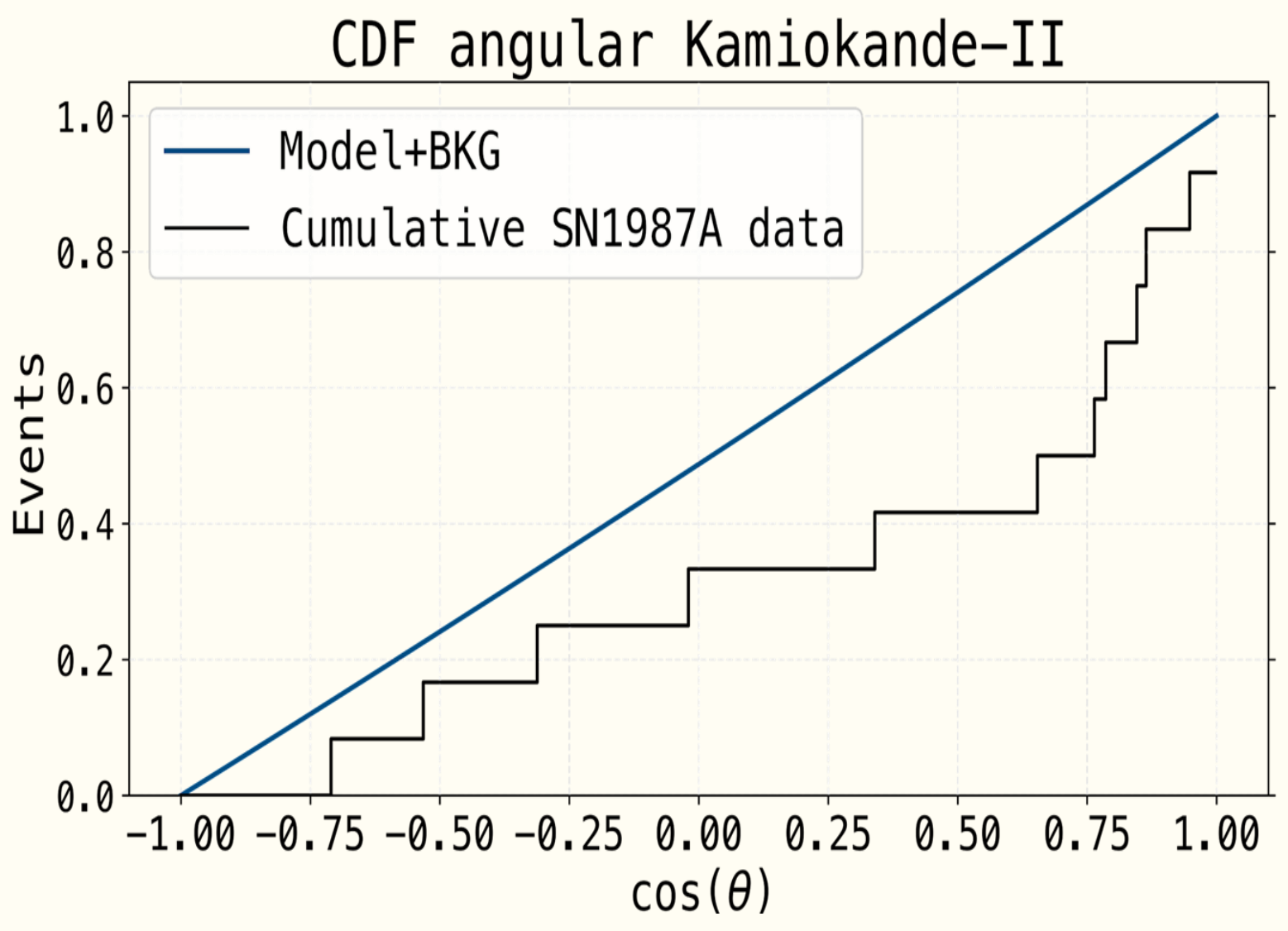
ENERGY





ANGLE





G.O.F

GOODNESS OF FIT - CRAMER TEST

Benchmark parameters used to evaluate g.o.f. and the test results are reported in the box below.

Benchmark parameters

Accretion time = 0.3 s
Cooling time = 5.0 s
Neutron star radius = 12 km
Signal rise time = 0.1 s
Temperature scale = 5.0 MeV

p-values	Kamiokande-II	Baksan	IMB
Rate	Cramer: 46%	Cramer: 83%	Cramer: 44%
Energy	Cramer: 17%	Cramer: 55%	Cramer: 17 %
Angle	Cramer: 8%	N/A	Cramer: 9 %

Result of the Best Fit Analysis

Likelihood Maximization results

	tau_a [s]	tau_c [s]	T0 [MeV]	Rns [km]	Csi_0	t_0 [s]	t_{delay} Kamiokande-II [s]	t_{delay} IMB [s]	t_{delay} Baksan [s]
Value and Uncertainty	**0.51 +/- 0.15**	**5.5 +/-1.3**	**4.5 +/-0.5**	**18 +/- 7**	**0.02 +/- 0.02**	**0.10 +/- 0.06**	**0.00 +/- 0.02**	**0.00 +/- 0.02**	**0.00 +/- 0.03**

Conclusions & Next Steps

The agreement with the **temporal** and **energy** distributions of the model is **excellent**; that with the **angular** distributions not excellent, but **acceptable**. We conclude that our model can effectively describe an **anti-neutrino burst** from a **core-collapse supernova**. Proceeding and **maximising** the combined probability of all experiments yields parameter estimates whose values are consistent with the expectations of the theory. The next steps in this analysis are as follows.

- Estimating confidence interval and correlations.
- Investigate the delay times of experiments.
- Use the model to derive predictions with uncertainty intervals based on SN1987A.

Image Credit: NASA, ESA, CSA, M. Matsuura (Cardiff University), R. Arendt (NASA's Goddard Spaceflight Center & University of Maryland, Baltimore County), C. Fransson (Stockholm University), J. Larsson (KTH Royal Institute of Technology), A. Pagan (STScI)