

# Krytyczne badania relatywistycznych dżetów w blazarach OCRA -Gamma Monitoring + RoboPol

CA UMK Piwnice 3.03.2014



**Krytyczne badania relatywistycznych dżetów w blazarach**

Projekt finansowany przez NCN w latach 2012-2014 490 tys zł

**Główni wykonawcy** (zespoły)

**A.Kus** (TCfA: B.Pazderska, R.Feiler, E.Pazderski)

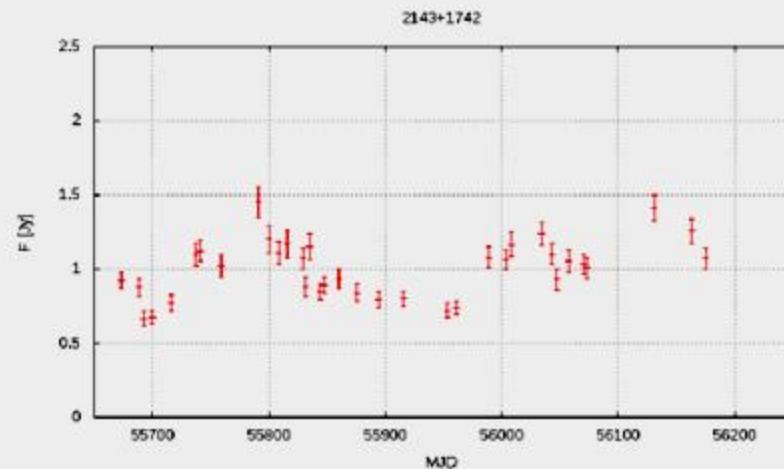
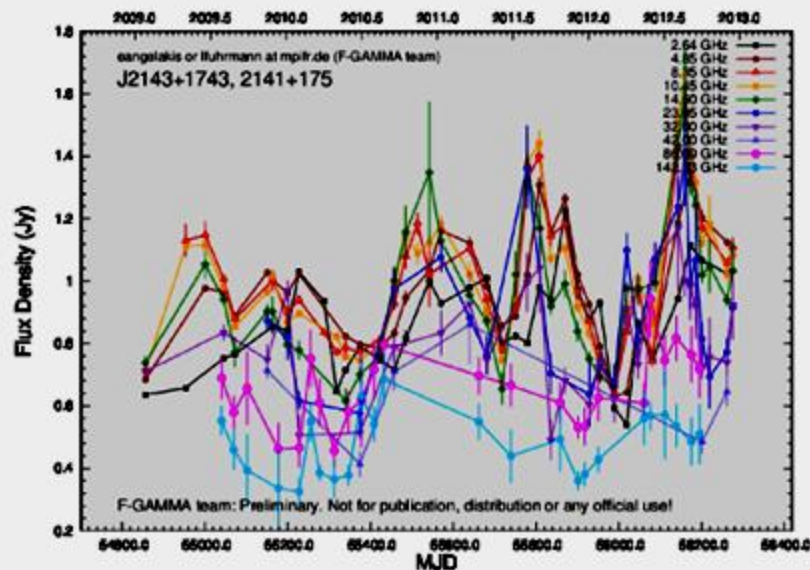
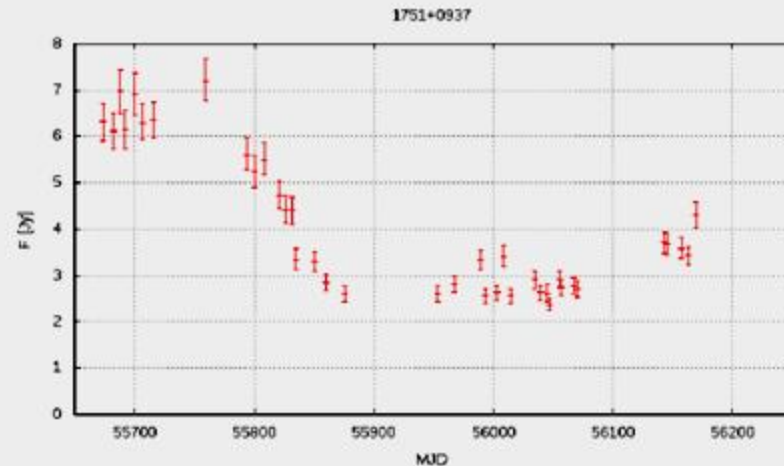
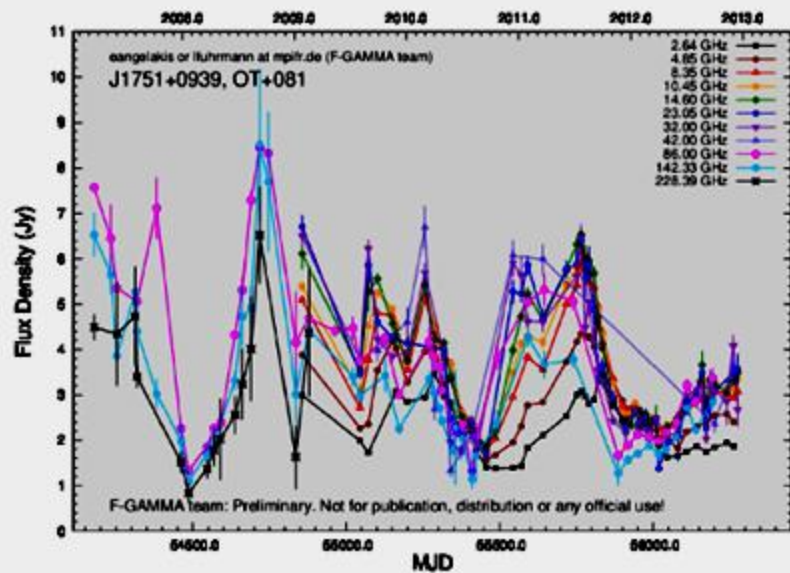
**A.C.Readhead** (Caltech: O.King, T.Pearson, V.Pavlidou - UoC)

**A.Zensus** (MPIfR: L.Fuhrmann, M.Angelakis)

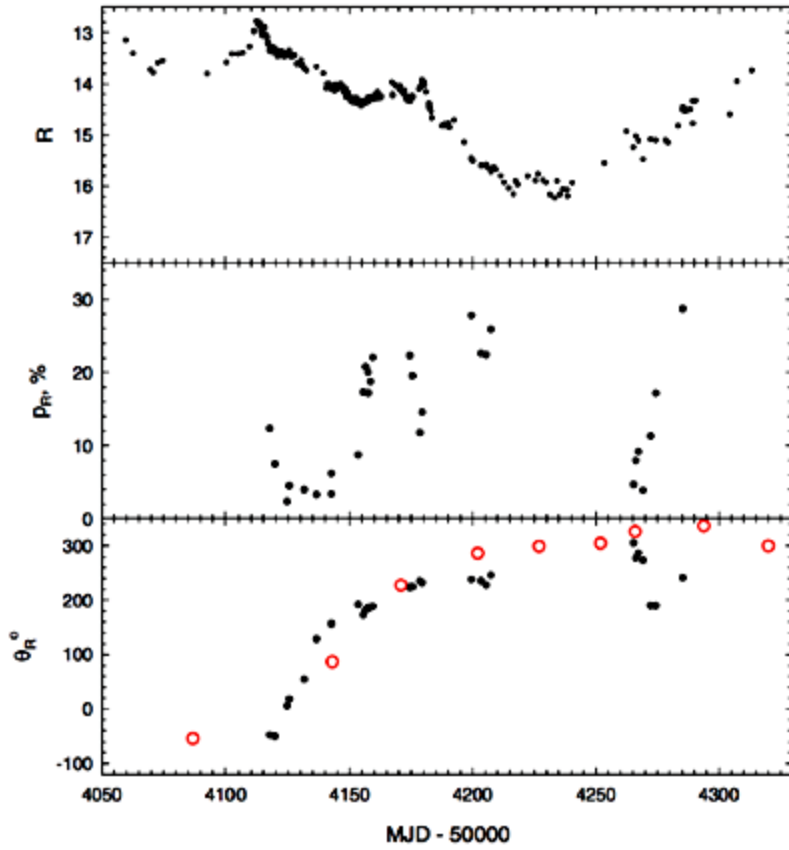
**Zadania:**

1. Wspólne obserwacje przy pomocy RT32m na 30GHz i 22 GHz (polaryzacja) we współpracy z OVRO 15 GHz, Effelebserg 5-18 GHz dla wyselekcjonowanej próbki aktywnych źródeł Fermi
2. Obserwacje polaryzacji w pasmach V i R w podprojekcie **RoboPol**
3. Udział we interpretacji danych i wspólnych publikacjach

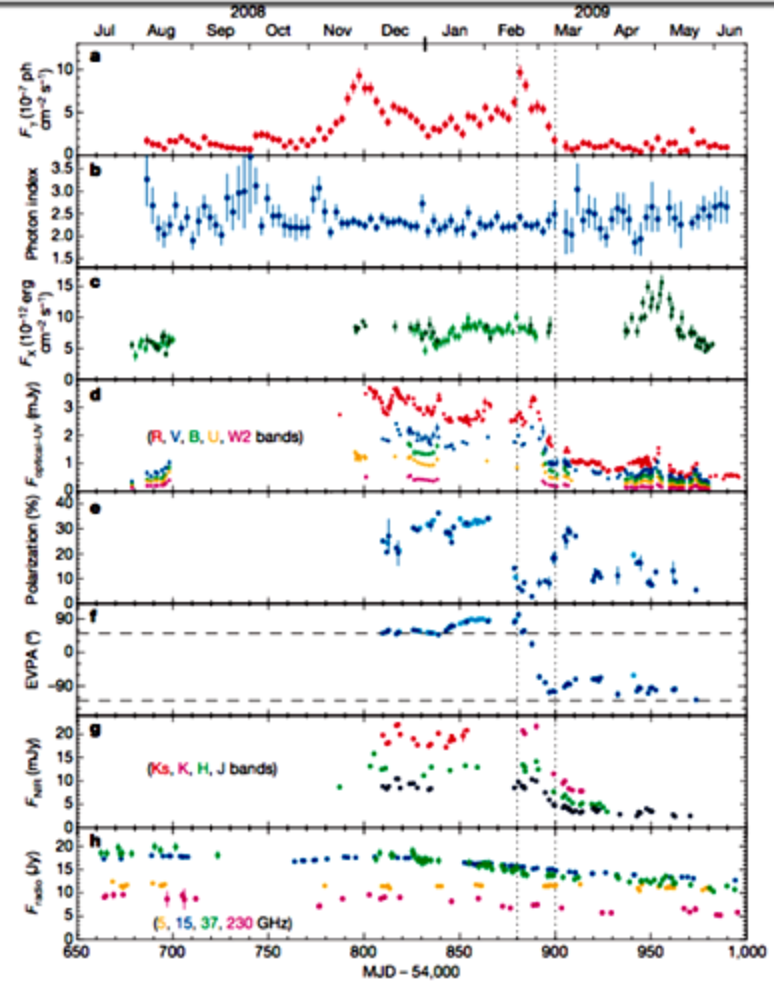
# OCRA light curves vs. MPIfR



wszystkie dane są dostępne dla wykonawców projektu

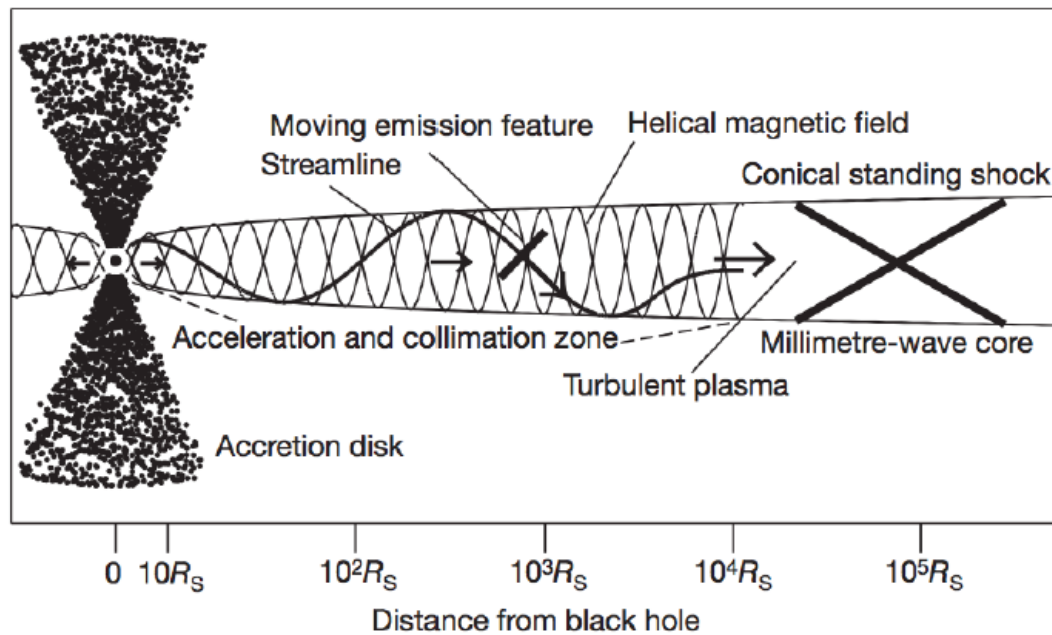


[18] LARIONOV, V. M., JORSTAD, S. G., MARSCHER, A. P., RAITERI, C. M., VILLATA, M., AGUDO, I., ALLER, M. F., ARKHAROV, A. A., ASFANDIYAROV, I. M., BACH, U., BACHEV, R., BERDYUGIN, A., BÖTTCHER, M., BUEMI, C. S., CALCIDESE, P., CAROSATI, D., CHARLOT, P., CHEN, W.-P., DI PAOLA, A., DOLCI, M., DOGRU, S., DOROSHENKO, V. T., EFIMOV, Y. S., ERDEM, A., FRASCA, A., FUHRMANN, L., GIOMMI, P., GLOWIENKA, L., GUPTA, A. C., GURWELL, M. A., HAGEN-THORN, V. A., HSIAO, W.-S., IBRAHIMOV, M. A., JORDAN, B., KAMADA, M., KONSTANTINOVA, T. S., KOPATSKAYA, E. N., KOVALEV, Y. Y., KOVALEV, Y. A., KURTANIDZE, O. M., LÄHTEENMÄKI, A., LANTERI, L., LARIONOVA, L. V., LETO, P., CAMPION, P. L., LEE, C.-U., LINDFORS, E., MARILLI, E., MCHARDY, I., MINGALIEV, M. G., NAZAROV, S. V., NIEPPOLA, E., NILSSON, K., OHLERT, J., PASANEN, M., PORTER, D., PURSIMO, T., ROS, J. A., SADAKANE, K., SADUN, A. C., SERGEEV, S. G., SMITH, N., STRIGACHEV, A., SUMITOMO, N., TAKALO, L. O., TANAKA, K., TRIGILIO, C., UMANA, G., UNGERRECHTS, H., VOLVACH, A., AND YUAN, W. Results of webt, vlba and rxte monitoring of 3c 279 during 2006-2007. *Astronomy and Astrophysics* 492 (Dec 2008), 389.

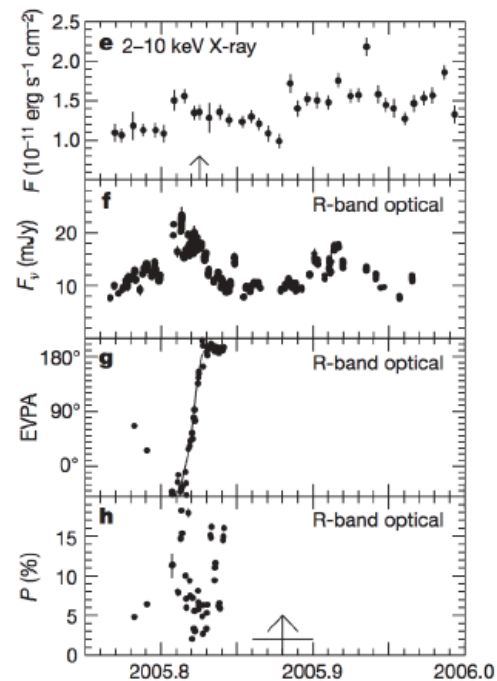


] ABDO, A. A., ACKERMANN, M., AJELLO, M., AXELSSON, M., BALDINI, L., BALLEST, J., BARIPELLINI, G., BASTIERI, D., BAUGHMAN, B. M., BECHTOL, K., BELLAZZINI, R., BERENJI, B., BLANDFORD, R. D., BLOOM, E. D., BOCK, D. C.-J., BOGART, J. R., BONAMENTE, E., BORGAND, A. W., BOUVIER, A., BREGEON, J., BREZ, A., BRIGIDA, M., BRUEL, P., BURNETT, T. H., BUSON, S., CALIANDRO, G. A., CAMERON, R. A., CARAVEO, P. A., CASANDJIAN, J. M., CAVAZZUTI, E., CECCHI, C., ÇELİK, Ö., CHEKHTMAN, A., CHEUNG, C. C., CHIANG, J., CIPRINI, S., CLAUS, R., COHEN-TANUGI, J., COLLMAR, W., COMINSKY, L. R., CONRAD, J., CORBEL, S., CORBET, R., COSTAMANTE, L., CUTINI, S., DERMER, C. D., ANGELIS, A. D., DE PALMA, F., DI-

MCHARDY, I. M., MELNICHUK, D. A., MOMMERT, M., NILSSON, K., DI PAOLA, A., REINTHAL, R., RICHTER, G. M., ROCA-SOGRB, M., ROUSTAZADEH, P., SIGUA, L. A., TAKALO, L. O., TORNIKOSKI, M., TRIGILIO, C., TROITSKY, I. S., UMANA, G., VILLFORTH, C., GRAINGE, K., MODERSKI, R., NALEWAIKO, K., SIKORA, M., COLLABORATION, F.-L., AND OF THE 3C MULTI-BAND CAMPAIGN, M. A change in the optical polarization associated with a -ray flare in the blazar 3c279. *Nature* 463 (Feb 2010), 919.



(a)



(b)

Figure 2: A model (a) and supporting data (b) of the inner jet of BL Lac from [22]. An emission feature is accelerated along a streamline in the helical magnetic field. Its emission comes to dominate the emission from the rest of the jet as it enters the last spiral, and we see the optical polarization angle rotate before the emission feature exits the acceleration and collimation zone. We need to capture a significant number of these polarization flips in order to be able to do rigorous statistics on them and to be sure that selection effects are not biasing our conclusions.

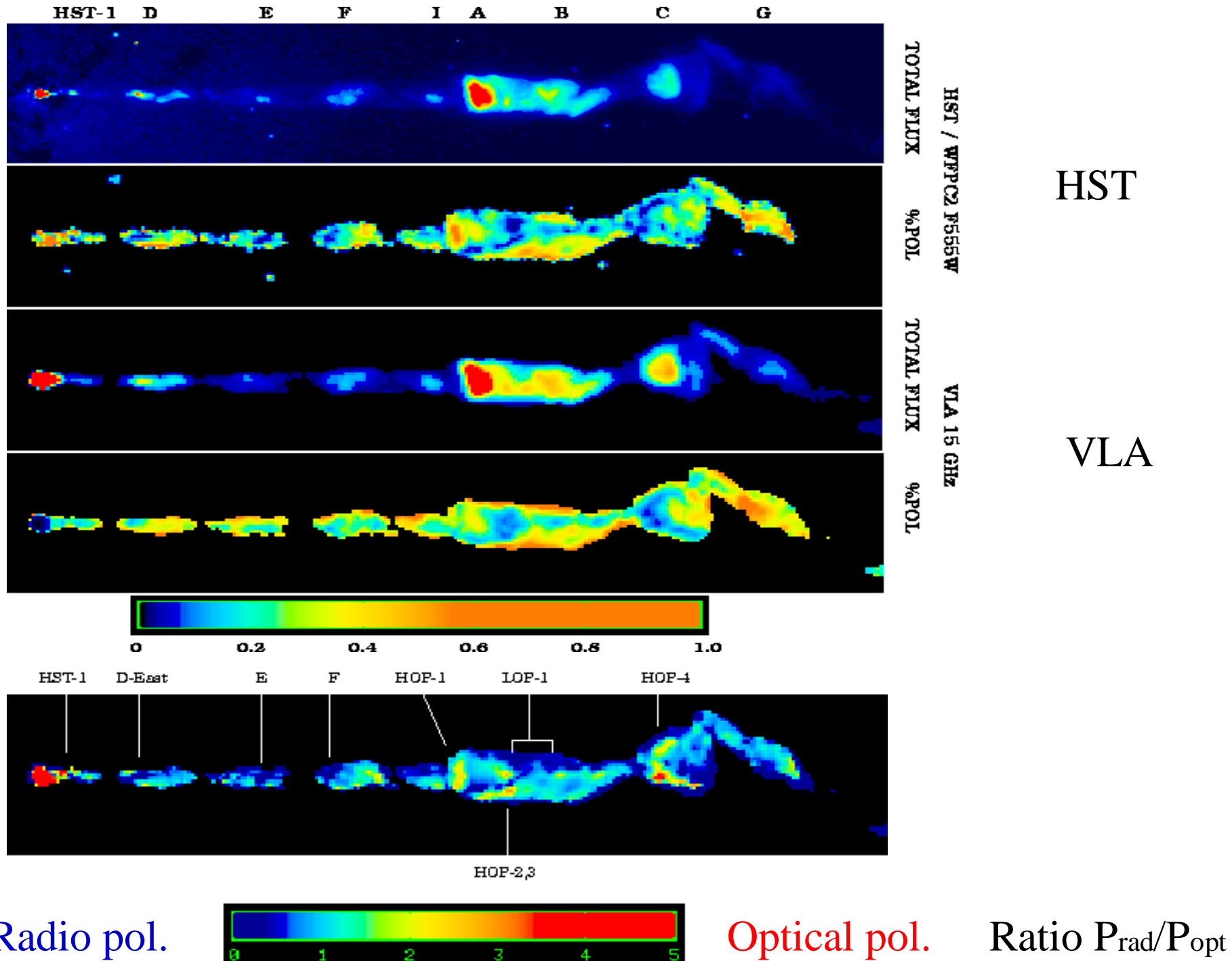
# Optical and Radio Polarimetry of the M87 Jet at $0.2''$ Resolution

Eric S. Perlman, John A. Biretta, Fang Zhou, William B. Sparks, and F. Duccio Macchetto  
Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218

## ABSTRACT

We discuss optical (HST/WFPC2 F555W) and radio (15 GHz VLA) polarimetry observations of the M87 jet taken during 1994-1995. The angular resolution of both of these observations is  $\sim 0.2''$ , which at the distance of M87 corresponds to 15 pc. Many knot regions are very highly polarized ( $\sim 40 - 50\%$ , approaching the theoretical maximum for optically thin synchrotron radiation), suggesting highly ordered magnetic fields. High degrees of polarization are also observed in interknot regions. The optical and radio polarization maps share many similarities, and in both, the magnetic field is largely parallel to the jet, except in the “shock-like” knot regions (parts of HST-1, A, and C), where it becomes perpendicular to the jet.

We do observe significant differences between the radio and optical polarized structures, particularly for bright knots in the inner jet, giving us important insight into the radial structure of the jet. Unlike in the radio, the optical magnetic field position angle becomes perpendicular to the jet at the upstream ends of knots HST-1, D, E and F. Moreover, the optical polarization appears to decrease markedly at the position of the flux maxima in these knots. In contrast, the magnetic field position angle observed in the radio remains parallel to the jet in most of these regions, and the decreases in radio polarization are smaller. More minor differences are seen in other jet regions. Many of the differences between optical and radio polarimetry results can be explained in terms of a model whereby shocks occur in the jet interior, where higher-energy electrons are concentrated and dominate both polarized and unpolarized emissions in the optical, while the radio maps show strong contributions from lower-energy electrons in regions with  $\mathbf{B}$  parallel, near the jet surface.



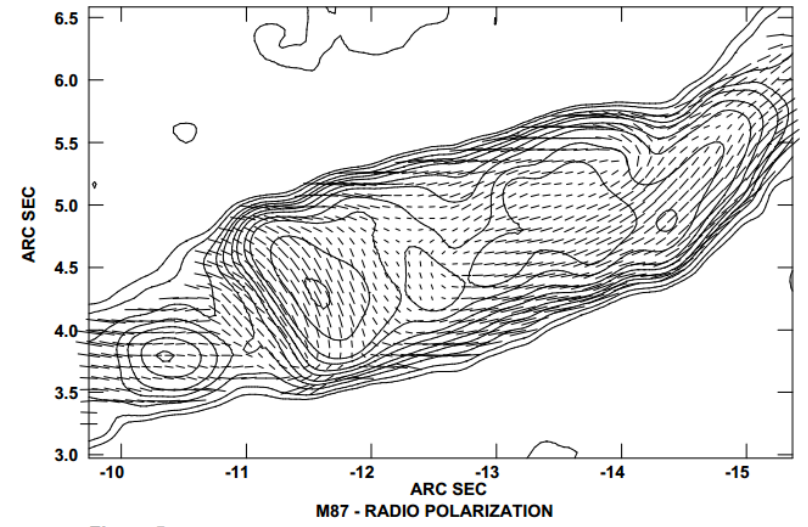
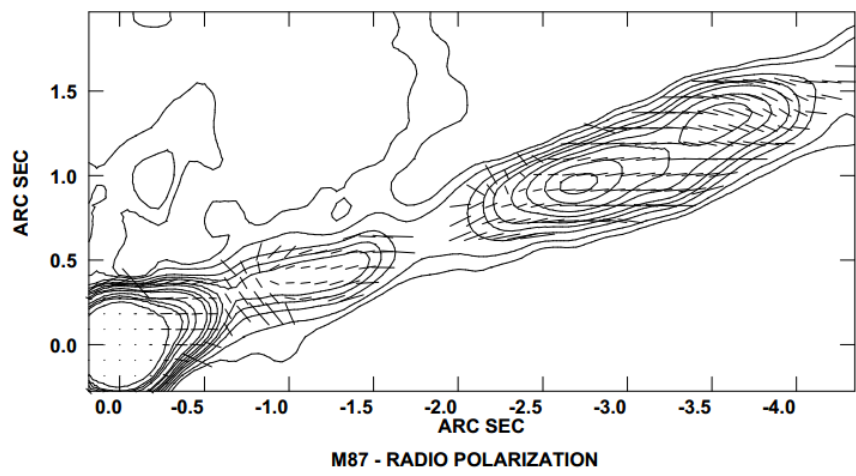
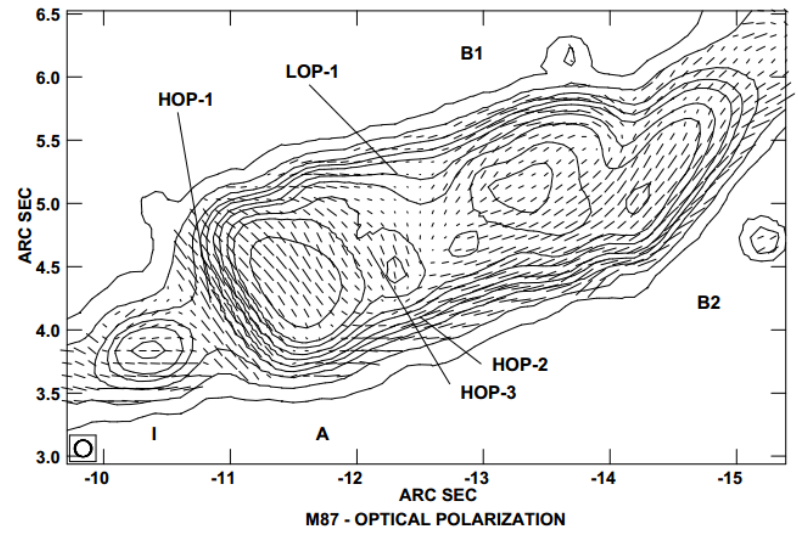
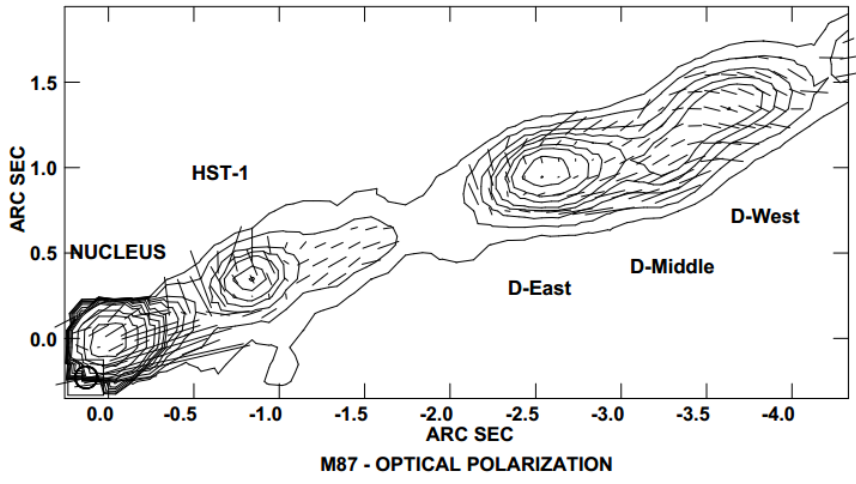
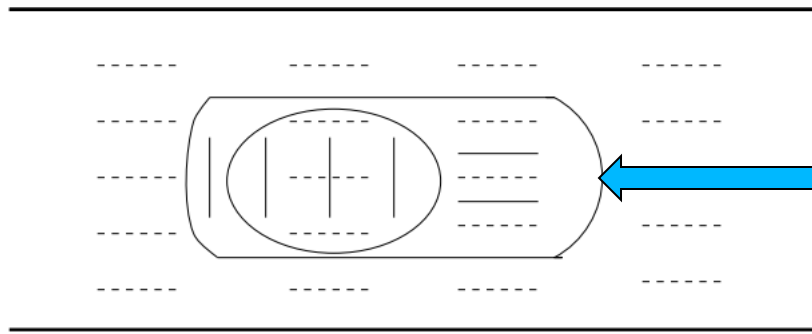


Figure 3

Figure 5

**optical and radio emitting electrons  
are not completely co-located**

### Magnetic Field in M87 Jet and Knots



the optical emitting electrons  
are located closer to the jet axis,

most of the radio emitting electrons are  
located nearer the jet surface (along B)

**Key:**    - - - - -    **Surface of Jet, brightest in radio**  
          — — — — —    **Center of Jet, brightest in optical**

the degree of polarization varies less in the radio than in the optical

at the upstream ends (knots HST-1, D and F), the optical MFPA rotates  
to a direction nearly perpendicular to the jet,

whereas the radio MFPA remains primarily along the jet axis in D and F

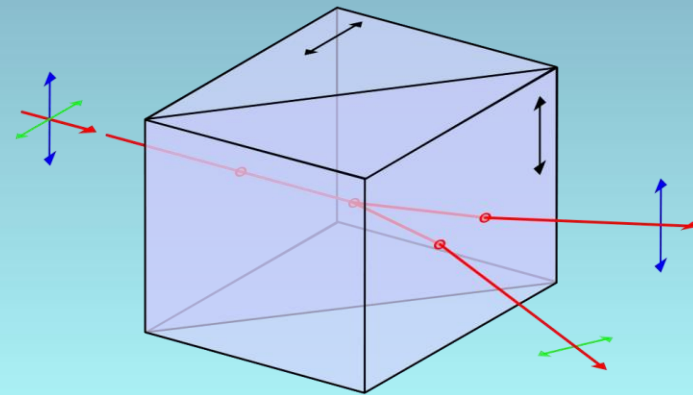
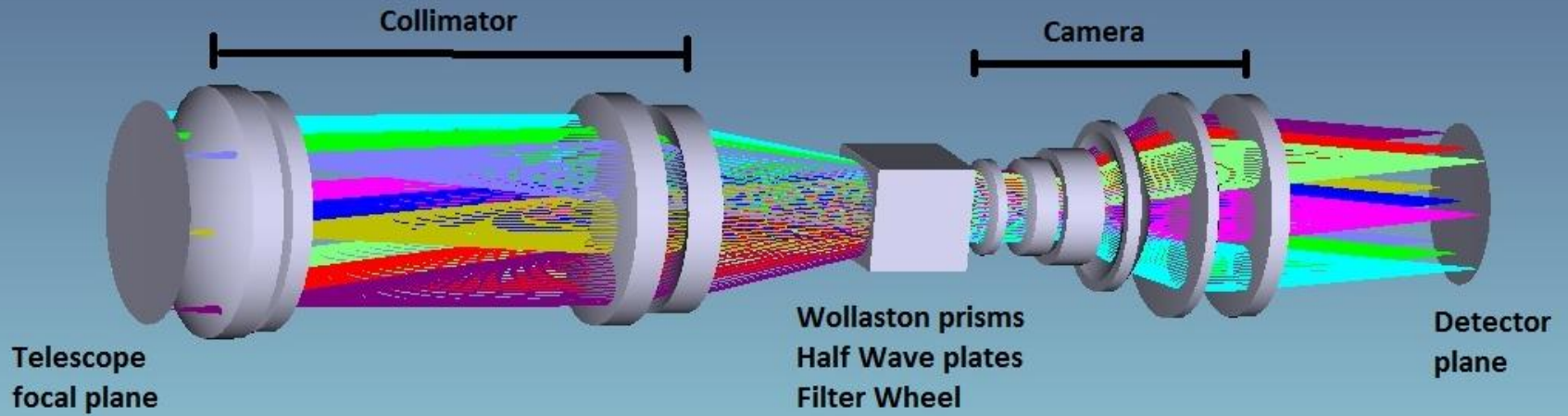
$$\text{MFPA} = 1/2 \times \tan^{-1}(U/Q) + 90^\circ$$

# RoboPol Collaboration Meeting, Pasadena January 2013



# RoboPol Annual Meeting at Torun 29 July - 1 August 2013





A. N. Ramaprakash, IUCAA

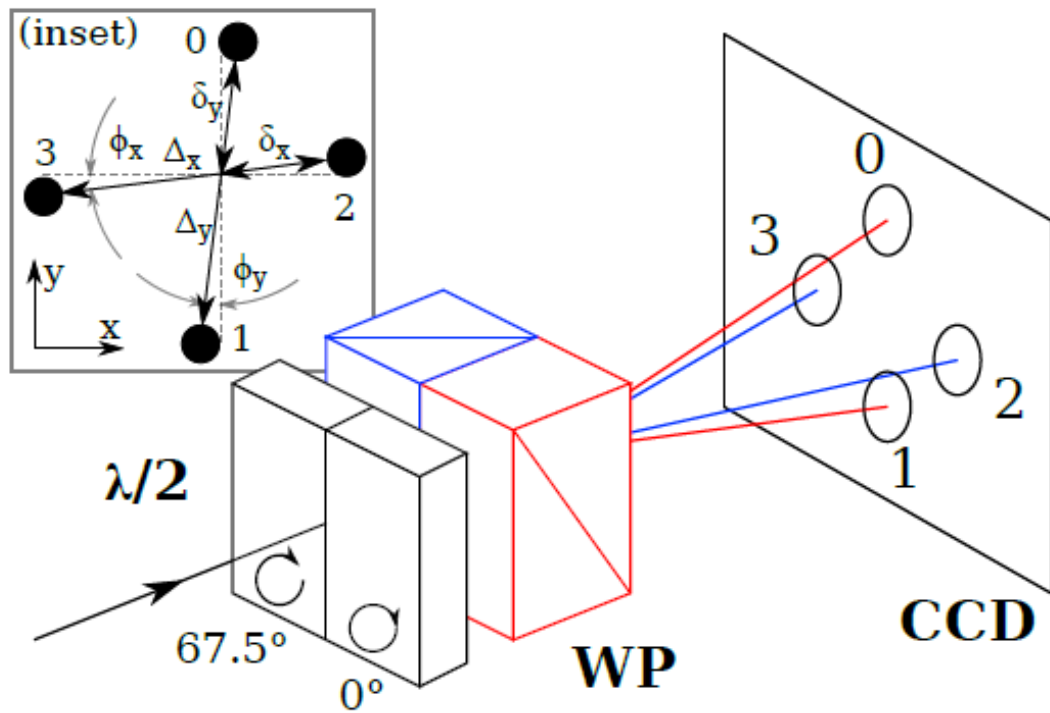
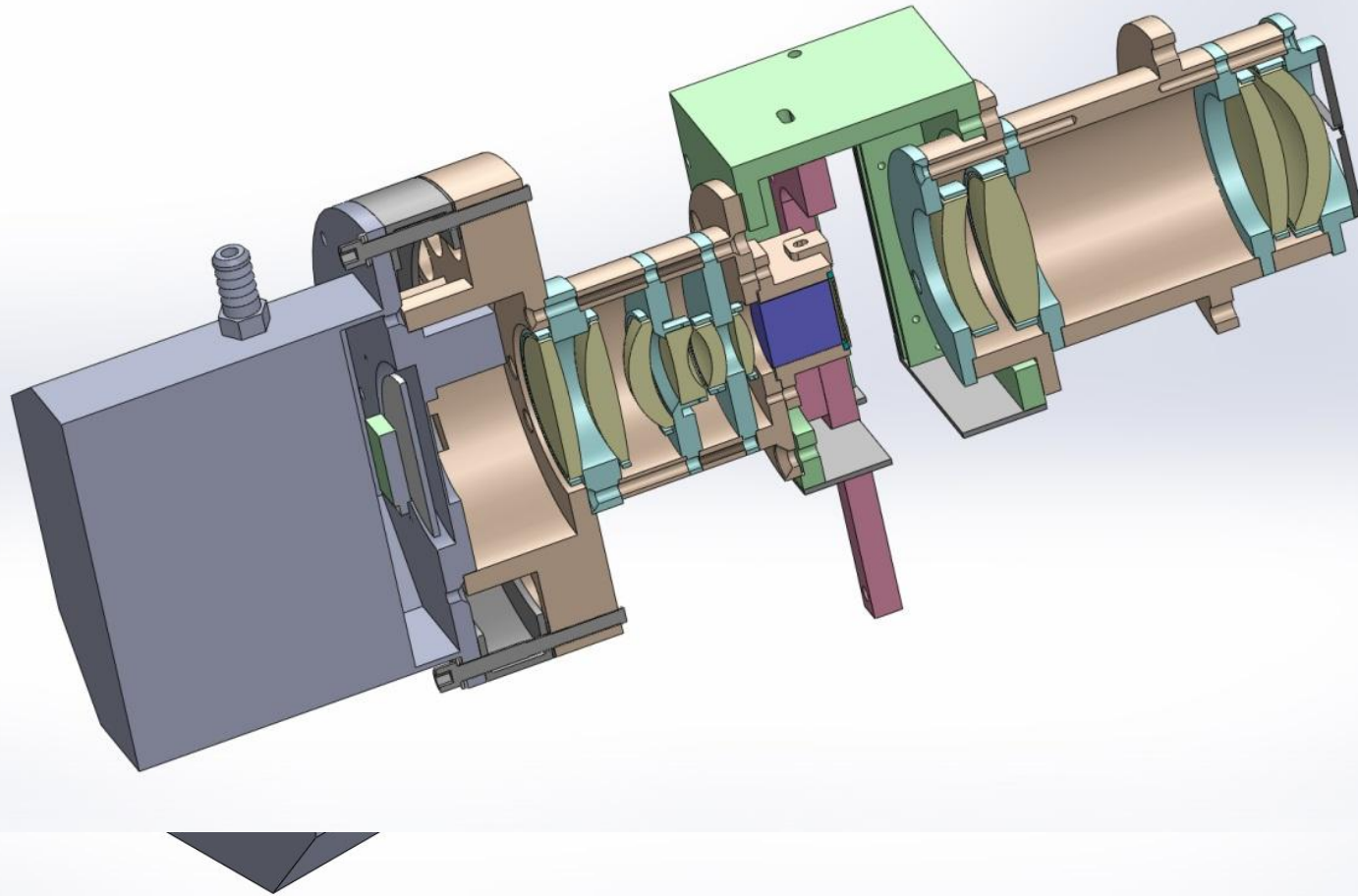


Figure 1. Diagram showing the basic operation of the RoboPol instrument. The pupil of the instrument is split in two, each half incident on a half-wave retarder followed by a Wollaston prism, labelled  $\lambda/2$  and WP respectively, with differing fast axis and prism orientations as indicated. The blue pair split the rays horizontally to produce the spots labelled 2 and 3, while the red pair produce the vertical spots 0 and 1. The linear polarization parameters are then calculated using Eqn. [1](#). (inset) The pattern of spots at each position on the CCD is described by this model. The distance between the spots  $\Delta_x$  and  $\Delta_y$ , their distance from the intersection point  $\delta_x$  and  $\delta_y$ , and their angle with respect to the CCD axes  $\phi_x$  and  $\phi_y$  all vary independently across the field.

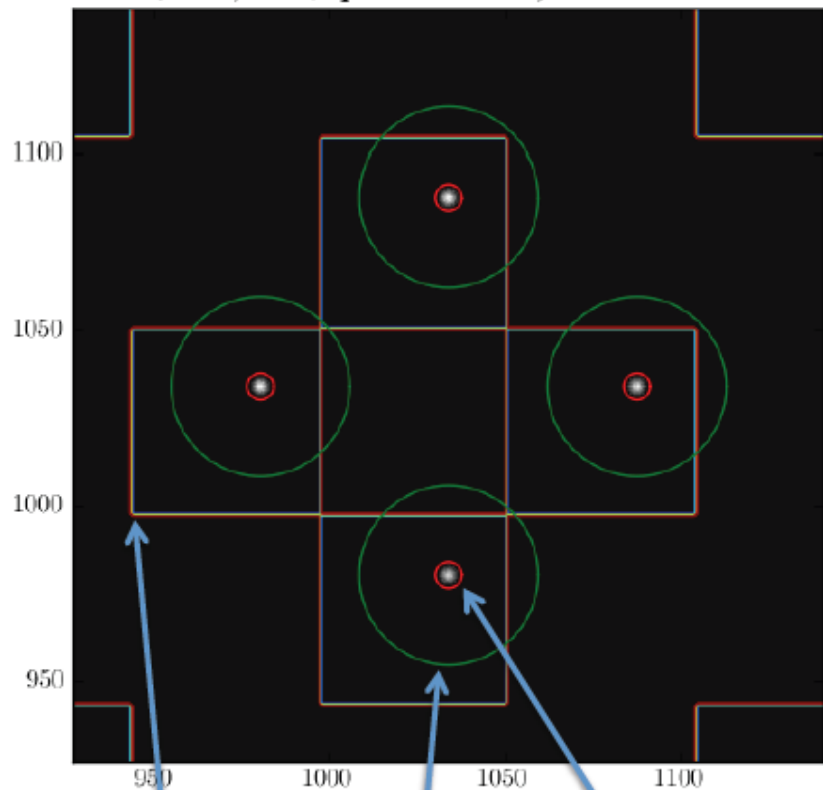
# RoboPol



A. N. Ramaprakash, IUCAA  
Inter-University Centre for Astronomy and Astrophysics, Pune, India

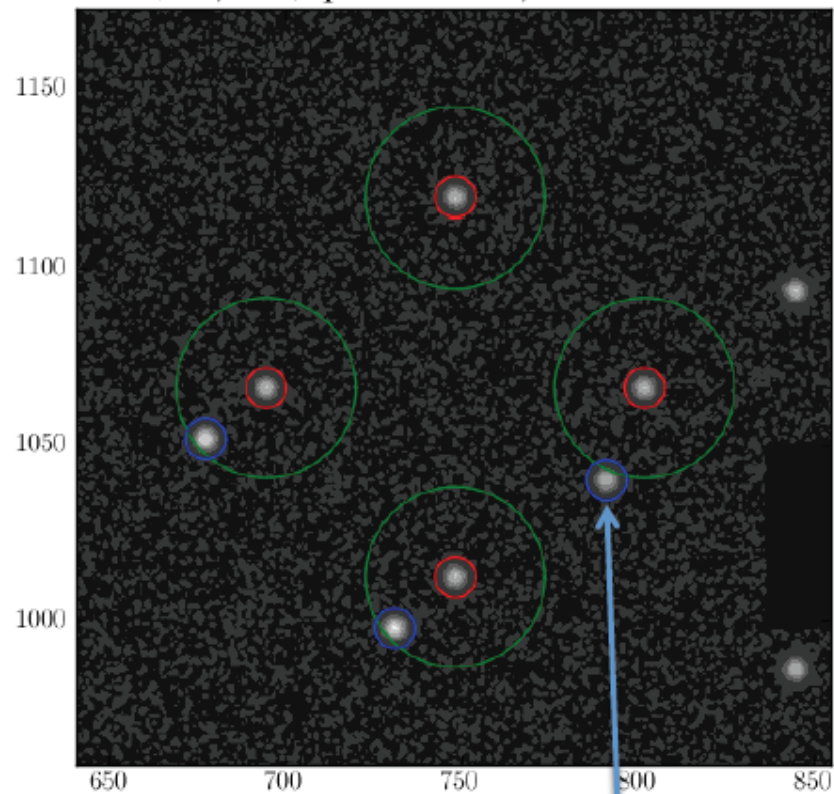
## Target source

Source at (1034,1033):  $p = 9.7 \pm 0.2$ ,  $\theta = 10.3 \pm 0.5$  deg



## Field source

Source at (748,1065):  $p = 0.6 \pm 0.8$ ,  $\theta = -52.7 \pm 38.9$  deg



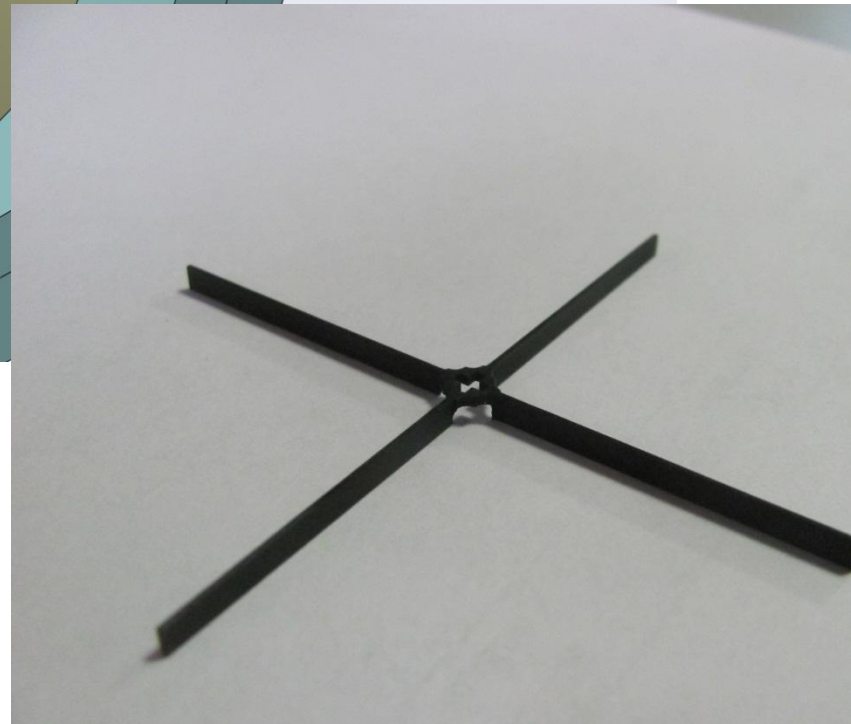
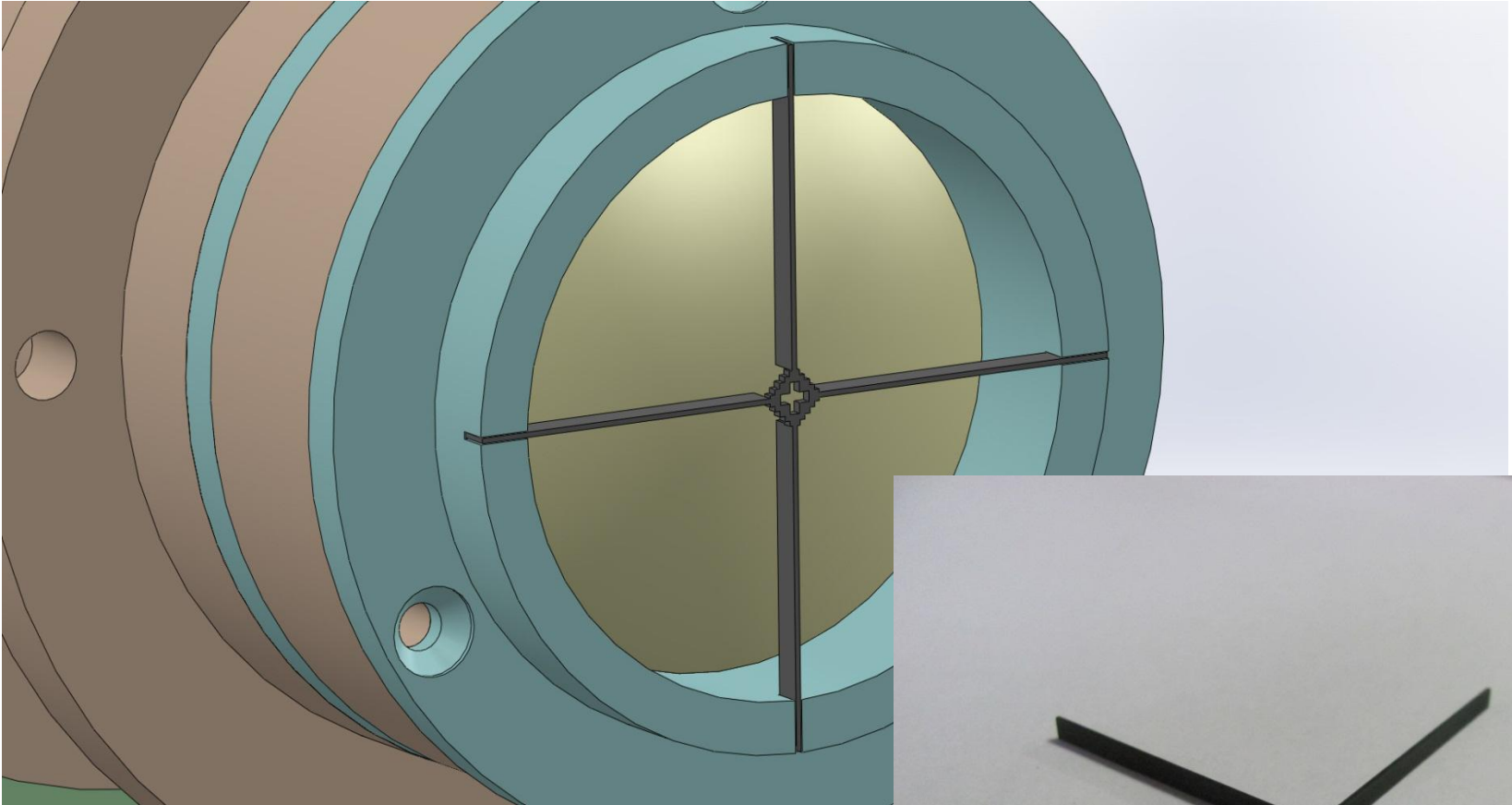
Sky mask

Outer photometry aperture

Inner photometry aperture

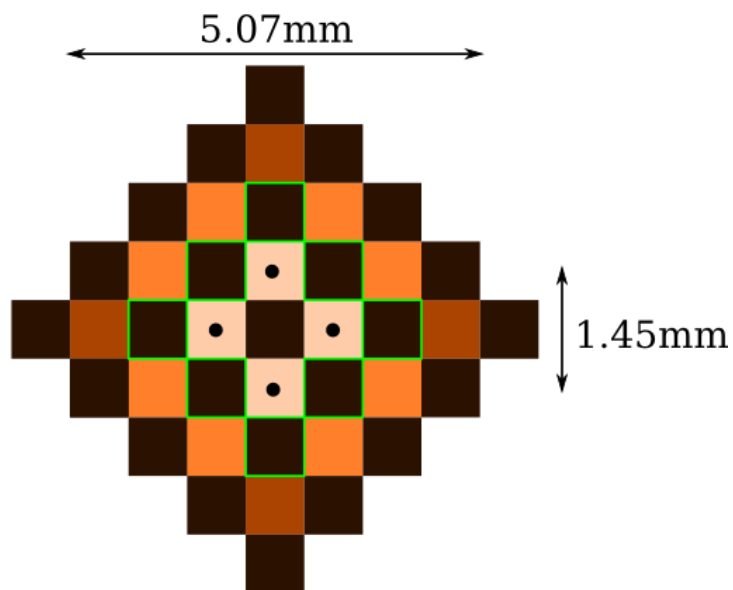
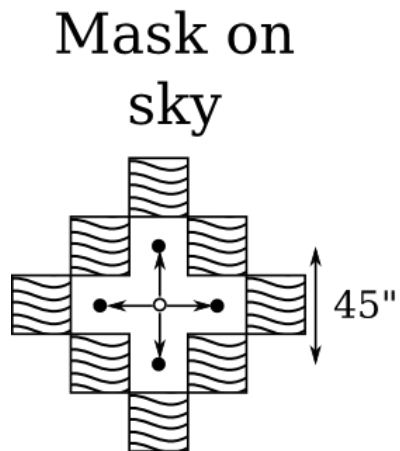
Masked region

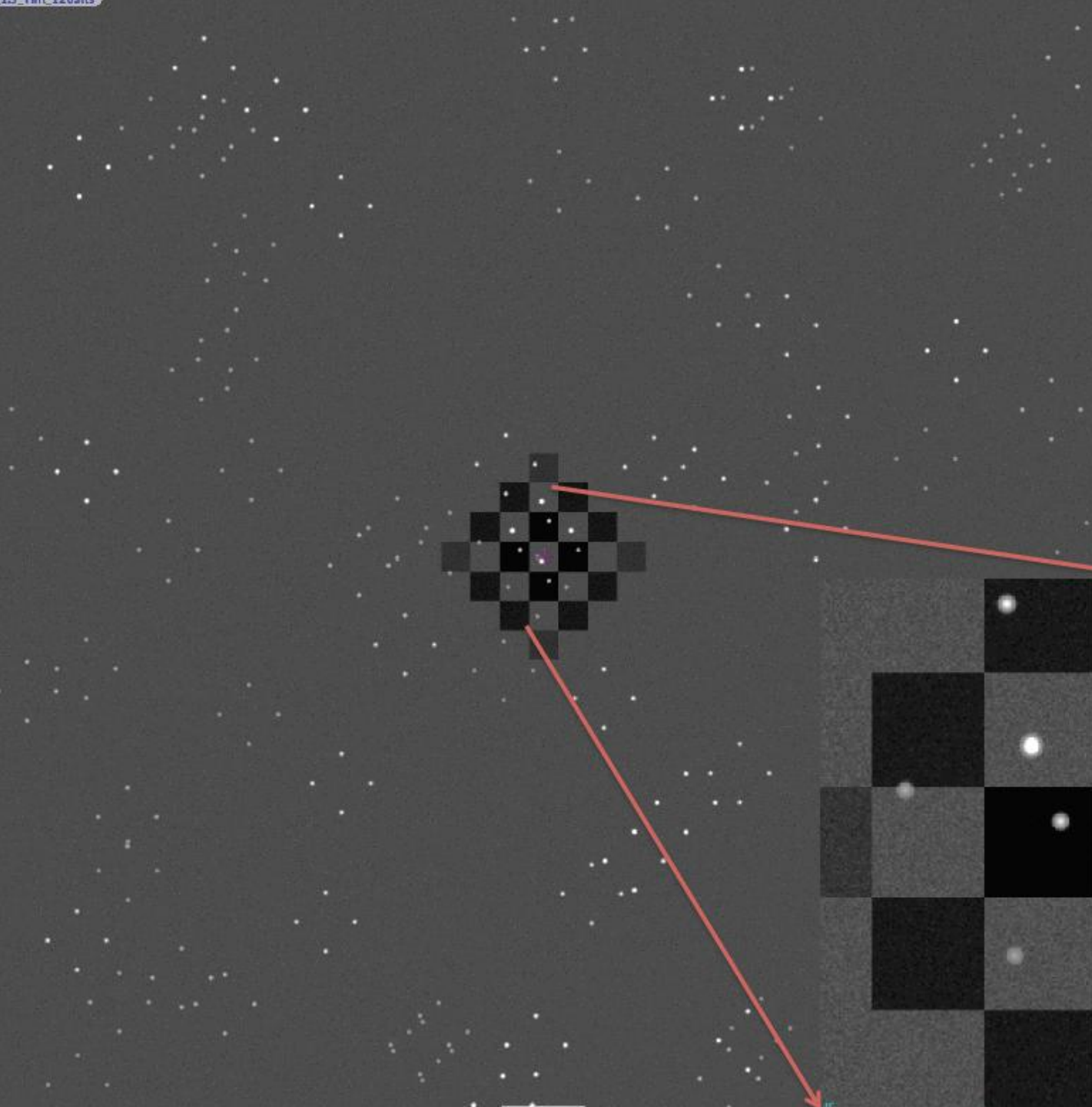
# Mask



# Focal Plane Mask

CCD sky  
brightness



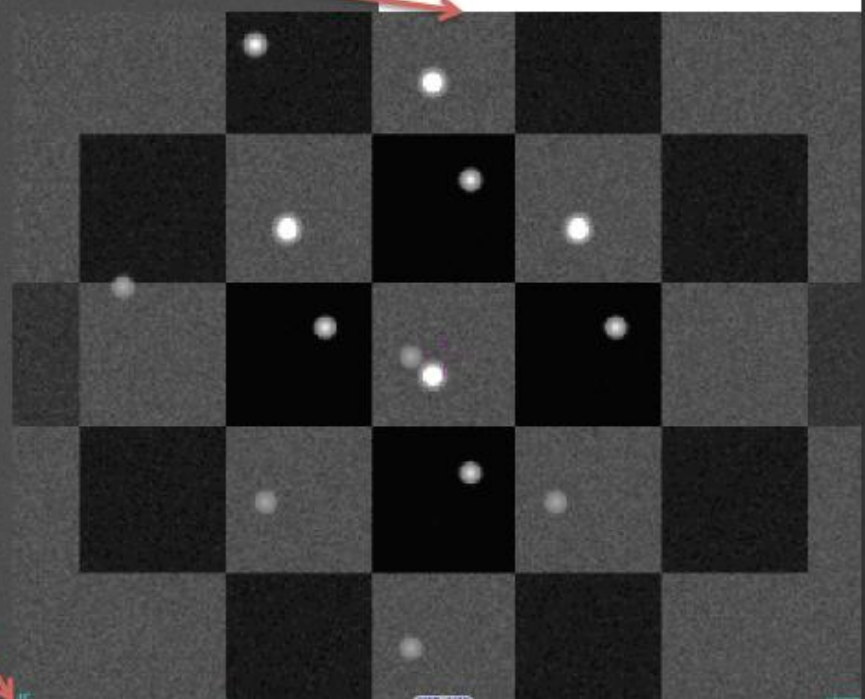
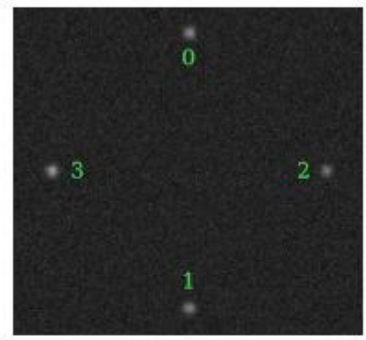


$$I_0 = \frac{I_{up}}{2} + I_p \cos^2(\theta_p)$$

$$I_1 = \frac{I_{up}}{2} + I_p \sin^2(\theta_p)$$

$$I_2 = \frac{I_{up}}{2} + I_p \cos^2(\theta_p + \pi/4)$$

$$I_3 = \frac{I_{up}}{2} + I_p \sin^2(\theta_p + \pi/4)$$





# The RoboPol optical polarizaton survey of gamma-ray–loud blazars

V. Pavlidou<sup>1,2\*</sup>, E. Angelakis<sup>3\*</sup>, I. Myserlis<sup>3</sup>, D. Blinov<sup>2,7</sup>, O. G. King<sup>4</sup>, I. Papadakis<sup>2</sup>, K. Tassis<sup>2,1</sup>, T. Hovatta<sup>4</sup>, B. Pazderska<sup>5</sup>, E. Paleologou<sup>2</sup>, M. Baloković<sup>4</sup>, R. Feiler<sup>5</sup>, L. Fuhrmann<sup>3</sup>, R. Goenka<sup>5</sup>, P. Khodade<sup>6</sup>, A. Kus<sup>5</sup>, N. Kylafis<sup>2,1</sup>, G. Panopoulou<sup>2</sup>, I. Papamastorakis<sup>2,1</sup>, E. Pazderski<sup>5</sup>, T. J. Pearson<sup>4</sup>, C. Rajarshi<sup>6</sup>, A. Ramaprakash<sup>6</sup>, P. Reig<sup>1,2</sup>, A. C. S. Readhead<sup>4</sup>, A. Steiakaki<sup>2</sup>, J. A. Zensus<sup>3</sup>

<sup>1</sup>*Foundation for Research and Technology - Hellas, IESL, Voutes, 7110 Heraklion, Greece*

<sup>2</sup>*Department of Physics and Institute for Plasma Physics, University of Crete, 71003, Heraklion, Greece*

<sup>3</sup>*Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany*

<sup>4</sup>*Cahill Center for Astronomy and Astrophysics, California Institute of Technology, 1200 E California Blvd, MC 249-17, Pasadena CA, 91125, USA*

<sup>5</sup>*Toruń Centre for Astronomy, Nicolaus Copernicus University, Faculty of Physics, Astronomy and Informatics, Grudziadzka 5, 87-100 Toruń, Poland*

<sup>6</sup>*Inter-University Centre for Astronomy and Astrophysics, Post Bag 4, Ganeshkhind, Pune - 411 007, India*

<sup>7</sup>*Astronomical Institute, St. Petersburg State University, Universitetskii pr. 28, Petrodvoretz, 198504 St. Petersburg, Russia*

## The RoboPol Pipeline and Control System

O. G. King<sup>1\*</sup>, D. Blinov<sup>2</sup>, A. N. Ramaprakash<sup>3</sup>, I. Myserlis<sup>4</sup>, E. Angelakis<sup>4</sup>, M. Baloković<sup>1</sup>, R. Feiler<sup>5</sup>, L. Fuhrmann<sup>4</sup>, T. Hovatta<sup>1</sup>, P. Khodade<sup>3</sup>, A. Kougentakis<sup>6</sup>, N. Kylafis<sup>2,6</sup>, A. Kus<sup>5</sup>, E. Paleologou<sup>2</sup>, G. Panopoulou<sup>2</sup>, I. Papadakis<sup>2,6</sup>, I. Papamastorakis<sup>2,6</sup>, G. Paterakis<sup>2</sup>, V. Pavlidou<sup>6,2</sup>, B. Pazderska<sup>5</sup>, E. Pazderski<sup>5</sup>, T. J. Pearson<sup>1</sup>, C. Rajarshi<sup>3</sup>, A. C. S. Readhead<sup>1</sup>, P. Reig<sup>6,2</sup>, R. Rouneq<sup>3</sup>, A. Steiakaki<sup>2</sup>, K. Tassis<sup>2,6</sup>, J. A. Zensus<sup>4</sup>

<sup>1</sup>*Cahill Center for Astronomy and Astrophysics, California Institute of Technology, 1200 E California Blvd, MC 249-17, Pasadena CA, 91125, USA*

<sup>2</sup>*Department of Physics and Institute of Theoretical & Computational Physics, University of Crete, PO Box 2208, GR-710 03, Heraklion, Crete, Greece*

<sup>3</sup>*Inter-University Centre for Astronomy and Astrophysics, Post Bag 4, Ganeshkhind, Pune - 411 007, India*

<sup>4</sup>*Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany*

<sup>5</sup>*Toruń Centre for Astronomy, Nicolaus Copernicus University, Faculty of Physics, Astronomy and Informatics,*

Title: GRB 131030A - RoboPol optical afterglow polarimetry.

Authors: Balokovic, M.; Hovatta, T.; King, O.; Pearson, T.;  
Readhead, A.; Blinov, D.; Kylafis, N.;  
Panopoulou, G.; Papadakis, I.; Papamastorakis, I.;  
Pavlidou, V.; Reig, P.; Tassis, K.; Khodade, P.;  
Rajarshi, C.; Ramaprakash, A.; Rouneq, R.;  
Angelakis, E.; Myserlis, I.; Fuhrmann, L.;  
Zensus, J. A.; **Feiler, R.; Kus, A.; Pazderska, B.;**  
**Pazderski, E.**

Publication: GRB Coordinates Network, Circular Service, 15430, 1 (2013)

Publication Date: 00/2013

Origin: SIMBAD

Bibliographic Code: **2013GCN..15430...1B**

**Atel** Optical, Gamma Ray, AGN, Polarization, Blazar

D. Blinov (Univ. of Crete, Greece and St. Petersburg Univ., Russia), A. Kougentakis (Univ. of Crete, Greece) on behalf of RoboPol collaboration.

We perform R-band photometric and polarimetric monitoring of the blazar S5 1044+71 (2FGL J1048.3+7144) as part of the RoboPol program. Preliminary relative photometry based on PTF catalog magnitudes (Ofek et al., 2012, PASP, 124, 854) shows that the blazar is in a flaring state at optical wavelengths. Its R magnitude is observed to be  $R=16.0$  on 25 Oct, 2013, substantially brighter than  $R=17.49$  reported by (Healey et al., 2008, ApJS, 175, 97) and at the previous period of availability of this object  $R=17.4$  on 13 Aug, 2013. We are also observing a smooth rotation of optical polarization angle in the clockwise direction at rate of about 15 deg/day coincident with rise of polarization degree reaching  $P=27.2\%$  on 25 Oct, 2013.

Optical activity is accompanied by increasing flux and variability in gamma. Daily averaged gamma-ray flux reached  $0.5E-6 \text{ ph cm}^{-2}\text{s}^{-1}$  ( $E>100\text{MeV}$ ) on Oct 24, which is comparable to a previously reported flare of this object ATel#4941. Multi-wavelength observations of the blazar are encouraged.

RoboPol is a collaboration of Caltech USA, Univ. of Crete Greece, MPIfR Germany, IUCAA India and Nicolaus Copernicus Univ. Poland.

# RoboPol 2013 survey

1. Badania statystyczne dużej próbki blazarów
2. Maksymalizacja możliwości wykrywania rotacji polaryzacji

Gamma flares  $\Leftrightarrow$  optical polarization rotation (?)

Pierwsza sesja obserwacji RoboPol June-November 2013 Skinakas

Radio: 40m OVRO 15 GHz (dwa razy w tygodniu), Torun 32m 30 GHz  
Effelsberg 100m 5GHz – 43 GHz ; - mutli band covarage

KRYTERIA wyboru próbki (*gamma-ray-loud sample 557 sources*)

- Fermi LAT (II) catalog (bzb, bzq, agu)  $F (> 100 \text{ MeV}) 10^{-8} \text{ cm}^{-2} \text{ s}^{-1}$
- $|b| > 10 \text{ deg}$
- Elev  $> 30 \text{ deg}$
- R magnitude  $< 18$  ( $< 17,5$ )
- Flux at 15 GHz  $> 60 \text{ mJy}$  (for *control sample 22 sources*) gamma-ray-quiet

2013 session 21 nights, cadence 3 days, (*Bogna i AJK observers*)  
exp. time 3x5 min (up to 17,5 min), S/N 10:1, 17mag, pol. fraction 0.03

135 gamma-ray-loud targets, 18 control-sample sources, 10 pol standards

Rmag 17  $p \geq 0.015$ ; Rmag 18  $p \geq 0.035$ , PA  $\pm 0.5$  deg ( $\pm 5-10$  deg)  
uniform

- Kilka przypadków szybkiej rotacji PA, oddzielne prace

- Stopień polaryzacji  $p$  dla

- Gamma-ray-loud  $p=0.067 \pm 0.01$

- Gamma-ray-quiet  $p=0.032 \pm 0.015$

Zatem mają różne własności polaryzacyjne (różne populacje ?)

Nowa sesja April 2014 –November 2014

# New twin beam receiver for RT32m K-band 22 GHz +/- 3 GHz

$$T_{\text{rec}} = 25\text{K}, T_{\text{sys}} \sim 70\text{K}$$

