CTA-pol

Optical Blazar Polarimetry from Australia

Nick Tothill, Western Sydney University

for CTA-Oz

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A sample result

Astronomer's Telegram 16381, 2023 Dec 15
'First Detection of VHE gamma-ray emission from FSRQ OP 313 with LST-1'

- most distant AGN ($z \approx 1$) detected at VHE ($\geq$ 100 GeV) gamma-ray energy
- LST-1 is the first stage of the Cherenkov Telescope Array
  - 'Large Size Telescope', 23 m IACT
  - La Palma, Canaries
  - Southern array going to Paranal

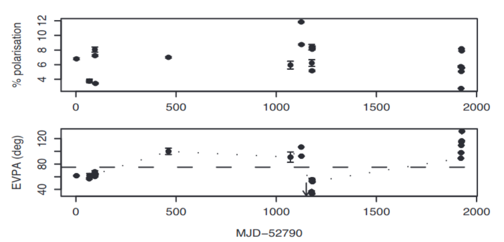
Astronomer's Telegram 16360, 2023 Dec 04
'Optical follow-up of the gamma-ray flare of the blazar OP 313 reveals a bright state with high polarization degree'

- DIPOL-1 polarimeter on Sierra Nevada Obs 0.9m telescope
- linear polarisation up to 22%

Blazars

Blazars consitute most of the (known) extragalactic TeV population

- Bright across entire spectrum
- Highly variable
- lots of non-thermal (i.e. synchrotron) emission

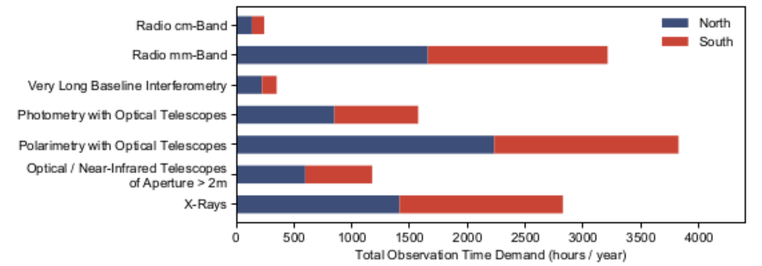


(Barres de Almeida et al 2009, ICRC)

Synchrotron emission is strongly polarised, so optical polarisation sees the non-thermal emission well.
Blazars are highly polarised in optical emission.

The CTA Science Programme

- CTA will be a northern and a southern array, seeing blazars over the whole sky.
- The CTA AGN KSP will monitor some blazars, but not all.
- CTA will also expand the TeV blazar population
- Optical polarimetry is important to complement TeV detections of flaring
- Optical polarimetry can spot a flare occuring and generate an alert to CTA
- Programme of blazar monitoring for as many sources as possible with polarimetry (and maybe other stuff).
- N hemisphere is full of small to medium-size telescopes available for monitoring, eg RoboPol (Crete); Liverpool Telescope (Canaries)...
- Plan to site a 1m-class optical telescope with polarimetry on CTA-South site.
- More will be needed, and greater time coverage helps.



3800 h/year = 1.3 FTE

Polarisation — a guide for the forgetful

- Polarisation is a *statistical* property of electromagnetic radiation.
- (forget about circular polarisation — linear only)
- *Natural light* (most light in the universe) is unpolarised or (more accurately) randomly polarised

$$\overline{E_x} = \overline{E_y}$$

  with propagation along z, averaged over time

- *partially linearly polarised* light

$$\overline{E_x} > \overline{E_y}$$

  with degree of polarisation

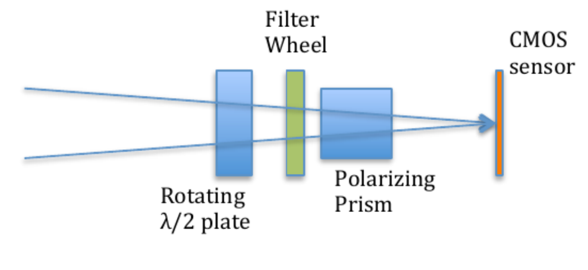
$$P = \frac{I_x - I_y}{I_x + I_y}$$

  ($I_x \propto E_x^2$)

Polarimetry with incoherent detection

- measure the intensity of light in the two different plane polarisations, calculate P
- Wollaston prism splits light into two beams with orthogonal polarisation, so two images
    - unknown polarisation direction
    - differences in brightness caused by other effects
- Use a *half-wave plate* ($\lambda/2$) or *retarder*: When the plate is rotated by ϕ, the polarisation plane is rotated by 2ϕ.
- Rotate the $\lambda/2$ plate:
    - one image will be a bit brighter
    - maximum brightness difference when $\lambda/2$ rotates the polarisation direction with more light onto the Wollaston prism's preferred direction
    - zero brightness difference when Wollaston prism's preferred direction is 45° from plane of polarisation.
    - sinusoidal change in brightness difference

PICSARR $\rightarrow$ CTA-pol



PICSARR is a high-precision stellar polarimeter (Bailey et al., 2023[a])
Design goals: bright stars with very high precision
Fast-rotating retarder; sCMOS camera.

[a] https://doi.org/10.1093/mnras/stad271

CTApol design goals: faint sources with high polarisation:
stepper motor driving retarder;
slow steps;
higher-performance camera

Design, Fabrication, Testing

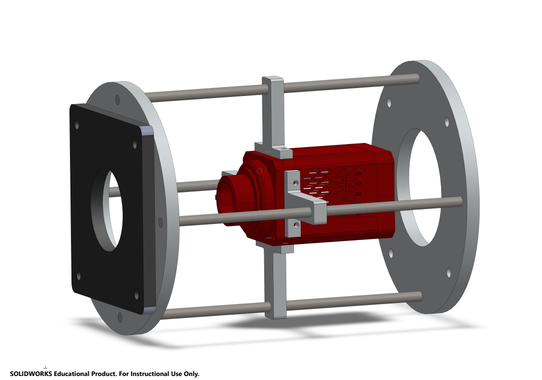
- Camera: Andor Marana 11μm pixels
- half-wave plate: Bernhard Halle
- wollaston prism: Bernhard Halle quartz 1deg sep
- filters: Chroma SDSS *ugriz*

Development, testing, commissioning on Western Sydney University Penrith Observatory 0.6 m telescope.[1]

▫IMG20231103133325040.png

[1] R-C reflective optics, equatorial mount, cassegrain focus

Initial testing



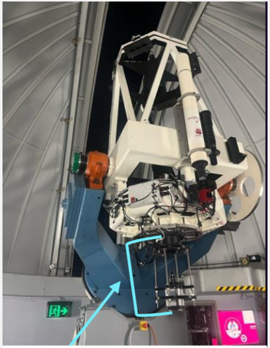
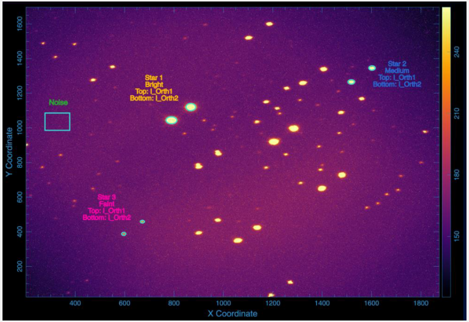
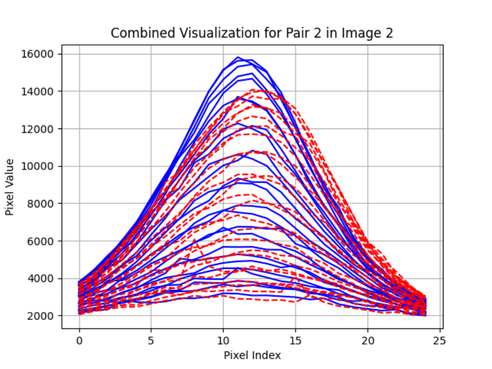


Figure 3: CTA-Pol Attached to WSU 0.6m Telescope

(Courtesy N. Novaretti)

Initial results





Left: a star field (N. Novaretti); Right: comparison of two polarisations (A. Al-khalailah)

Next steps — Summer 2024–5

Mount stepper-motor/retarder in instrument

Drive retarder with stepper motor — JB's board

fiducial for retarder — magnetic sensor on stepper

Design and fabricate 'stage 1' — WSUPO

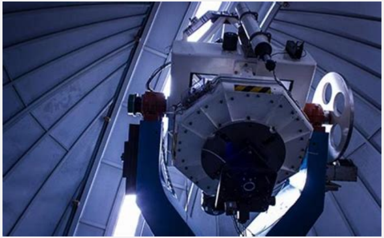
Design interface structure — ANU

Test observations to fainter stars → Test observations brightest blazars

Next stages

- Commissioning on 2.3m ANU telescope[a], Siding Spring as visiting instrument.
- Commissioning on other telescopes
- Development and construction of 2nd generation instrument to act as facility instrument integrated with 2.3 m
- Development and construction of a 'CTA-Pol-lite' for other facilities

[a]altaz mount, cassegrain focus under development



Elephants in the Room

- Software — polarimetry data collection and analysis
- Software — integration with ANU control systems
- Integration with information infrastructure for transients

Funding

LE21 — Funding for construction of CTA-Pol;
ends October 2025
LE25 — Funding for further development of CTA-Pol;
2025–2029
Funded!

CTA-Oz and CTApol

- WSU: NFHT, Ain De Horta, Darren Maybour, Miroslav Filipovic
- WSU students: Luke Dickson, Hryan Raj, Nastasia Novaretti, Zachary Smeaton, Ahmad Al-khalailah, Isabel Rahme…
- UNSW: Jeremy Bailey
- MIRA: Daniel Cotton
- Adelaide: Gavin Rowell

CTA-Oz Consortium

Adelaide

ANU

Curtin

Monash

UNSW

Sydney

Western Sydney