CTA-Pol update

Nick Tothill

CTA-Pol:
WSU: Nick Tothill, Ain De Horta, Darren Maybour, Miroslav Filipovic;
UNSW: Jeremy Bailey;
MIRA: Daniel Cotton;
Adelaide: Gavin Rowell.

2023-IV-13

Outline

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

Rationale

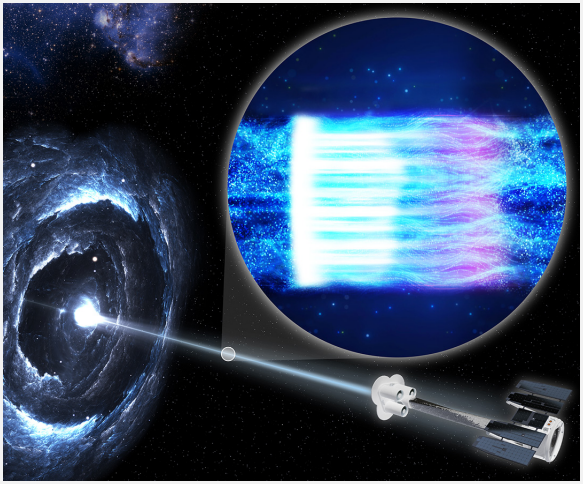
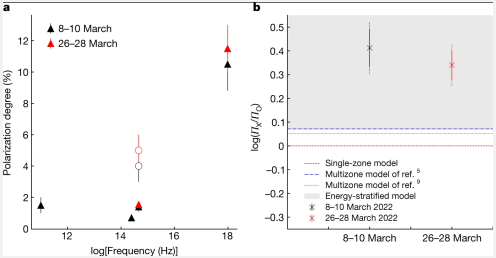


Image: NASA/Pablo Garcia

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 $\delta \approx 40°$.

Calar Alto & Sierra Nevada Observatory: 37° N

Palomar: 33° N

La Palma (NOT): 29° N

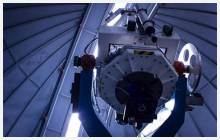
Haleakalā (T60): 21° N

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

Personnel

- Luck Dickson is doing a project this semester
- Contract for Darren Maybour being procured

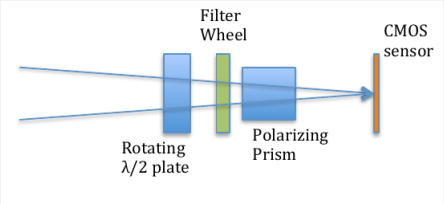
Design work ongoing.

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.
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.

Bill of Materials

sCMOS camera:

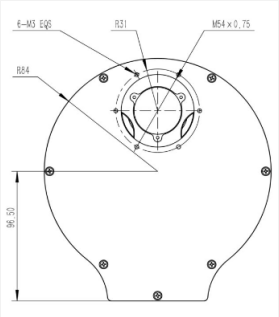
- low read noise
- fast readout
- big pixels (10μm now available)
- high QE (back-illuminated now available)

Andor Marana 4B-11 (AUD65k) uses the GSense 400 BSI sensor

Polarising Optics:
Half-wave plate: B-Halle RSU 1.2.25
MgF_2; 600–2700 nm
Wollaston Prism: B-Halle PWQ 60.25
Quartz; 230–2800 nm; 1° beam separation
Stepper motor: Faulhaber DM66-200
Rotation stage: Thorlabs HDR50/M

Bill of Materials

Filters: Chroma.com *ugriz* Sloan filters
(USD1175+120S& H)
1.25 in threaded
Filter wheel — candidate:
QHY CFW3S-US
This should control the problem of filter wheel rotation



Preliminary Design

	ANU 2.3m Cassegrain	WSU 0.6m Ritchey-Chretien
Focal length	18.4m ($f/8$)	6.24m ($f/10.4$)
Plate scale	11.2″ / mm	33″ / mm
PSF diameter (2″)	180μm	61μm
PSF area (2″)	200 pix	30 pix
Mrk 501 ($V \approx 13$)	$\sim 2 \times 10^5$ photons s^{-1}	$\sim 1.4 \times 10^4$ photons s^{-1}
Mrk 501 1 pix	$\sim 10^3$ photons s^{-1} pix^{-1}	~ 500 photons s^{-1} pix^{-1}
Polarisation signal	few to tens	few to tens

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.

Preliminary Design

Wollaston prism splits beams by $\theta = 1^\circ$.
Distance from prism to camera array d, 1–10 cm
Separation of beams on array $d \sin\theta$ = 200 − 2000 μm
Beams will be cleanly separated for separations of few cm.

Parts status

1. Marana on order
   1.1 ETA 15 May 2023
   1.2 we have a loan camera to start work
2. filter set procurement approved
3. polarising optics, stepper motor, rotation stage moving to start procurement
4. filter wheel still under consideration
5. computer resources not procured yet.

CTA-Pol Next Steps

- 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