

Gamma-ray follow-up observations of dwarf nova AT2021afpi as a possible neutrino counterpart with the VERITAS instrument

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14.01.2022



Transients as gamma-ray sources

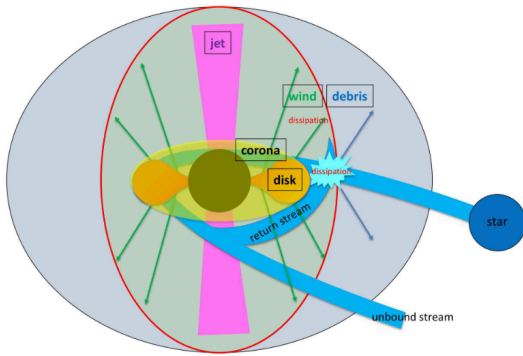
Shock interaction might power optical transients: supernovae, classical novae, TDEs, ...

Classical novae: confirmed γ -ray and expected to be ν sources

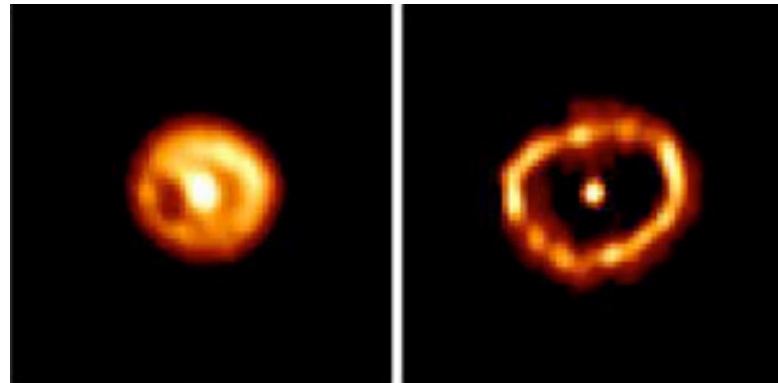
(Ackermann et al. 2014, Fang et al. 2020)

2020 -> VHE γ -ray emission from recurrent nova RS Ophiuchi was detected by H.E.S.S.

ν alert -> follow-up observations to identify a possible astrophysical source
(perhaps a shock-powered transient source)

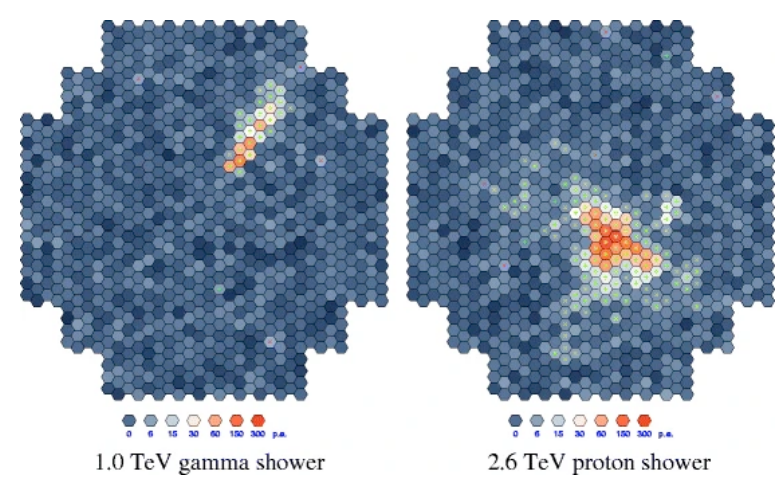
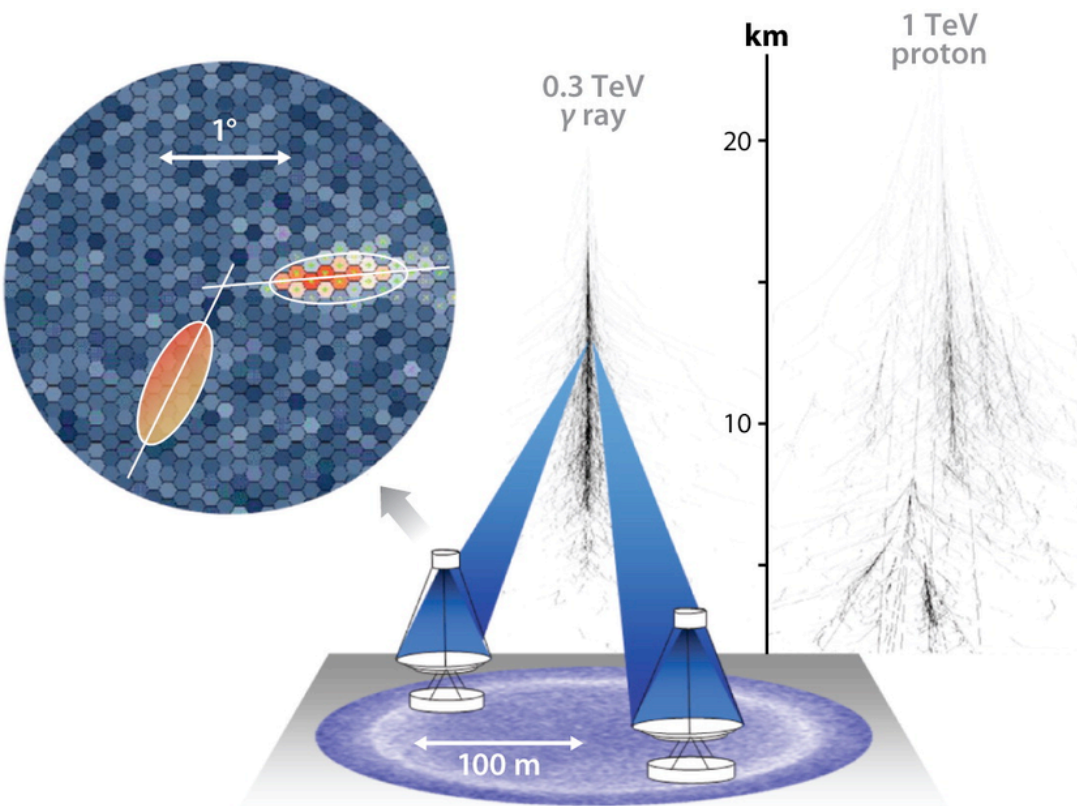


Schematic picture of neutrino and gamma-ray production, Murase, 2020.

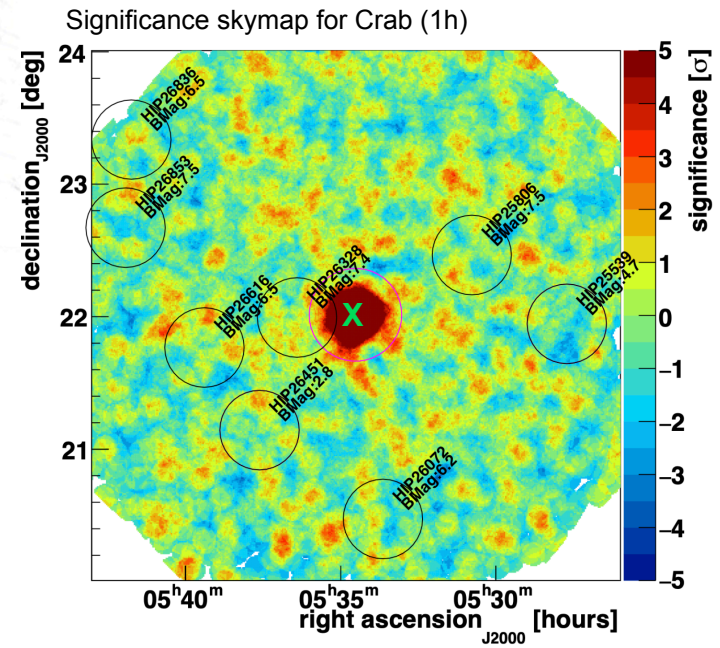


Evolution of the shell of material around Nova Cygni 1992. F. Paresce, R. Jędrzejewski, NASA/STScI/ESA

Imaging Air Cherenkov Technique: indirect detection of gamma-rays



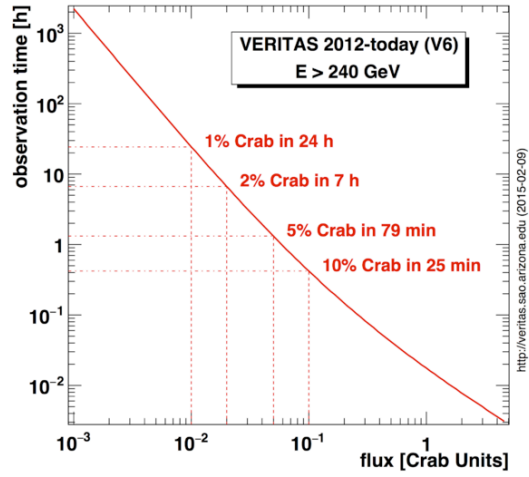
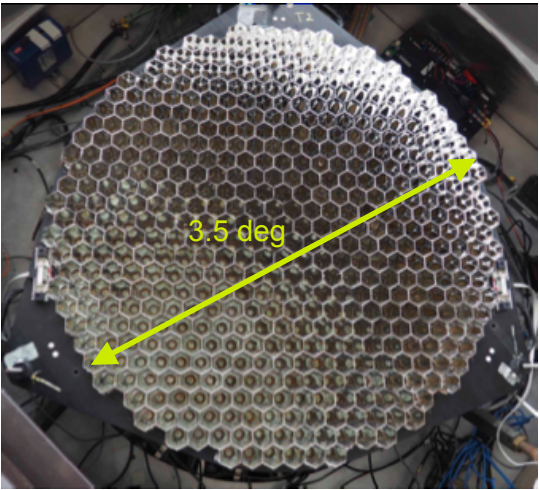
DOI: <https://doi.org/10.1007/s10686-009-9151-z>



DOI: 10.1146/annurev-astro-082708-101816

The VERITAS array: a ground-based gamma-ray instrument

Sensitivity: 1% of Crab ~ 24h
Energy range: ~ 80 GeV - 30 TeV



The timeline of the searches for counterparts

- **25.11 GCN 31226: IceCube-211125A: IceCube obs. HE neutrino candidate**
- **27.11 #15067 AT2021afpi / MASTER OT J030227.28+191754.5/ (10 mag), initially classified as a classical nova**
- 29.11 #15074 Okayama Observatory confirms WZ Sge-type DN
- **29.11 #15076 flaring AGN coincident with IceCube ν (BL Lac - 4FGL 0258+2030)**
- 30.11 #15078 VERITAS observations of AT2021afpi
- 1.12 #15081 Schmidt telescope -> pre-discovery of AT2021afpi 8.5 h before ν
 - probably unrelated to the neutrino event.

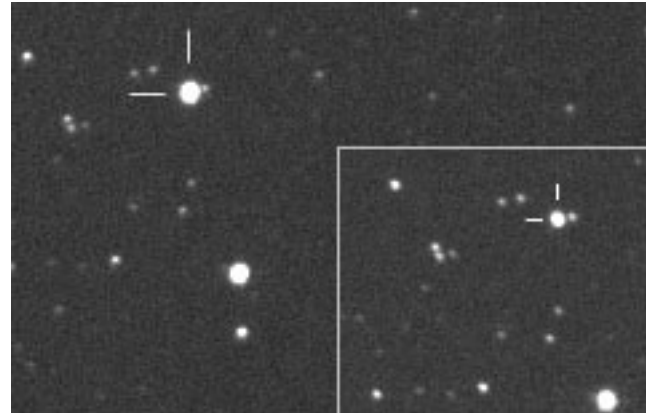
Dwarf Novae vs Classical Novae

Dwarf novae:

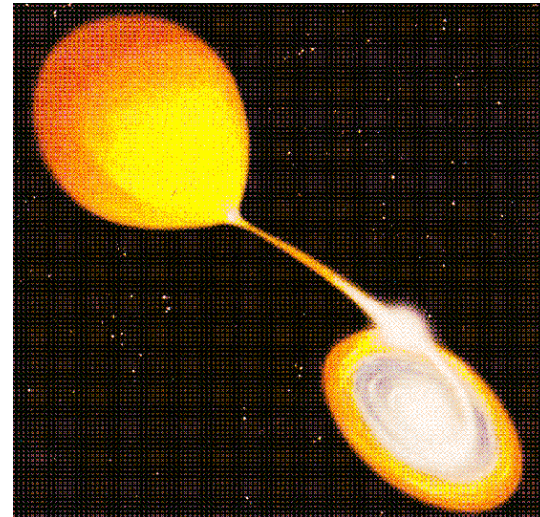
- dimmer (2 to 6 mag)
- instabilities in the accretion disk
(increase in luminosity)
- no acc. HE / no HE ν expected

Classical nova:

- brighter (6 to 19 mag)
- thermonuclear reaction
H from surface (shell)
- confirmed γ / expected ν sources



WZ Sge -- Cataclysmic Variable Star, Simbad



Dana Berry and the Astronomical Visualization Laboratory at the Space Telescope Science Institute.

VERITAS observations of AT2021afpi

Summary of run with duration = 30 min

Run Summary

Run Number: 100617; Run Type: observing; Weather: A

Run Start: 2021-11-28 05:45:45.000000000 (59546.24010)

Run Duration [min:sec]: 30:1

Observation: MASTER OT J030227.28+191754.5 / wobble

Offset (RA, Dec) [deg]: (0.00, 0.50)

Participating Telescopes: T1 T2 T3 T4

Events found: 711361

Elapsed Time L3 [sec]: 1800.3

Live Time L3 [sec]: 1538.2 (85.44%); Mean Rate [Hz]: 462.5

Mean Elevation [deg]: 78.06

Mean RA, Dec [deg]: 45.62, 19.80

- 1st brightening report of AT2021afpi: 27/11/2021
- 1st day of VERITAS obs.: 28/11/2021
- 11 runs of 30 min each:
total usable time: 5h29min

VERITAS observations of 4FGL J0258+2030

Summary of run with duration = 30 min

Run Summary

Run Number: 100668; Run Type: observing; Weather: B

Run Start: 2021-11-30 05:34:45.000000000 (59548.23247)

Run Duration [min:sec]: 30:1

Observation: 4FGL J0258.1+2030 / wobble

Offset (RA, Dec) [deg]: (0.00, 0.50)

Participating Telescopes: T1 T2 T3 T4

Events found: 685724

Elapsed Time L3 [sec]: 1800.3

Live Time L3 [sec]: 1537.0 (85.37%); Mean Rate [Hz]: 446.1

Mean Elevation [deg]: 79.28

Mean RA, Dec [deg]: 44.54, 21.00

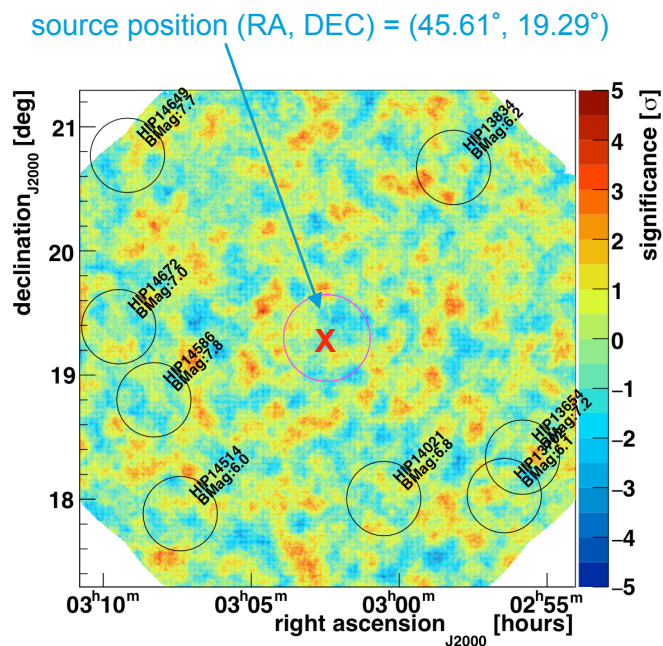
- 1st flaring report: 29/11/2021
- 1st day of VERITAS obs.: 30/11/2021
- 2 runs of 30 min each:
total usable time: 1h

Upper flux limits for AT2021afpi analysis

Analysis results:

Significance: -2.0

Upper Flux Limit: $F(E > 0.300 \text{ TeV}, 99\% \text{ C. L.}) [\text{cm}^{-2} \text{ s}^{-1}]$: $1.08\text{e-}12$



NO_n: 47, NO_{ff}: 381

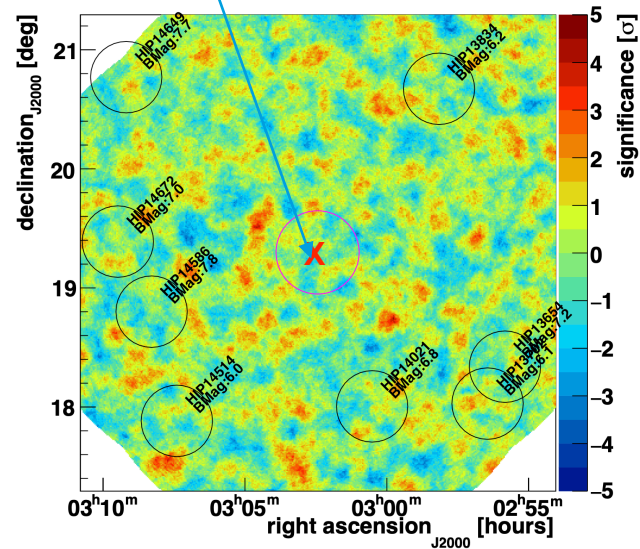
Upper flux limits for AT2021afpi + 4FGL 0258+2030

Analysis results:

Significance: -1.7

Upper Flux Limit: $F(E > 0.300 \text{ TeV}, 99 \% \text{ C. L.}) [\text{cm}^{-2} \text{ s}^{-1}]$: $1.19\text{e-}12$

analysis target position at AT2021afpi (RA, DEC) = (45.61°, 19.29°)

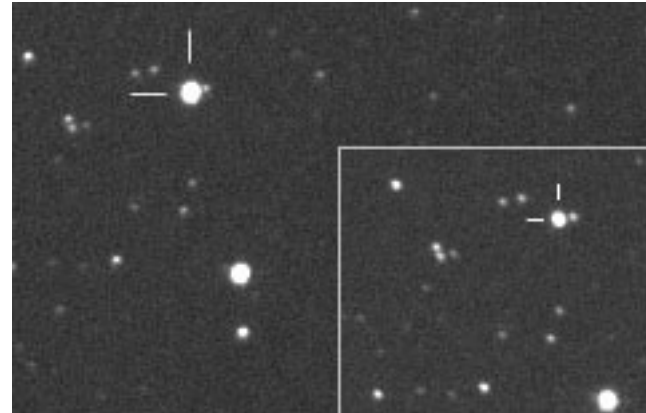


NO_n: 53, NO_{ff}: 487

Conclusions

- AT2021afpi:
 - temporal coincidence with IC20211125A
 - outside of the 90% C.R. of IC20211125A
 - no strong evidence they are correlated (pre-discovery hours before the detection of IC20211125A)
 - no signal detection from VERITAS observation (5h30 exp)
- 4FGL 0258+2030:
 - inside 90% C.R. reported by IceCube
 - 1h exposure lead to no detection
 - combined analysis with AT2021afpi lead to no detection
- Importance of fast alert system in transient astrophysics:
 - classification is an important information when allocating telescope obs. time
 - transient astrophysics is a multi messenger approach: follow up observations might lead to a unique discovery in the gamma-ray spectrum.

Thank you



WZ Sge -- Cataclysmic Variable Star, Simbad

WZ Age-Type Dwarf Novae:

- presence of periodic brightness variations
- long or multiple rebrightenings

Contact

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