# THE TRANTY CONCEPT AND DEMONSTRATOR

Michele Doro, University of Padova, Italy <u>michele.doro@unipd.it</u> XX International Workshop on Neutrino Telescopes

UNIVERSITÀ

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Dipartimento

e Astronom

di Fisica

### DSIAMR



 $\langle \mathbf{y} \rangle$ 

During Trinity demonstrator installation campaign fall '23 with master and PhD students

### Nepomuk Otte

Pl of Trinity School of Physics & Center for Relativistic Astrophysics Georgia Institute of Technology Atlanta, GA



## TRINTY IDEA AND OUTLINE



- Detect UHE earthskimming astrophysical tau-neutrinos (1-100 PeV)
- One demonstrator in place at Frisko Peak (Utah) reported here

Michele Doro - Trinity - XX Neutrino Telescopes

 <sup>3+</sup> arrays of <=6 groundbased air-Cherenkov telescopes

## EARTHSAMMINGTAU NEUTRINCS



10<sup>6</sup>-10<sup>10</sup> GeV UHE nu-tau, when crossing 1-100 km of rock have significant **probability of emerge as tau-lepton**   The emerging UHE tau-leptons can generate e.m. atmospheric (sub)showers

| Decay                                           | Secondaries                              | Probability | Air-shower                    |
|-------------------------------------------------|------------------------------------------|-------------|-------------------------------|
|                                                 |                                          |             |                               |
| $\tau \rightarrow \mu^- \bar{\nu}_\mu \nu_\tau$ | $\mu^-$                                  | 17.4%       | weak showers                  |
| $	au  ightarrow e^- ar{ u}_e  u_	au$            | <i>e</i> <sup>-</sup>                    | 17.8%       | 1 Electromagnetic             |
| $	au  ightarrow \pi^-  u_{	au}$                 | $\pi^-$                                  | 11.8%       | 1 Hadronic                    |
| $	au  ightarrow \pi^- \pi^0  u_	au$             | $\pi^-, \pi^0 	o 2\gamma$                | 25.8%       | 1 Hadronic, 2 Electromagnetic |
| $	au  ightarrow \pi^- 2 \pi^0  u_	au$           | $\pi^-, 2\pi^0 	o 4\gamma$               | 10.79%      | 1 Hadronic, 4 Electromagnetic |
| $	au  ightarrow \pi^- 3 \pi^0  u_{	au}$         | $\pi^-, 3\pi^0 \rightarrow 6\gamma$      | 1.23%       | 1 Hadronic, 6 Electromagnetic |
| $	au  ightarrow \pi^-\pi^-\pi^+  u_	au$         | $2\pi^{-},\pi^{+}$                       | 10%         | 3 Hadronic                    |
| $\tau \to \pi^- \pi^+ \pi^- \pi^0 \nu_\tau$     | $2\pi^-,\pi^+,\pi^0 \rightarrow 2\gamma$ | 5.18%       | 3 Hadronic, 2 Electromagnetic |

 Imaging Cherenkov telescopes (IACT) record image of air shower →



### DEVONSTRATED BY MAGCTELESCOPES



Two 17-m diameter ground-based Imaging Cherenkov telescopes for TeV astrophysics at ORM, La Palma (Spain)

• Operating since 2003



- They can point toward the ocean (-2 deg altitude)
- A window of 60x5 deg<sup>2</sup>, but FOV is 3x3 deg<sup>2</sup>







Astroparticle Physics Volume 102, November 2018, Pages 77-88



Limits on the flux of tau neutrinos from 1 PeV to 3 EeV with the MAGIC telescopes

#### Proton injected at the top of the atmosphere (~800 km to the detector for 87°)



#### Deep tau-induced shower (~50 km to the detector)





## Very easy discrimination

between tau-induced (closeby, intense) showers and muons



Michele Doro - Mr. in Dibro XXIN My rin Pathle Anne Physics 2021





### It works, but very poor sensitivity, how to cope?



## THE MACHETE IDEA

MACHETE: A transit Imaging Atmospheric Cherenkov Telescope to survey half of the Very High Energy  $\gamma\text{-ray}_{\rm sky}$ 

J. Cortina<sup>a</sup>, R. López-Coto<sup>a</sup>, A. Moralejo<sup>a</sup>



### Trinity optics borrows from MACHETE optics concept *Astropart.Phys.* 72 (2016) 46-54

### Keys for FOV of 60x10deg<sup>2</sup>:

- Thoroidal section as primary dish
- Curved rectangular camera
- Different camera regions see different mirror regions



M. Doro - Trinity - Latin American Webinars on Physics 2021

## TRINTY DESGN

Based on J. Cortina et al., Astrop. Physics 72 (2016) 46

#### FoV 5° X 60°.

- 5.6 m focal length.
- 68 m<sup>2</sup> mirror area  $\rightarrow$  **16 m<sup>2</sup>** in any direction.

#### • 0.3° optical PSF.

- 3,300 pixel camera.
- 20 mm Winston cones coupled to **9 mm SiPMs**.
- Thin-glass replica mirror technology ~\$2k/m<sup>2</sup>.
- Implementation based on MAGIC structure.
- Rotates in elevation.
- \$170k for one telescope.
- \$330k for one camera.











## AN ARRAY OF THEM



- Each telescope has 60deg wide FOV:
- Array of of <=6 telescopes to cover entire horizon
- Mountain peak and arranged in a circle
- Sensitivity computed for 3x such installations over different sites





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### FRENDS AND FOES

#### Georgia Tech







- Prof. Nepomuk Otte Prof. Ignacio Taboada
- Dr. Mahdi Bagheri
- Dr. Mariia Fedkevych
- Dr. Mathew Potts
- Graduate Student Jordan Bogdan
- Graduate Student Eliza Gazda
- Graduate Student Sofia Stepanoff
- Graduate Student Oscar Romero Matamala
- Undergraduate Srikar Gadamsetty
- Prof. Anthony Brown
- Prof. Dave Kieda
- Prof. Wayne Springer
- Prof. Michele Doro
- Prof. Mosè Mariotti

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Trinity The Extreme Neutrino Observatory

Science Technique The Demonstrator Collaboration Publications Contact

### The Trinity Tau Neutrino Observatory

#### Webcams, info, etc+



Indoor Camera



Outdoor Camera





## DEVONSTRATOR FROF OF CONCEPT

- Davies Cotton optics
- 0.75 m<sup>2</sup> mirror area
- 5°x5° field of view
- 256 pixel camera (0.3° resolution)
- 100 MS/s AGET readout











https://www.youtube.com/watch?v=Qp5-jweuQBc

- Facility with optical telescopes funded by Ekkels, managed by W.
   Springer and D. Kieda (U. Utah)
- N38 W113, at 3,000 m asl, about 1,500 m above the surrounding terrain



### DO/E





- Funded by NSF grant PHY-2112769 (800k\$, PI N. Otte).
  - NSF MRI calls under prep.
  - Custom-design building built by U. Utah (commercial contractor)

The telescope points towards an azimuth of 280° and one degree above the horizon.



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### DEVONSTRATOR FACTS







- 84 spherical mirrors (1.5f, 15cm) for a total of 0.75 m2 area
- Provided by U. Delaware (J Holder)
- Mirror alignement with drone emitting blue light (see reference)

- SiPM-based camera from SPB2 balloon experiment
- 256 pixel 6x6 mm2
- Curved focal plane
- See ICRC...



### **DEVONSTRATOR FACTS**#2



- 32 Commercial MUSIC board used to set/read 8 SiPMS
- Single SIPM trigger
- Topological SW trigger on FPGA



- ✓ Dome built in 2022
- ✓ Telescopes and subsystem installed in two weekly campaing in 2023
- ✓ All systems check
- ✓ First 'light' in September 2023
- First 'image' under preparation





## DEVONSTRATOR FROF OF CONCEPT





#### demonstrate:

- Atmospheric monitoring
- Long-term stability
- Backgrounds
- Camera concept
- Remote operation
- Analysis
- ...





TXS 0506+056 and NGC 1068 both passing through FOV



- Imaging Cherenkov works for tauneutrinos
- Effective 'volume' is 100/1000x time that of IC, but atmosphere and not ice
- Wide FOV is key
- Simpler design than g-ray IACTs





Full Trinity bridges gap between IC/radio (1-100 PeV)

Demonstrator has good science output forecasts

