

# Spatiotemporal correlation between gamma-ray bursts and ultra-high energy neutrinos

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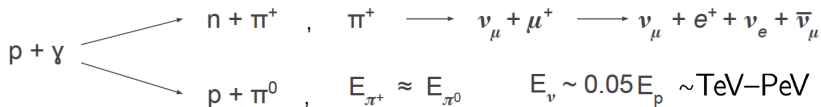
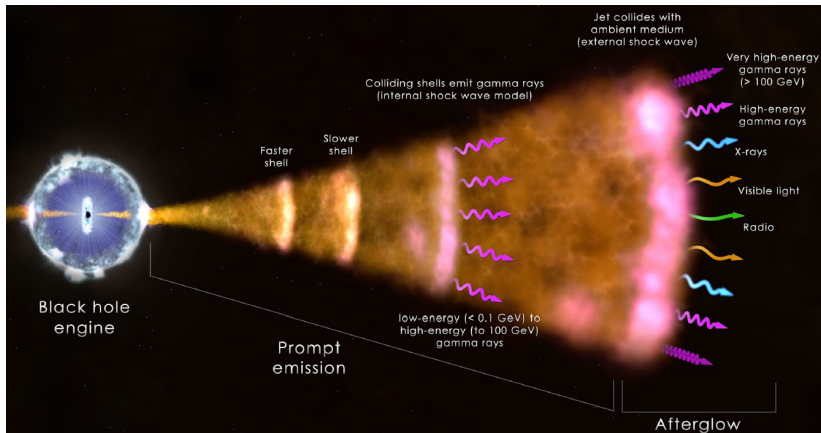
Ihor Neporozhnii

Department of Nuclear Physics  
Taras Shevchenko National University  
Kyiv, Ukraine

9<sup>th</sup> Fermi Symposium

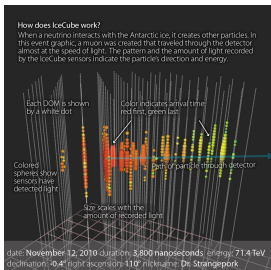
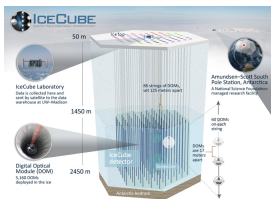
15 April 2021

# GRBs and UHE $\nu$ s



# Data sources

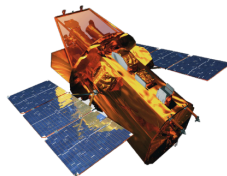
160 UHE $\nu$ s



3221 GRBs



Fermi Gamma-ray Space Telescope



Swift Observatory

[https://user-web.icecube.wisc.edu/~grbweb\\_public/Summary\\_table.html](https://user-web.icecube.wisc.edu/~grbweb_public/Summary_table.html)

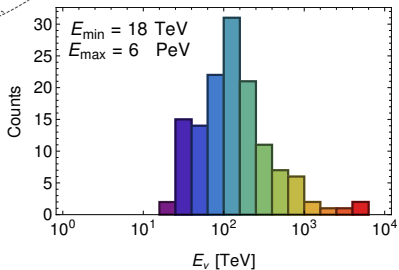
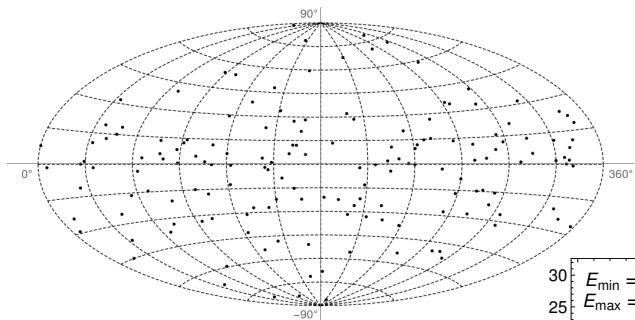
GRBweb by P. Coppin

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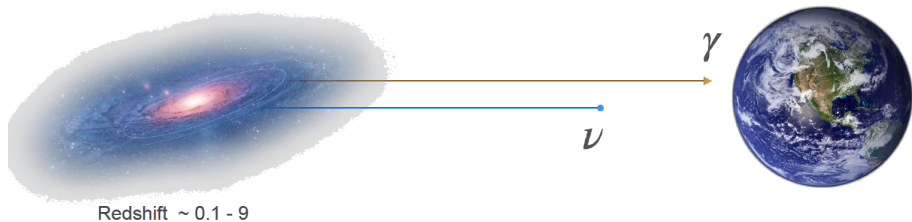
GRB_name	GRB_name_Fermi	T0	ra	decl	pos_error	T90	T90_error	T90_start	fluence	fluence_error	redshift	'T100'	GBM_located	mjd (T0)
		UTC	°, j2000	°, j2000	°, 1-sigma	s	s	UTC	erg/cm <sup>2</sup>	erg/cm <sup>2</sup>		s		day
<a href="#">GRB210404A</a>	GRB210404141	3:23:22.270	175.5500	2.3400	10.842735	1.3440	0.7400	3:23:22.270	2.1673e-07	1.5176e-08	---	1.3440	True	59308.14122998
<a href="#">GRB210403A</a>	---	8:27:13	2.8130	-33.0240	0.020193	168.3000	---	8:27:13	2.7000e-06	---	---	168.3000	False	59307.35223380
<a href="#">GRB210402A</a>	---	22:04:16.980	198.2593	44.5145	---	---	---	---	---	---	---	---	False	59306.91964097
<a href="#">GRB210401A</a>	GRB210401970	23:17:04	263.0700	-31.5800	2.843081	301.0610	4.4040	23:17:06.845	7.4899e-05	3.1777e-07	---	303.9060	True	59305.97018519
<a href="#">GRB210328A</a>	GRB210328865	20:45:16	207.8700	-8.5600	2.878118	54.7850	3.7270	20:45:16.458	1.1056e-05	8.0972e-08	---	55.2430	True	59301.86476852
<a href="#">GRB210326A</a>	GRB210326057	1:22:24.798	58.0100	15.0600	14.375604	0.5760	0.3450	1:22:24.798	1.5879e-07	2.6594e-08	---	0.5760	True	59299.05723146
<a href="#">GRB210324C</a>	GRB210324833	19:59:58	35.1110	-48.6060	---	67.0730	4.1670	20:00:03.954	6.1103e-05	2.5530e-07	---	73.0270	False	59297.83331019
<a href="#">GRB210324B</a>	GRB210324809	19:25:06	173.5200	6.5500	8.661007	4.8640	0.9230	19:25:06.230	5.6276e-07	3.3384e-08	---	5.0940	True	59297.80909722
<a href="#">GRB210324A</a>	GRB210324468	11:14:28	148.5300	37.1800	3.727866	31.7450	1.3790	11:14:28.724	6.6793e-06	4.1852e-08	---	32.4690	True	59297.46837963
<a href="#">GRB210323B</a>	GRB210323502	12:03:28.741	253.0800	7.8200	6.227013	13.5680	2.2020	12:03:28.741	5.8568e-07	4.5551e-08	---	13.5680	True	59296.50241598

- 1 *Observation of High-Energy Astrophysical Neutrinos in Three Years of IceCube Data*, Aartsen et al., PRL, 113, 101101 (2014)
- 2 *Observation of Astrophysical Neutrinos in Four Years of IceCube Data*, IceCube Collaboration, PoS, 236, 1081 (2015)
- 3 *Observation of Astrophysical Neutrinos in Six Years of IceCube Data*, IceCube Collaboration, PoS, 301, 981 (2017)
- 4 IceCube catalog of alert events  
([https://icecube.wisc.edu/science/data/TXS0506\\_alerts](https://icecube.wisc.edu/science/data/TXS0506_alerts))
- 5 IceCube Catalogue of Astrophysical Neutrino Candidates  
(<https://neutrino-catalog.icecube.aq/main>)
- 6 AMON IceCube Gold and Bronze Events with energy in the sub-PeV to 1 PeV region ([https://gcn.gsfc.nasa.gov/amon\\_icecube\\_gold\\_bronze\\_events.html](https://gcn.gsfc.nasa.gov/amon_icecube_gold_bronze_events.html))



# Time delay

Assume that photon and UHE $\nu$  are emitted simultaneously



What is the  $\Delta t$  between photon and neutrino arrival?

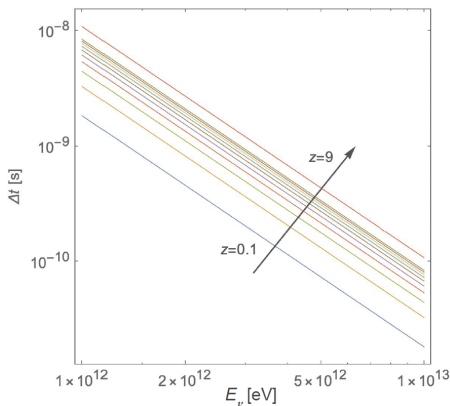


In an FLRW metric:

$$\Delta t = \frac{1}{2} \left( \frac{mc^2}{E_\nu} \right)^2 \int_0^z \frac{dz}{H(z)(1+z)^2},$$

$$H(z) = H_0 \sqrt{\Omega_m(1+z)^3 + \Omega_\Lambda}$$

**This delay is negligible.**





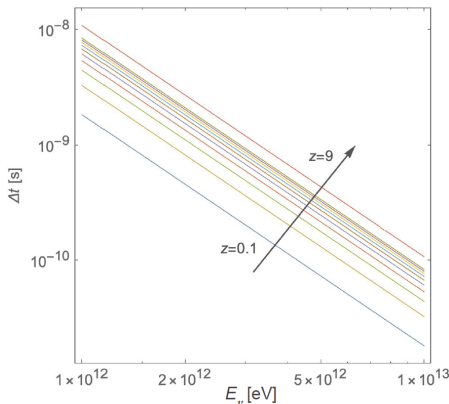
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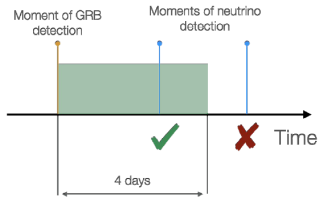
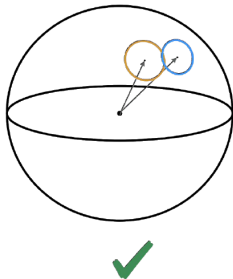
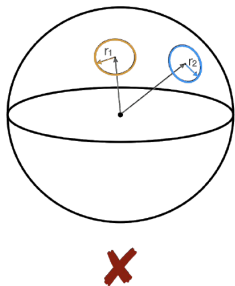
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Prompt: seconds – hours; afterglows: days after the burst is triggered.

# Cross-matching



Events are matched spatially if their error circles overlap

# Results

20 matches:

Neutrino	GRB
Event 2	GRB100604A
Event 7	GRB110108A
Event 9	GRB110503A
Event 11	GRB110531A
Event 12	GRB110625B
Event 14	GRB110807A
Event 33	GRB121017A
Event 34	GRB121028A
Event 34	GRB121027B
Event 34	GRB121025A

Neutrino	GRB
Event 44	GRB140113B
Event 46	GRB140129C
Event 50	GRB140320B
Event 60	GRB140928A
Event 66	GRB150128A
Event 72	GRB150428C
IceCube-171015A*	GRB171011D
IceCube-170922A*	GRB170921B
13270754984442**	GRB190619A
Event 6	GRB100811A

\* - IceCube Catalogue of Astrophysical Neutrino Candidates

\*\* - AMON IceCube Gold and Bronze Event Information

# Monte Carlo simulations

160 UHE $\nu$ s and 3221 GRBs, with significant location errors — what is the chance to get so much matches between random samples?

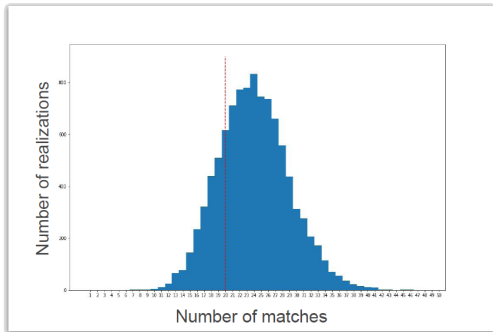
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## Simulation setup:

- Neutrino and GRB coordinates randomly and uniformly distributed on unit sphere
- Error circles are randomly assigned to each event
- Performed with 10 000 realizations

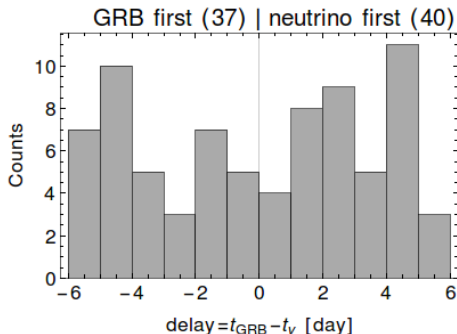
There is an 82% chance of obtaining at least 20 matches by distributing positions randomly



UHE $\nu$ s shouldn't arrive before GRBs. But they can arrive even a few days after (if from afterglow).

# Statistical validation

UHE $\nu$ s shouldn't arrive before GRBs. But they can arrive even a few days after (if from afterglow).



Distribution is uniform. There is **no significant difference** in matches of UHE $\nu$ s before and after GRBs.

- 1 There are about 20 (37) GRB and UHE $\nu$  matches, within a 4- (6-)day window.



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Thank you for your attention!