

International Centre for Radio Astronomy Research

# What's new in the world of neutrino astronomy?

Clancy W. James ICRAR/Curtin Institute of Radio Astronomy clancy.james@curtin.edu.au Thanks to KM3NeT









Government of Western Australia Department of the Premier and Cabinet Office of Science



## What's old in neutrino astronomy? (recap)



## Astrophysics

## How do we (expect to) get neutrinos?

- Astrophysical shocks accelerate protons (cosmic rays)
- Protons interact with gas and photons to produce pions
- Pions decay to produce
  neutrinos and gamma-rays

$$\pi^{+} \rightarrow \mu^{+} + \nu_{\mu}$$
$$\mu^{+} \rightarrow e^{+} + \nu_{e} + \overline{\nu}_{\mu}$$

$$n \rightarrow p_{CR} + e^- + \overline{\nu}_e$$
  
 $\pi^0 \rightarrow 2\gamma$ 

 $e^- \rightarrow \gamma_{synch}, \gamma_{IC,bremms}$ 





1)



## **Basic detection method**

#### **Basic detection method**

- Neutrino traverses Earth, interacts near detector
- 2/9ths of the time: produces high-energy outgoing muon (travels kms)
- 100% of the time: produces 10m cascade of particles
- Light signature travels few 100m
- Reconstruct light => neutrino direction and energy







## Current instruments - IceCube



Courtesy icecube.wisc.edu





Astronomy with a Neutrino Telescope and Abyss environmental RESearch

#### ANTARES

- Southern coast of France (2.45km depth)
- Fully operational since 2008
- Scheduled to be decommissioned 2019 still going!
- 200k € annual operations cost (cheap!)
- Approx. 200x200x400m: 1% IceCube
- 885 PMTs



Courtesy IFRAMER





**Courtesy ANTARES Collaboration** 



## New detectors!

7



## Gigaton volume detector

#### GVD

- Lake Baikal, Russia
- Under construction completion ???
- First cluster, 'Dubna', deployed 2015
- 2021: 8 clusters deployed ("GVD-I")
- First events being detected!









## KM3NeT

#### **Two detectors planned**

- ORCA (smaller, denser) 1-100 GeV
- ARCA: (larger, sparser)
- 1 TeV 1 PeV

#### Composition

- ORCA 31 PMTs per OM
- 18 OMs per line
- ORCA: 115 lines
- ARCA: 230 lines











## Construction

#### Images courtesy KM3NeT











## Construction

#### ARCA

- 6 lines connected
- Size exceeds ANTARES!



#### ORCA

- 6 lines connected (of 230!)
- First neutrino events

Deployment: https://www.youtube.com/watch?v =4Aynn5lfZ3I Neutrino events: https://www.youtube.com/watch?v =AjQx8NpQJ8Y





## New neutrino sources?





#### ANTARES/IceCube coincidence (A. Albert et al., ApJ 911 (2021) 48)

- ANTARES / IceCube / Gamma-ray connection in blazar MG3 J225517+2409
- A-posteriori analysis: independently only 2.6 sigma



- Another significant spot: J0242+1101 (radio-bright blazar)
- Other searches: no hints so far.
- Stacking analyses with ~1000 bright blazars: no significant result

be presented at ICRC 2021



#### Radio-selected blazars

#### Plavin et al, ApJ 894 (2020) p13

- VLBI: blazars with strong radio cores (grey dots). Astrogeo database, including LBA
- IceCube events: high-energy sample of 56 events (blue ellipses; expect ~30% bkgd)



#### Ice-cube: point-source search CRAF IceCube et al, PRL 124 (2020) 051103 Search for excess of events in specific .70° 6.0



- Nearby Seyfert galaxy
- P-value: 10%...

NASA/HST



ARTICLES

astronomy

Check for updates

A tidal disruption event coincident with a high-energy neutrino

#### Artist's impression of a TDE Image credit: NRAO/AUI/NSF/NASA







#### Stein et al., Nature Astronomy 5 (2020) 510

- IC191001A: 59% chance of being astrophysical
- Coincident with TDE AT2019dsg (180 days into flare)
- Chance association with a radio-emitting TDE: 0.5 %



- Evidence for mildly relativistic outflow (0.2c)
- Proton acceleration to ~200 PeV
- Sufficient to produce observed neutrino



### Galactic sources: Cygnus region?

#### HAWC

- High-Altitude Water Cherenkov detector
- Siera Negra volcano, Mexico (4.1km)
- 1<sup>st</sup> catalogue: ApJ Volume 843 (2017), 21
- Huge FOV to TeV gamma-rays



- Nature Astronomy (online advanced access)
- Cygnus cocoon: emission to 100 TeV
- IceCube searches: no evidence for neutrino association (yet!). Need KM3NeT/GVD to study these



Credit: Jordan A. Goodman, Wikipedia





#### Glashow resonance event

1,000 (su) 1,000 Jime 600 Jime

600

400

300

#### Nature 591, 220–224 (2021)

- Anti-electron neutrino interaction with electron
- Neutrino energy in Earth frame: 6.3 PeV
- Centre-of-mass frame: 80 GeV (M<sub>W</sub>) •
- W then decays, most likely to q-anti-q pair
- Generates very energetic cascade event







## New outreach



## Draw a neutrino contest winners

"Once in a



"Ghostino" Evangelos Zacharopoulos (Greece)

"Ghost particle is on its way" Mariam Darjania, Georgia







## Draw a neutrino contest winners



"Untitled" Chahna Jain, India

More winners: http://wos.ba.infn.it/index.php/results-2/

> "The microscopic miracle!!!!" Amalia S. Kosmatou (Greece)



"Ghost particle" Aadishri Kher, India





## Summary

#### Neutrino sources?

- No breakthroughs since TXS 0506+056
- Lots of hints AGN, or TDE
- No sign of Galactic neutrino sources yet

#### **Experiments**

- ANTARES ageing
- IceCube
- Baikal GVD + KM3NeT: serious construction underway
- IceCube: very long-term plans

#### **Multimessenger links**

- VLBI important for studying AGN gets to innermost high-energy region
- Optical: identify TDEs
- X-ray/gamma ray facilities probe similar physics (but suffer ambiguities)

#### Not disussed here

- GRBs, PWN, exotic physics (TL;DR: no results yet)
- Neutrino oscialltions, mass hierarchy, and new physics searches
- Dark matter searches with neutrinos

