The Present and Future Real-Time Alerts from AMON

TeVPA

August 9th 2017

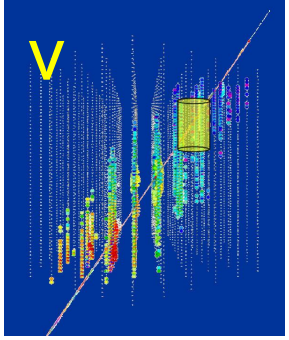
Jimmy DeLaunay
AMON team

Outline

- What and who is AMON
- What's being/been done
- Upcoming AMON γ - ν alerts

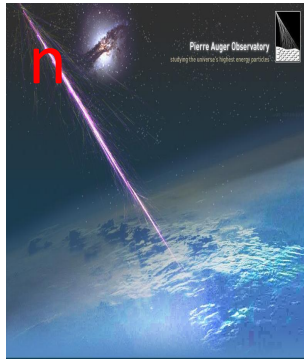
The AMON Idea

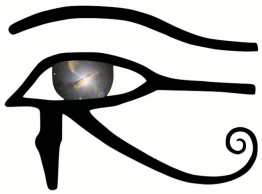
AMON searches for multimessenger transients using the messenger particles of all four fundamental forces



Triggering Observatories

- Provide sub-threshold candidate events to AMON in real time
- They have large FOV and high duty cycles



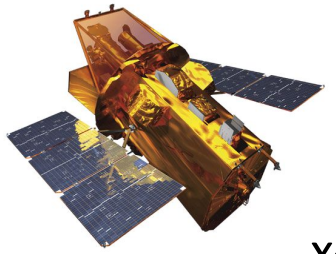


AMON

- Seeks coincidences in time and space
- Generates alerts, broadcasts and archives
- Enables archival analyses
- Pass-through of above-threshold events (e.g. IceCube HESE)

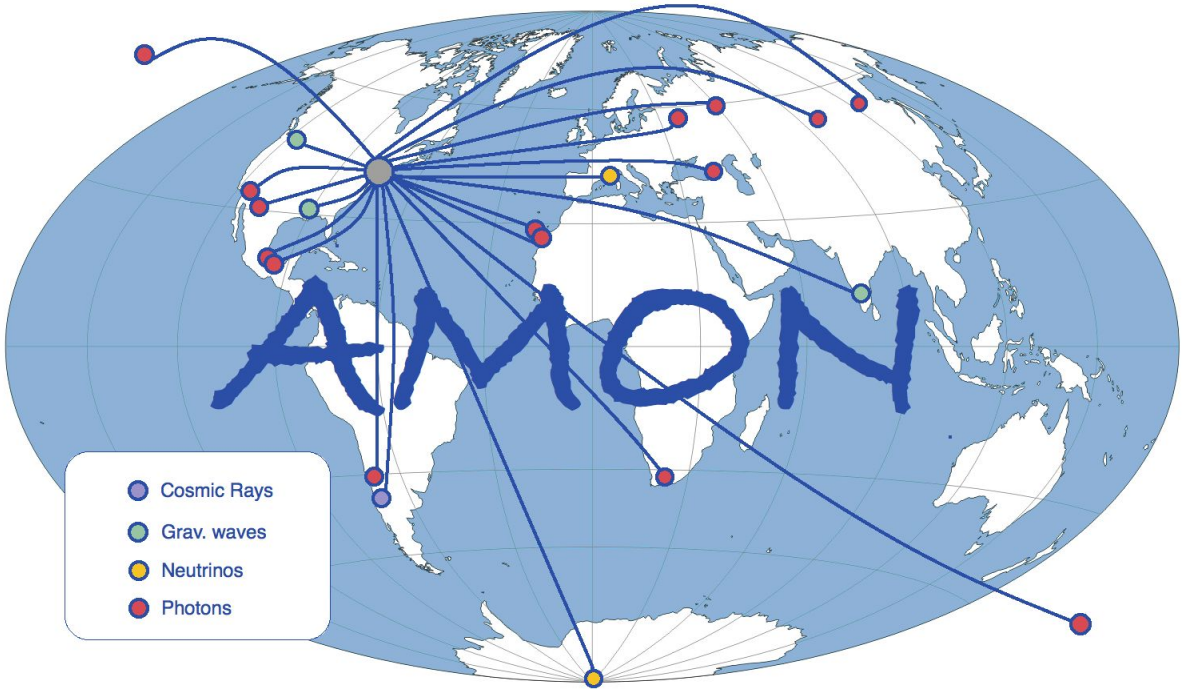
Follow-up Observatories

- Receive and respond to AMON alerts
- Provide afterglow or delayed feedback on potential multimessenger transients



x-ray, UV, optical

AMON Network



<u>Triggering</u>: IceCube, ANTARES, Pierre Auger, HAWC, VERITAS, FACT, Swift BAT, Fermi LAT & GBM, LIGO-Virgo*

<u>Follow-up</u>: Swift XRT & UVOT, VERITAS, FACT, MASTER, LCOGT

* Ongoing MoU negotiations

More observatories in talks about joining AMON

For info about joining AMON: https://sites.psu.edu/amon/join/

Current Real-Time Alerts

- Started issuing "pass-through" alerts of significant IceCube track-like events in April 2016
  - Sent via connection to GCN (γ-ray Coordinate Network)
  - Public Alerts (receivable by all)
    - High Energy Starting Events (HESE)
    - Extremely High Energy (EHE)
  - https://gcn.gsfc.nasa.gov/gcn/amon.html - AMON GCN page

Stream	HESE	EHE
Description	Starting tracks	Very high energy through going tracks
Angular Error	0.4° - 1.6°	0.1° - 0.4°
Rate	~ 4/year	~ 4 - 6 / year

More info about the IceCube realtime system can be found here https://doi.org/10.1016/j.astropartphys.2017.05.002

Follow-up

Alert name/type	160814A/HESE	160806A/EHE	160731A/HESE	160731A/EHE	160427A/HESE
RA/DEC (rev1) RA/DEC (rev2)	[199.31°, -32.02°] [200.25°, -32.35°]	[122.80°, -0.73°] [122.81°, -0.81°]	[215.11°, -0.46°] [214.54°, -0.33°]	[215.09°, -0.42°] [214.54°, -0.33°]	[239.66°, +6.85°] [240.57°, +9.34°]
Resolution	0.48° (50%), 1.49° (90%)	0.11° (50%)	0.42° (50%),1.23° (90%) 0.35° (50%), 0.75° (90%)	0.17° (50%), ~0.8° (90%) 0.35° (50%), 0.75° (90%)	1.6° (50%), 8.9° (90%) 0.6° (90%)
Energy	?	~62 TeV	~130 TeV	~130 TeV	~150 TeV
ST or Signalness	0.12	0.28	0.91	0.85	0.92
Latency: Event t0 to GCN alert sending	42 s	37 s	41 s	54 s	81 s
Followups					

AGILE, ANTARES, FACT, Fermi GBM, Fermi LAT, HAWC, H.E.S.S, INTEGRAL, IPN, Konus-Wind, LCOGT, MAGIC, MASTER, Maxi/GSC, Pan-STARRS, PTF, Swift, VERITAS

For follow-up analysis details see Azadeh's talk later this session at 4:45

γ-ν Analyses

Archival Analyses

- Fermi LAT – IC40 (AK et al, PoS(ICRC2015)786 (2015))
- VERITAS blazars – IC40 (C. F. Turley et al., APJ 833, 117 (2016))
- Fermi LAT – IC40/59 (C. F. Turley et al., in preparation)
  - See Colin Turley's talk - Multi-messenger session Friday 2:45

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Real Time Alerts

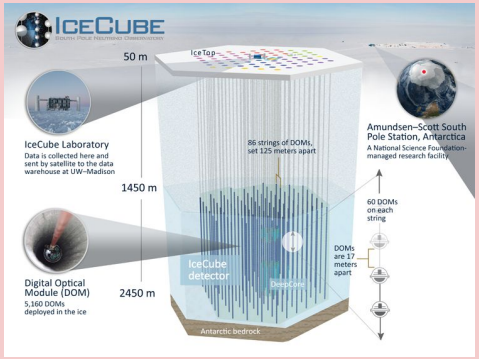
- **Real-Time γ-ν coincident alerts coming soon!**
  - To a follow up observatory near you
- **AMON infrastructure ready to go**
  - "Pass-through" alerts successfully brokered
  - Preliminary analyses running in real-time on scrambled/fake data
- **What needs to happen**
  - Cross-collaboration tuning and approval of analyses
  - Pull the "un-scramble" lever

Upcoming γ-ν Alerts

Neutrinos

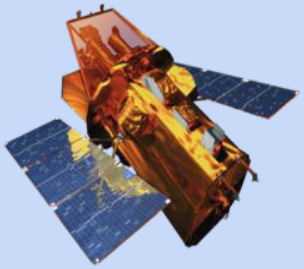
IceCube

Tev - PeV



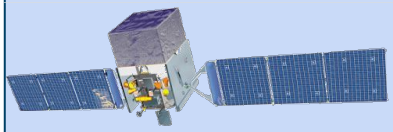
γ-Rays

Swift BAT



15 - 150 KeV

Fermi LAT



MeV - GeV

FACT

100 GeV - 10 TeV

HAWC

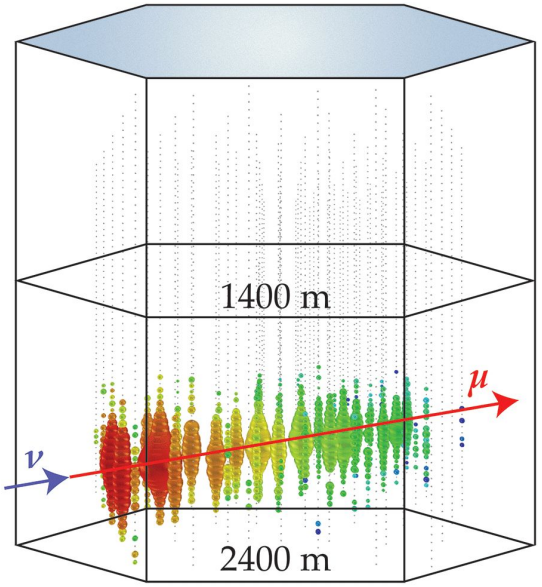
TeV

ENERGY

IceCube

Data proposed for AMON	Through-Going Tracks
FOV	All Sky
Position Error	~ 1°
Rate	100's/day
Latency	~ 1 min

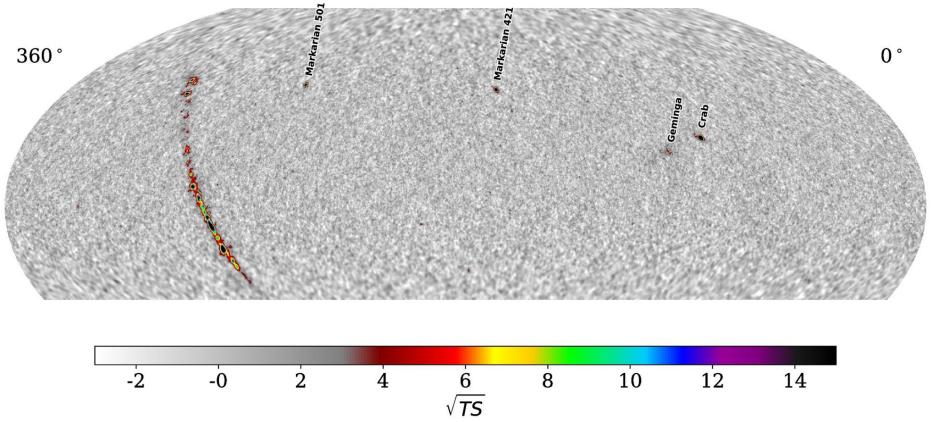
Through-going track



Credit: Illustration: APS/Joan Tycko; Neutrino event: IceCube

HAWC

Data proposed for AMON	Sub-threshold signals in daily maps of TeV γ's
FOV	~15% sky
Position Error	~ 0.1°
Rate	100's/day
Latency	hours



- <- HAWC's 2nd catalog
- Daily maps: source-candidates found in ~6 hour exposure time

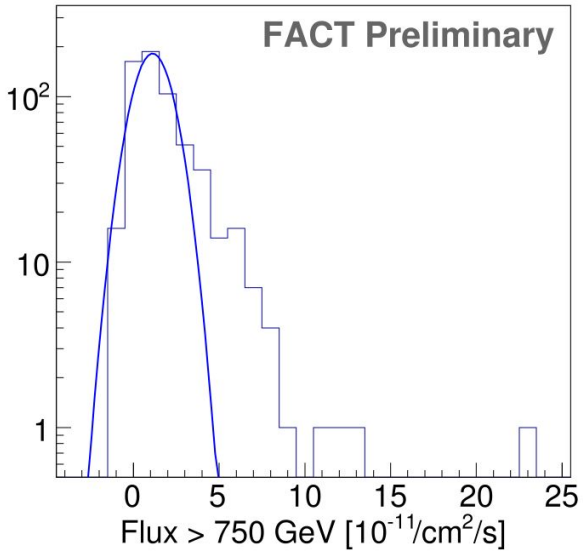
AstrophysJ. 843 (2017) 1, 40

FACT

γ-Ray Streams

Data proposed for AMON	**Tev γ-flares from a few bright sources in 20 minute bins**
FOV	**Small**
Position Error	**Known locations**
Rate	**?**
Latency	**~ hour**

Mkr 421



- Excess Flux seen above "normal" flux in 20 minute bins

Defining a flare

- Right of the Gaussian curve is considered a Flare

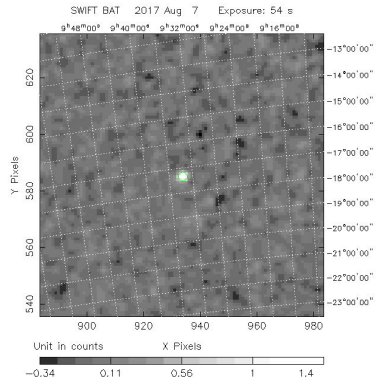
Work done by Daniela Dorner with the FACT collaboration

γ-Ray Satellite Streams

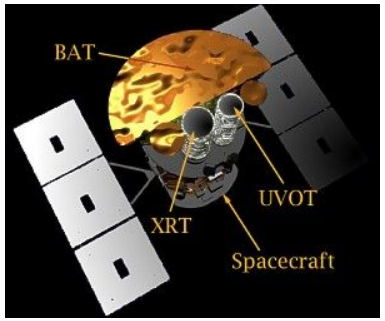
Swift BAT

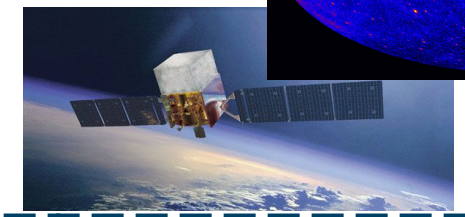
Fermi LAT

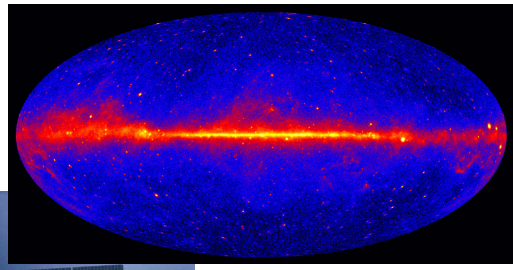
GRB170807A



https://gcn.gsfc.nasa.gov/notices_s/766821/BA/







Fermi γ-ray sky

Data proposed for AMON	**Low significance peaks found in onboard created images**	**>100 MeV single γ's**
FOV	**~15% sky**	**~15% sky**
Position Error	**~ 4 arcminutes**	**~ 0.1° - few°**
Rate	**100's/day**	**~ 10^4 / day**
Latency	**hours**	**hours**

Summary

- AMON has successfully brokered high-energy IceCube alerts to the follow-up community
- Infrastructure is up and running and ready to go for coincident searches
- Coincident analyses are in the works
- Keep your eyes open for these current and future alerts

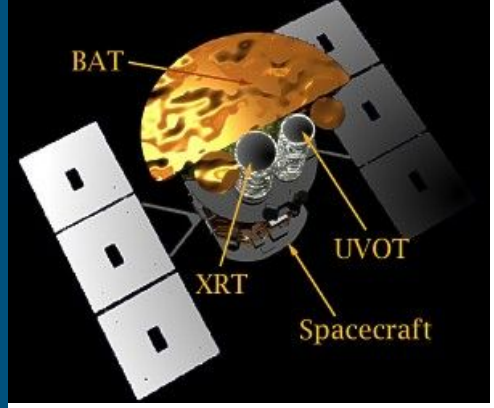
We're always interested in new partners to join AMON

Feel free to contact us about joining, receiving alerts, analyses, or anything else!

For info about AMON see
https://sites.psu.edu/amon

Backup Slides

Swift BAT



- FOV ~2 sr
- 15 - 350 keV
- Coded Imager
  - Performs FFT to create image
- Archival data available from end of 2004

Watching the hard X-ray sky for for sudden rate increases

Rate Trigger

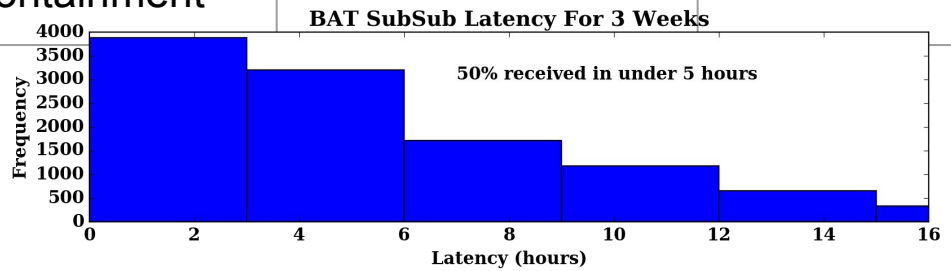
64s pass by

Make image, Search for unknown sources

snr > 6.5σ

snr > 3.8σ

Trigger Type	Above-Threshold	SubSub-Threshold
Rate	~100 per year	~500/day (~10^5/year)
Time from event to GCN transmission	seconds	hours
90% containment	1 - 3 arcmin	4 arcmin



Fermi LAT

- Pair-production high energy photon detector
- 20 MeV - >300 GeV
- FOV 2.4 sr
- Angular Resolution (on-axis)
  - < 3.5° (100 MeV)
  - < 0.15° (>10 GeV)
- Taking data since 2008

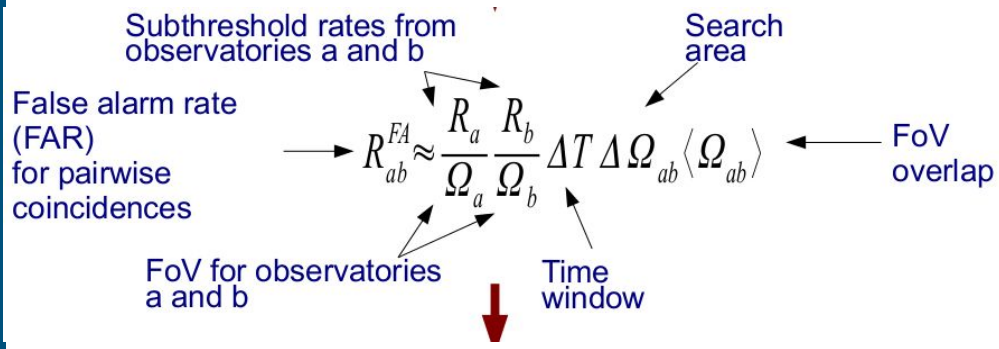
AMON Sub-Threshold Stream of LAT data

- Retrieved from LAT weekly map file, from LAT data servers
- All single photons E>100 MeV
- Very high rate, ~25 per minute (~10^7 per year)
- Angular Resolution (68% containment of PSF)
  - 100 MeV, 2° - 9°
  - 1 GeV, 0.5° - 2°
  - >10 GeV, < .4°
  - Calculated from King Function PSF as a function of incoming angle and energy

AMON Alerts

- VOEvent format
  - Structured in XML format with simple schema
  - Easily interpreted by software, to be read by robotic telescopes
  - Already used by much of the astronomical community
- Sent out to AMON partners through AMON-GCN connection
  - Very fast delivery
  - Some day in the future, will be sent out publicly
- Content of AMON Alert
  - What
    - id number, stream number, revision number
    - False alarm rate, number of events, duration of events in alert
  - WhereWhen
    - Time, position of best fit, positional error

Monte Carlo FAR



Astrop.Phys.
Vol. 45, 56–70, 2013

FAR per year from clustering analysis

ΔT=100 s and 3σ spatial window

		IceCube	ANTARES	LIGO-Virgo	Auger	BAT	GBM	LAT	HAWC
(a) Single streams	Above thresh.	~0	~0	~0	~0	~100	~250	~10	~10
	Subthreshold	8.8×10^4	2.9×10^4	3.2×10^3	2.4×10^5	1.4×10^5	3.1×10^2	3.9×10^4	2.6×10^4
	IceCube	30	1.5	35	1.8	11	10	24	6.5
	ANTARES	1.5	0.5	12	1.1	0.7	3.5	7.1	0.6
	LIGO-Virgo	35	12	N/A	8.4	53	0.6	16	10
(b) Pair-wise FPR	Auger[a]	1.8	1.1	8.4	20	2.9	2.5	5.9	1.5
	BAT	11	0.7	53	2.9	N/A	16	32	3.3
	GBM	10	3.5	0.6	2.5	16	N/A	5.0	3.2
	LAT	24	7.1	16	5.9	32	5.0	N/A	6.8
	HAWC	6.5	0.6	10	1.5	3.3	3.2	6.8	N/A
	GRB lt. curve[b]	0.071	0.003	0.16	-	0.0004	0.08	0.13	0.019
	SNe lt. curve[b]	1.5	0.07	3.4	-	0.009	1.6	2.7	0.4
(c) High significance	3-fold coinc.	0.15	0.03	0.31	0.64	0.12	0.09	0.40	0.08
	3-fold coinc[a]	0.10	0.02	0.15	0.06	0.08	0.04	0.23	0.04
	High-sig. EM[c]	0.015	0.002	0.045	0.044	0.010	0.014	0.039	0.005
	PBH search[d]	0.13	0.01	-	0.21	-	-	-	0.35

AMON Team

- Founded and hosted at Penn State
  - Internal initial funding
- Official NSF funded project as of 2014

AMON development and advisory team

Penn State

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[3]Institute for Gravitation and the Cosmos
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[5]Institute for CyberScience

Others

S. Barthelmy[1], I. Bartos[2], F. Feroz[3], M. Smith[4], I. Taboada[5]

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[2]Columbia University, Dept of Physics
[3]Cambridge University
[4]NASA JPL
[5]Georgia Institute of Technology

Motivation

- Difficulties with past searches for high energy astrophysical multimessenger transients
  - Searches have been bilateral, uni-directional
    - One observatory triggers follow-up with other observatory
  - “Above Threshold” non-EM detections are rare
    - Astrophysical signals are buried in “Sub Threshold” detections
- What AMON can offer
  - Create a central hub to unify search and follow-up efforts
  - More triggering observatories reduces background and allows for diving deeper into the noise
  - Enables fast alerts to more observatories for follow-up