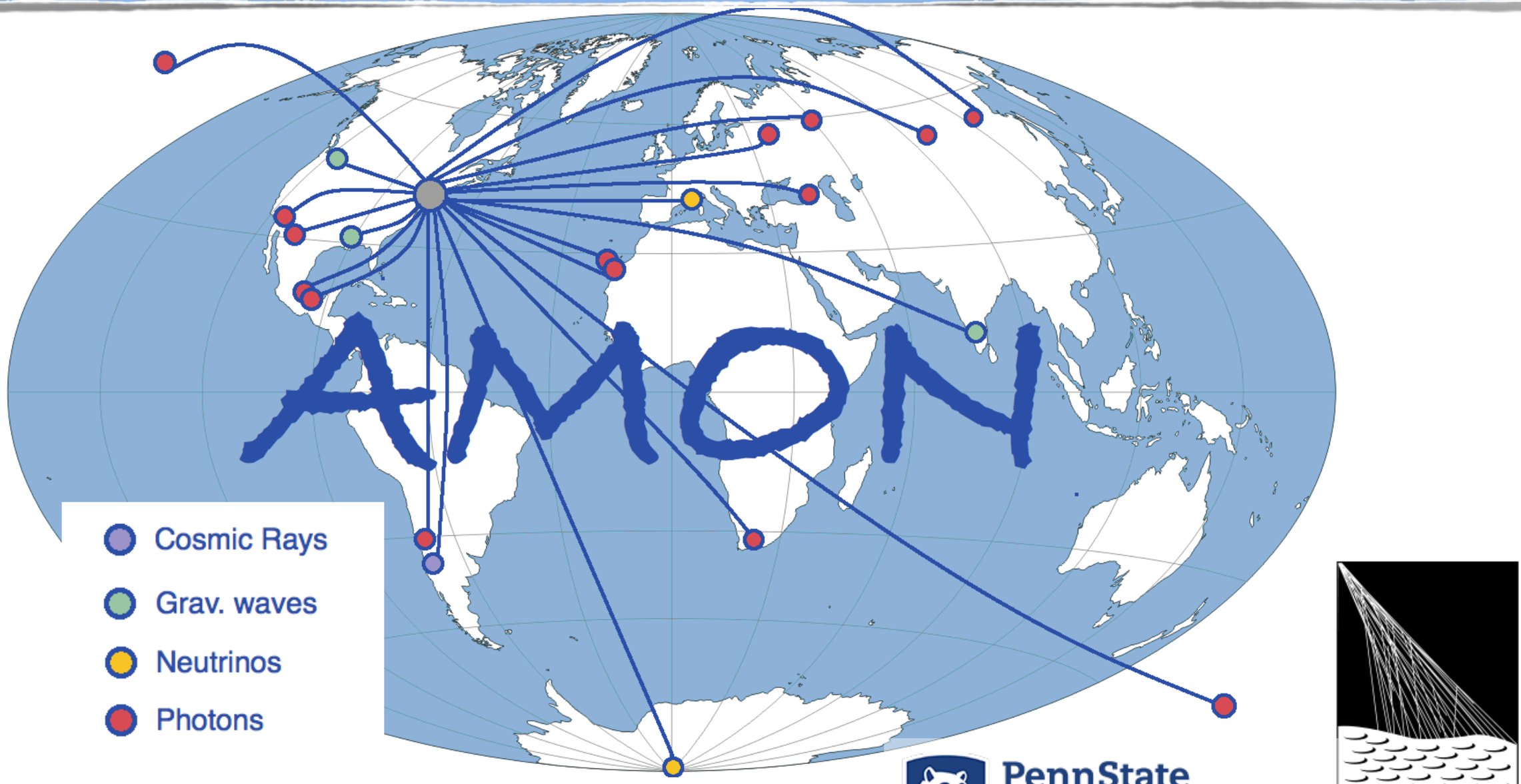
The Astrophysical Multi-Messenger Observatory Network



PennState
Eberly College of Science

Institute for Gravitation & the Cosmos

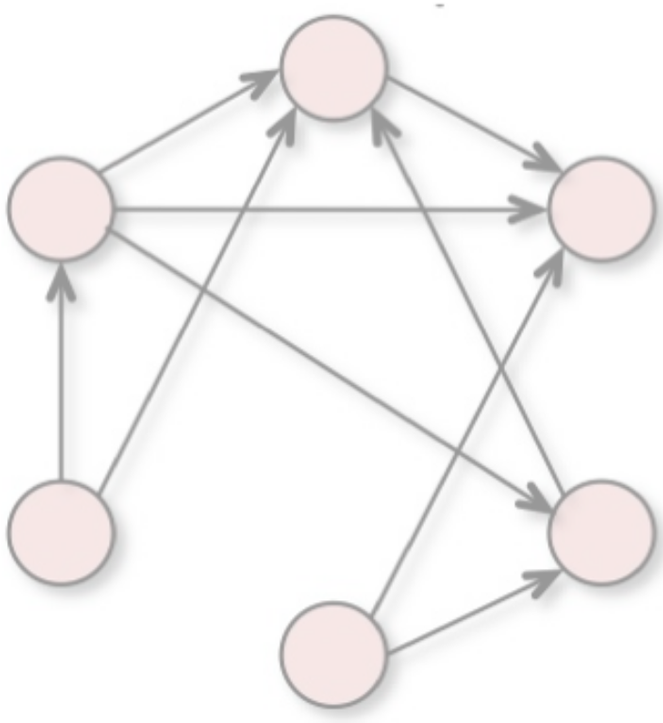
PIERRE AUGER OBSERVATORY

Foteini Oikonomou (for the AMON team)

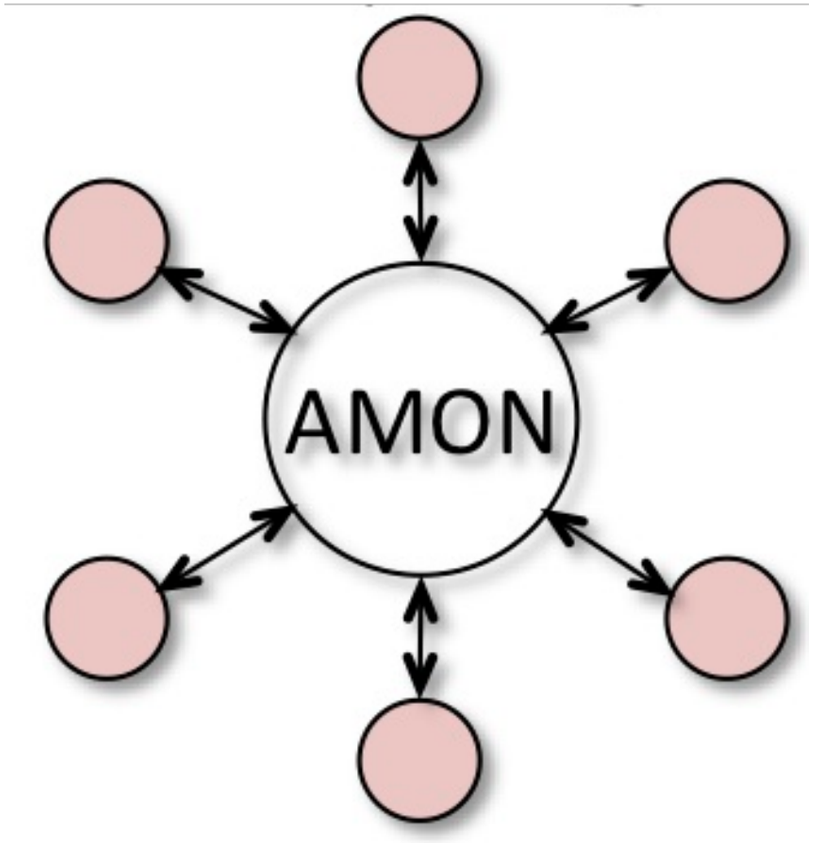
GRAPPA 13/4/2016

AMON Motivation

Multimessenger searches so far..

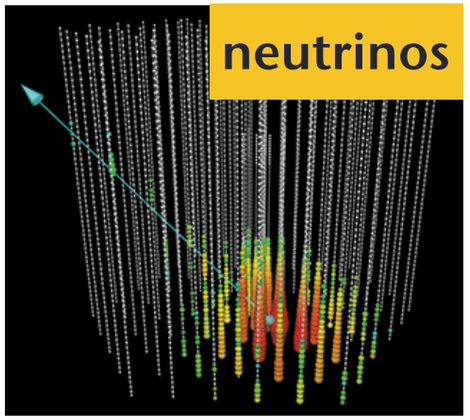


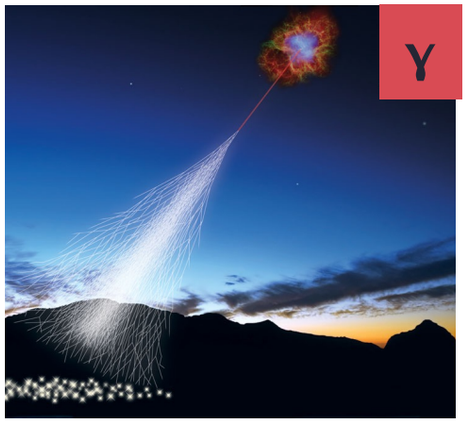
- Bilateral, uni-directional
- Low individual sensitivities (e.g. IceCube 10 HESE/year)
- Alert threshold ~ signal threshold

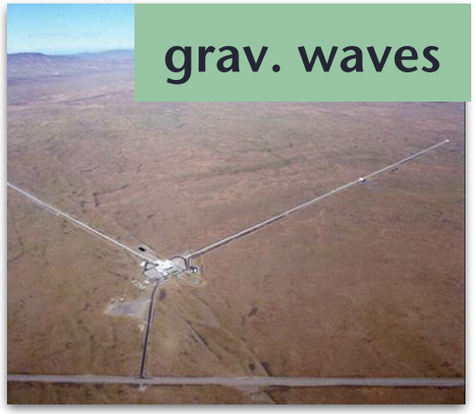


- Multilateral, omni-directional
- Sub-threshold alerts (e.g. IceCube doublets)
- **Reduces background, maximises discovery potential!!**

AMON Idea







AMON enables searches for multi-messenger coincidences using particles representing the *four fundamental forces*.

Triggering observatories:

- Transmit "sub-threshold" candidate events to AMON in real-time.

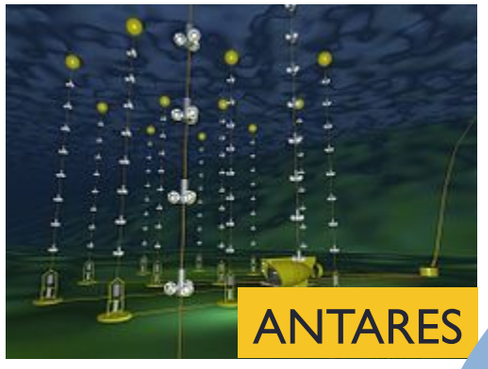
AMON:

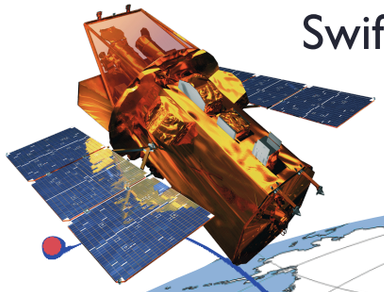
- Provides framework for *real-time coincidence searches* of data in direction & time.
- Broadcasts *real-time alerts* (via VOEvent & GCN).
- Enables *archival analysis* of sub-threshold data.

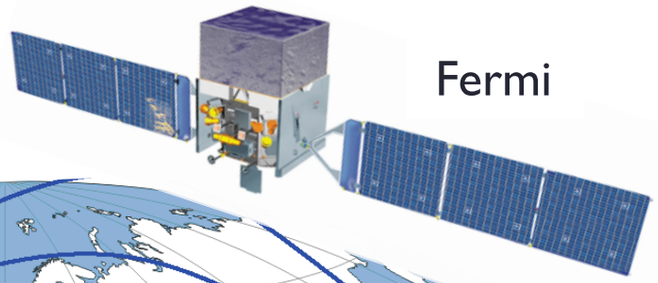
Follow-up observatories:

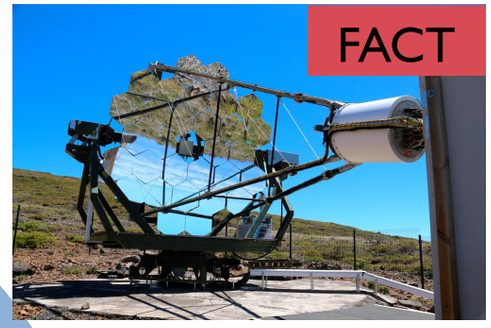
- Respond to AMON alerts.
- Provide optical feedback on potential multi-messenger transients.

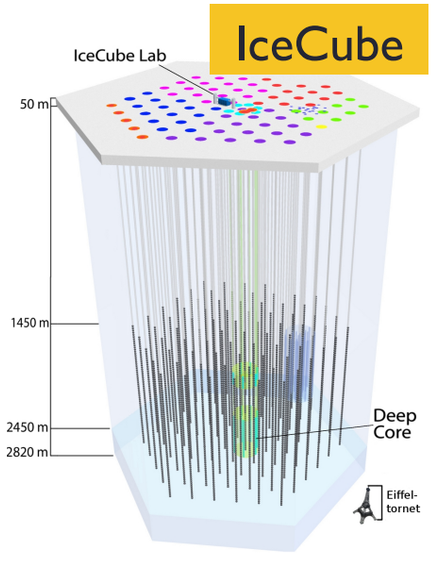
AMON Partners











+Follow-up:

Swift XRT&UVOT

LCOGT MASTER

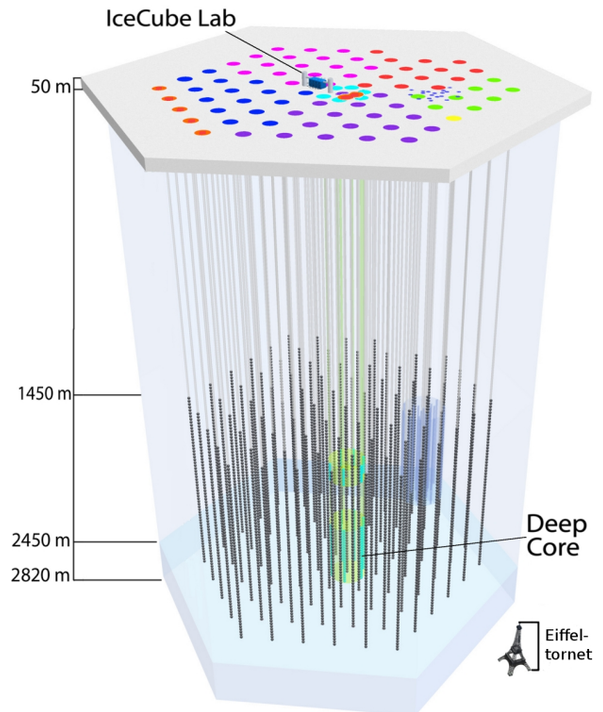
+soon LIGO, HESS, TA, PTF, MAGIC!

AMON case study: IceCube

IceCube cannot detect ν sources alone:

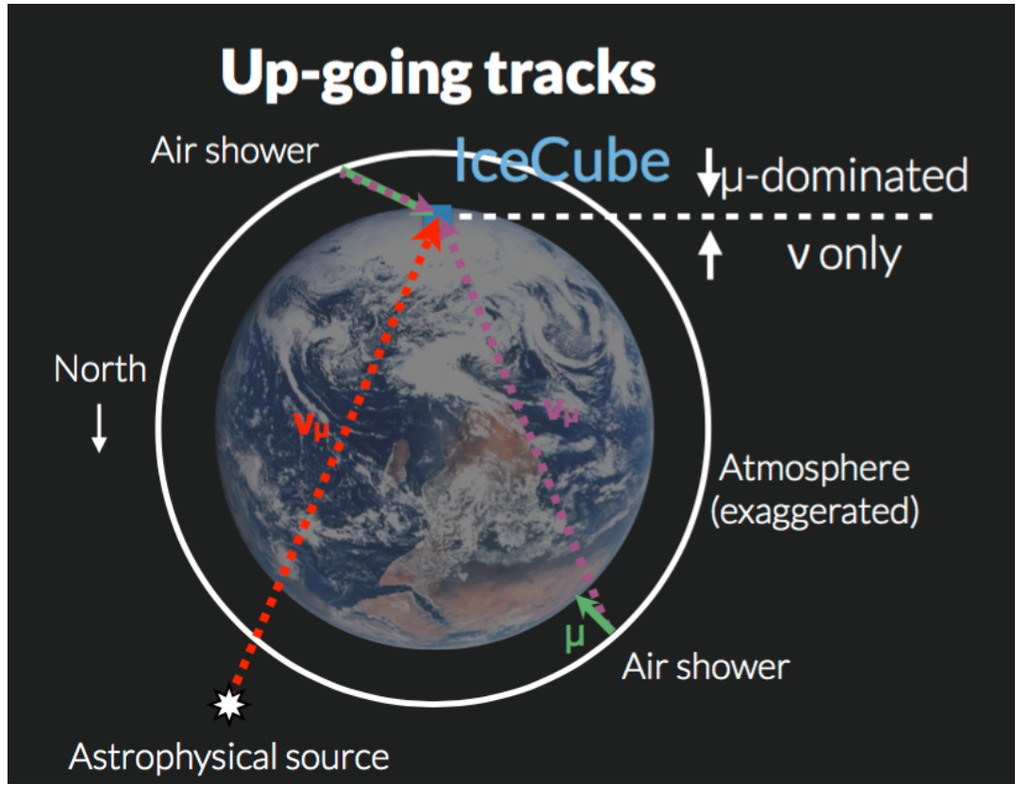
- ~ 10 HESE/year
- ~ 1/200 from z < 0.1, with high p_{cosmic}, and $\theta \sim 1°$

e.g. Ahlers&Halzen 2014, Waxman 2013



Realtime IceCube reconstructed events trigger AMON:

- **HESE** - 3 track-like highest p_{cosmic} events followed up by Swift *(NASA12/15235 award)* ~ 1 signal event
- **EHE** - 6 events /year ~ 3 signal events.
- **Up-going tracks** -Multiplets generate AMON alert
- **IceCube alerts distributed by AMON/GCN**



sketch from Claudio Kopper

AMON case study: The Pierre Auger Observatory

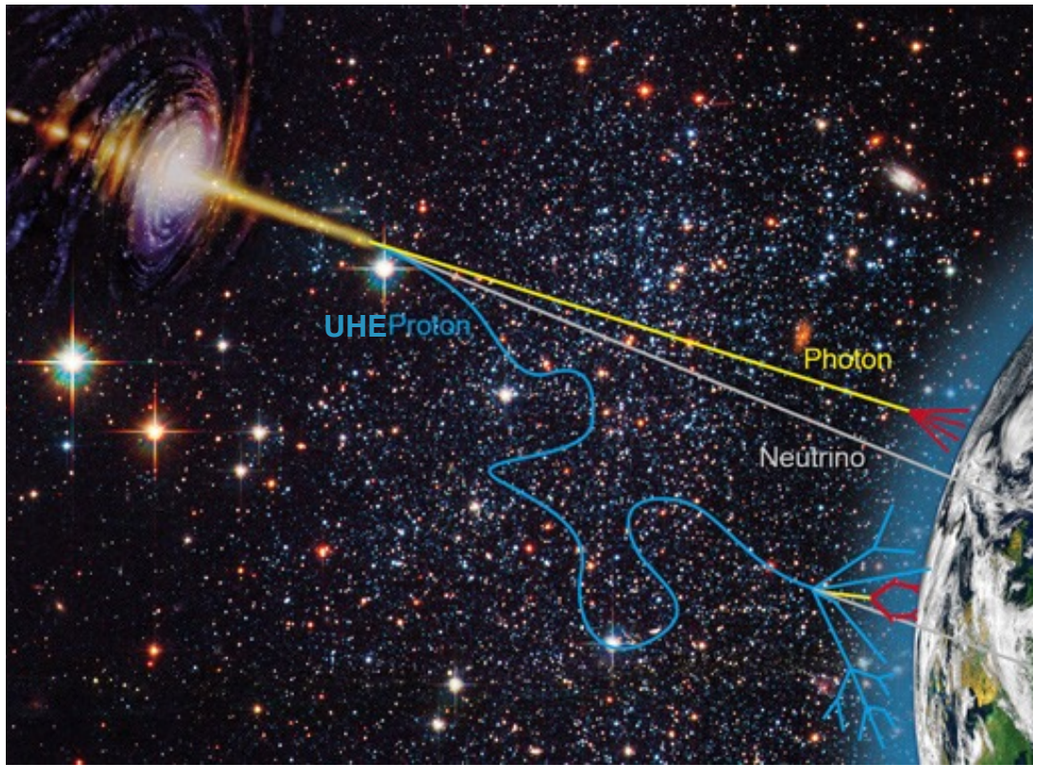
Auger unique among AMON partners:
Ultra-high energies!!

- **UHE Charged Hadrons** - deflections/delays ✗

- **UHE Neutrons**
  $L_n \sim c \cdot \tau_n \cdot \gamma_n \sim 9\ (E_n/1\ \mathrm{EeV})$ kpc
  Yes Galactic! ✓

- **UHE Neutrinos**
  $L_\nu\ (10^{20}\mathrm{eV}) \sim 4$ Gpc,
  But v. small interaction probability… ✓

- **UHE Photons**
  $L_\gamma\ (10^{20}\mathrm{eV}) \sim 10\text{-}100$ Mpc ✓



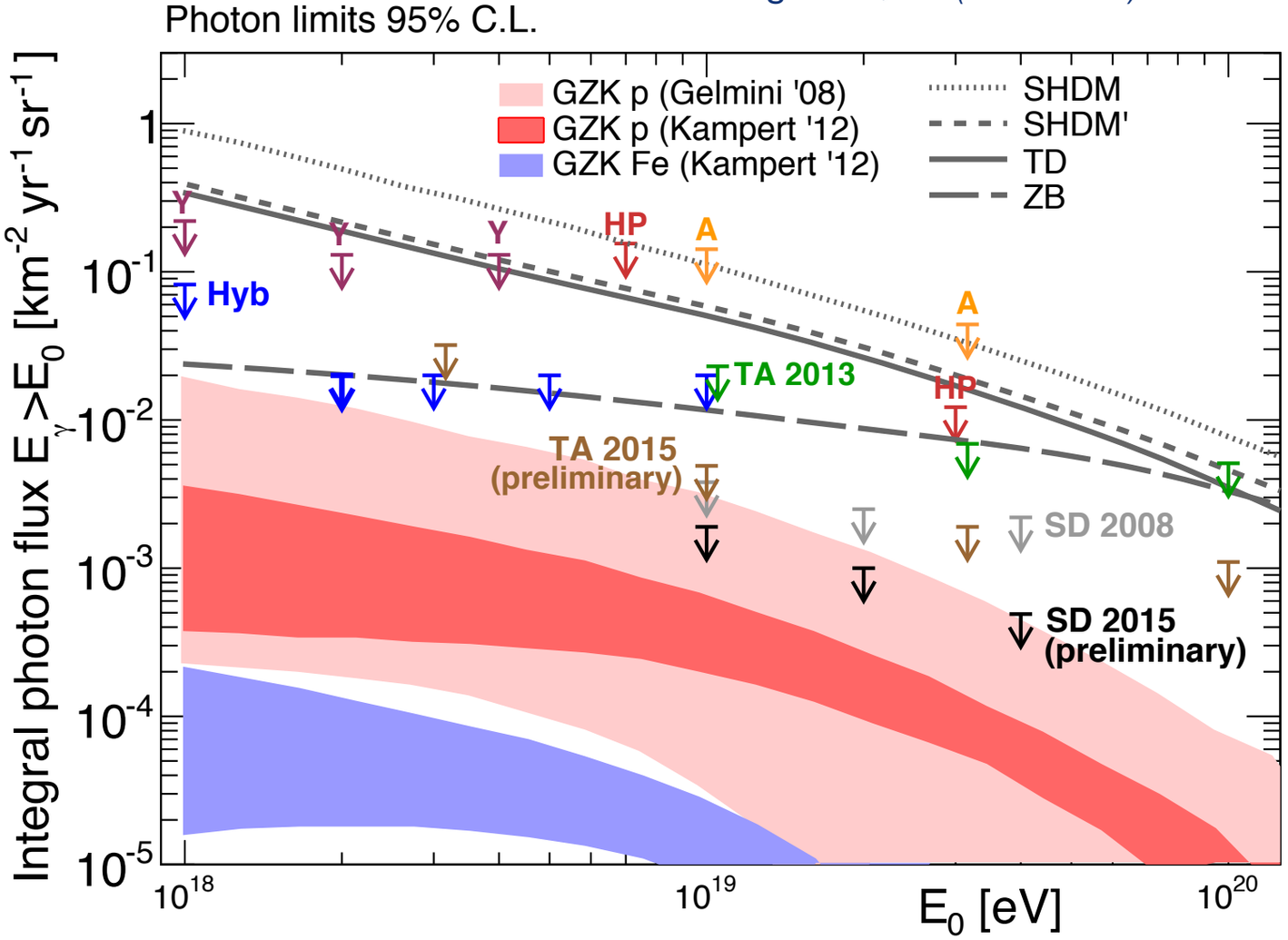
AMON case study: Auger photons

- World's strictest limits in range E > 1 EeV
- Pure p composition of UHECRs +strong source evolution disfavoured
- Sensitive to GZK p photon flux

Realtime Photon analysis

- 1st realtime analysis -> **transients!**
- γ-like showers ->AMON alerts

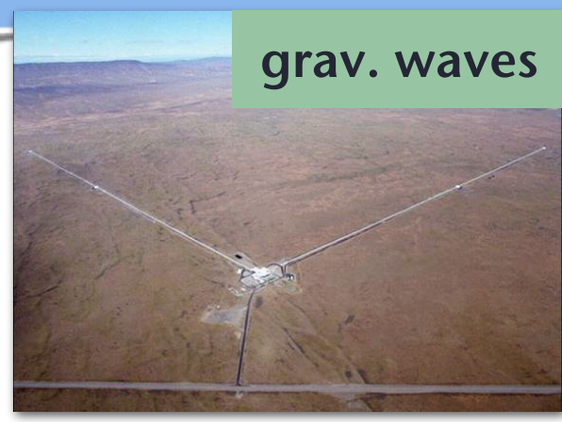
Auger Coll, PoS(ICRC2015) 1103

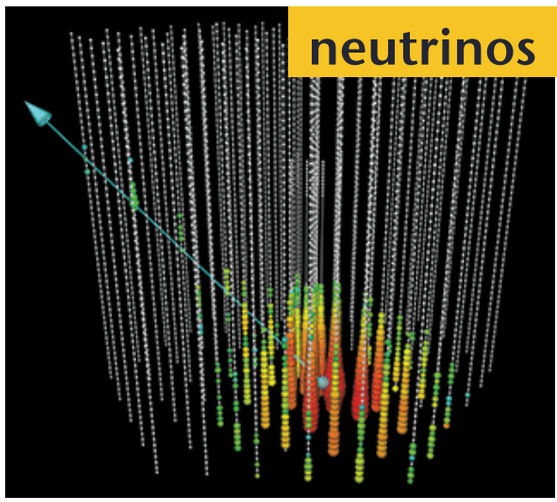


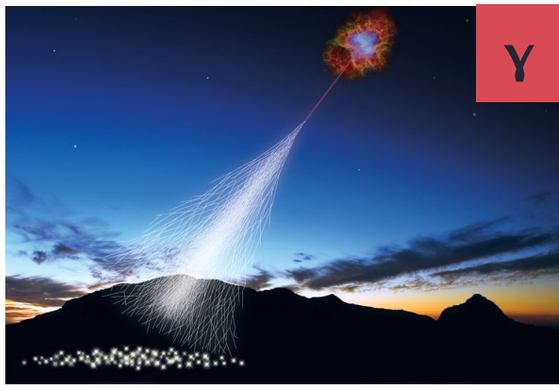
Summary

- AMON expands multi-messenger discovery space
- AMON greatly simplifies multi-messenger searches
- Real-time operation started in 2015 with IceCube
- More partners to join real-time phase in next months
- New partners always welcome

join us!







The AMON development and advisory team

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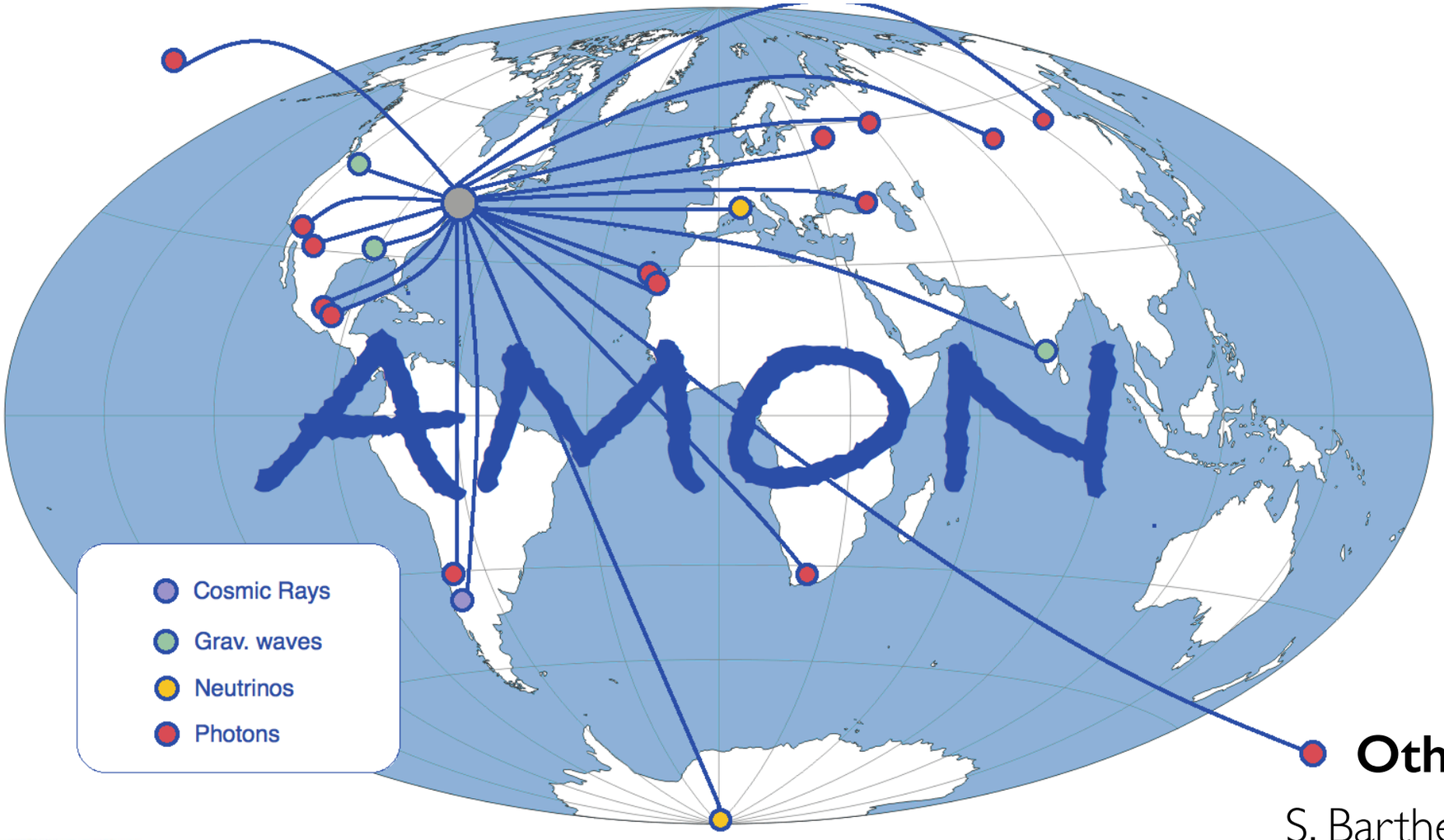

http://sites.psu.edu/amon/

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