CTA-Pol update

Nick Tothill

CTA-Pol:
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UNSW: Jeremy Bailey;
MIRA: Daniel Cotton;
Adelaide: Gavin Rowell.

2022-XI-30

Outline

1. Rationale
2. Project Outline
3. Progress
4. Preliminary Design
5. Next actions

Rationale

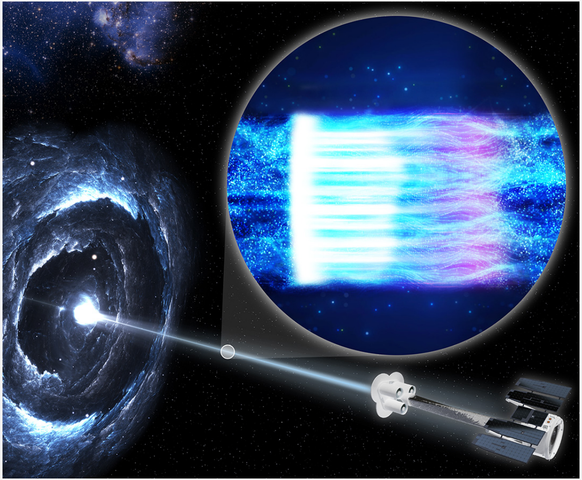
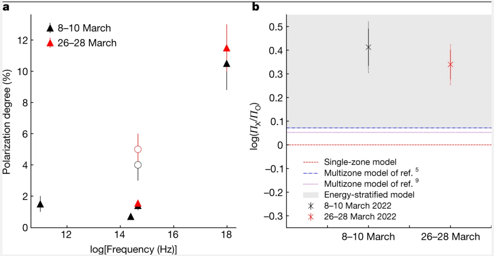
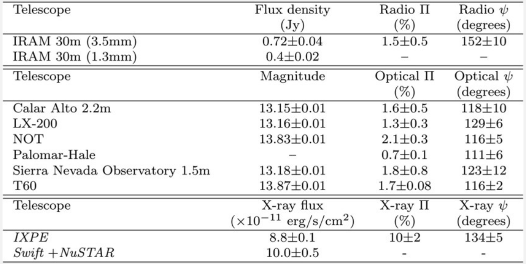


Image: NASA/Pablo Garcia

Blazars consitute most of the (known) extragalactic TeV population — and are bright across the entire EM spectrum. 23-xi-2022 (a week ago): Liodakis et al, Nature 611:677–681: *”Polarized blazar X-rays imply particle acceleration in shocks,”*

Mrk 501 Observing Campaign





Telescope	Flux density (Jy)	Radio Π (%)	Radio ψ (degrees)
IRAM 30m (3.5mm)	0.72±0.04	1.5±0.5	152±10
IRAM 30m (1.3mm)	0.4±0.02	–	–
Telescope	Magnitude	Optical Π (%)	Optical ψ (degrees)
Calar Alto 2.2m	13.15±0.01	1.6±0.5	118±10
LX-200	13.16±0.01	1.3±0.3	129±6
NOT	13.83±0.01	2.1±0.3	116±5
Palomar-Hale	–	0.7±0.1	111±6
Sierra Nevada Observatory 1.5m	13.18±0.01	1.8±0.8	123±12
T60	13.87±0.01	1.7±0.08	116±2
Telescope	X-ray flux ($\times 10^{-11}$ erg/s/cm^2)	X-ray Π (%)	X-ray ψ (degrees)
IXPE	8.8±0.1	10±2	134±5
Swift +*NuSTAR*	10.0±0.5	-	-

From Liodakis et al. (2022). The ratio of X-ray to optical polarisation fraction supports a shock model.

Mrk 501 is at $\delta \approx 40^\circ$.

Calar Alto & Sierra Nevada Observatory: 37° N

Palomar: 33° N

La Palma (NOT): 29° N

Haleakalā (T60): 21° N

Lots of polarimeters in the north — not much in the south!

Project outline — 1

- Build a simple polarimeter to operate on small- to medium-sized telescopes in Oz
    1. ANU 2.3 m, Siding Spring (primary)
    2. Zadko 1 m, WA (in discussions, $f/4$)
    3. UTas 1.2 m, Tas (preliminary discussions)
    4. WSU 0.6 m, Penrith (testing)
    5. +…

Project outline — 2

- This will allow us to contribute multi-wavelength follow-up to CTA
- Polarimeter based on Jeremy Bailey’s PICSARR design, which is an iteration of the HIPPI family of polarimeters.
- Funded by LIEF
    1. ARC funding (not for people)
    2. Institution funding (for people)
- Building a *prototype*

Progress

MoU signed with ANU/MSSSO

- initial 2.3 m access for prototype commissioning and early science
- a later version may be accepted as a facility instrument (new funding required)

Latest LIEFs

- automation of 2.3 m makes it far more suitable for CTA-pol
- upgrade of Zadko

Winter scholarships at WSU

- Started doing some basic blazar imaging, using WSU and LCO
- We hope to continue in 2023

Preliminary design work ongoing.

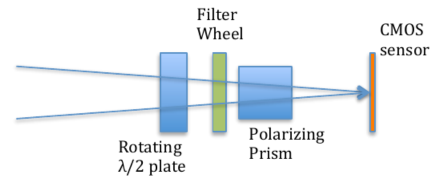
Conceptual Design

Incoming light is a mixture of elliptically polarised and unpolarised — we can assume that the elliptical component is actually linear, at arbitrary position angle ψ: $I = I_u + I\Pi_\psi$

It first hits a half-wave plate ($\lambda/2$ plate, retarder). Rotate the retarder by θ, and the linear PA changes by 2θ.

The Wollaston prism separates the incoming light into two separate beams with orthogonal linear polarisation (directions defined by the WP).

So we get two images on the CMOS, one from each polarisation.



When the plate is rotated so that the linear component is parallel to one of the axes of the prism, all of that polarised light will go into one image.

Difference in images will vary sinusoidally.

Preliminary Design

ANU 2.3 m f/8 Cassegrain; focal length = 18.4m; plate scale = 11.2 arcsec / mm
A 2-arcsec diameter image will have a diameter of about 180μm
Mrk 501 has $m \approx 13$.
For $V = 13$, about 2×10^5 photons per second arrive from Mrk 501,
distributed over about 200 10μm pixels.
Each pixel gets $\sim 10^3$ photons per second.
Polarisation signal will be a few to 10s of photons.
Need large pixels, low read noise (few e^-), good QE.
Each measurement (at a given angle of $\lambda/2$ plate) will take 1 s to 1 m.
Continuous rotation bad; use a stepper motor.

Cameras etc.

sCMOS cameras:

- low read noise
- fast readout
- big pixels (10μm now available)
- high QE (back-illuminated now available)

$\lambda/2$ plate (aka retarder) and Wollaston prism are (just about) COTS

The GSense 400 BSI sensor does all of this.
Cameras:

- Andor Marana 4B-11 AUD65k
- Teledyne KURO 1200 AUD37k
- FLI AUD32k?
- QHY42Pro BSI AUD24k

More expensive cameras are better engineered.
Cheaper cameras may be easier to prototype.
Lead times are an issue.

CTA-Pol Next Steps

- finalise design from PICSARR
- Quote and purchase key components
- recruit personnel
- build
- commission, test on WSU 0.6m telescope
- commission, demonstration science on 2.3 m
  - requires cassegrain focus
- discussions with other telescopes

CTA-Oz Consortium

Adelaide

ANU

Curtin

Monash

UNSW

Sydney

Western Sydney