Observations of *Fermi*-LAT blazars through optical spectroscopy and spectro-polarimetry with South Africa-based telescopes

Richard Britto*

(on behalf of the Fermi-LAT Collaboration)

with

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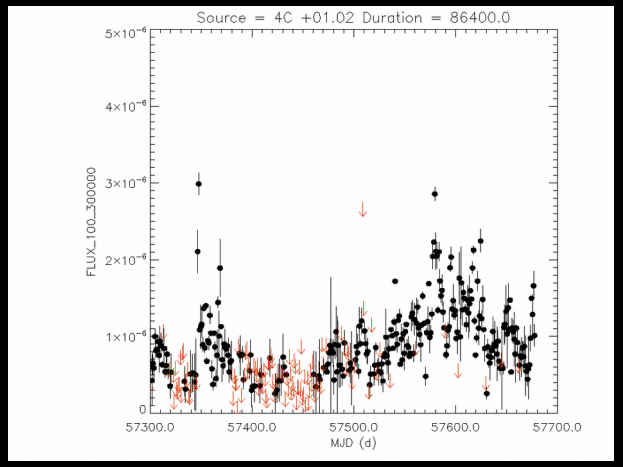
Brian van Soelen*

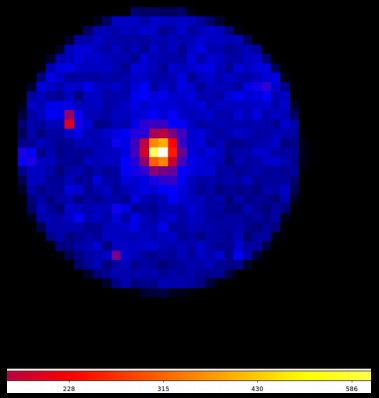
*University of the Free State
South Africa

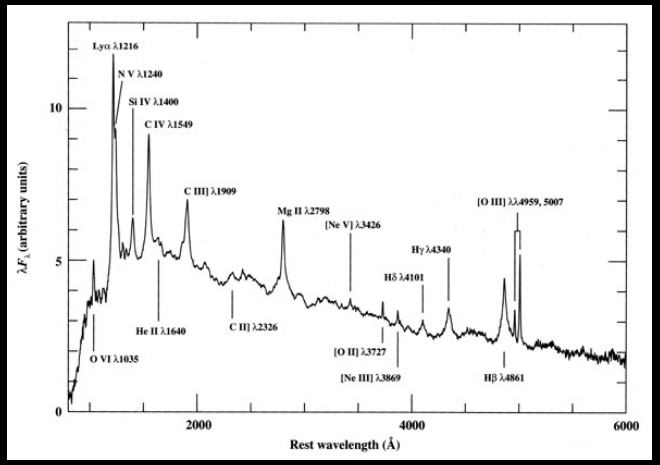
Other collaborators:

Markus Böttcher (NWU, SA)

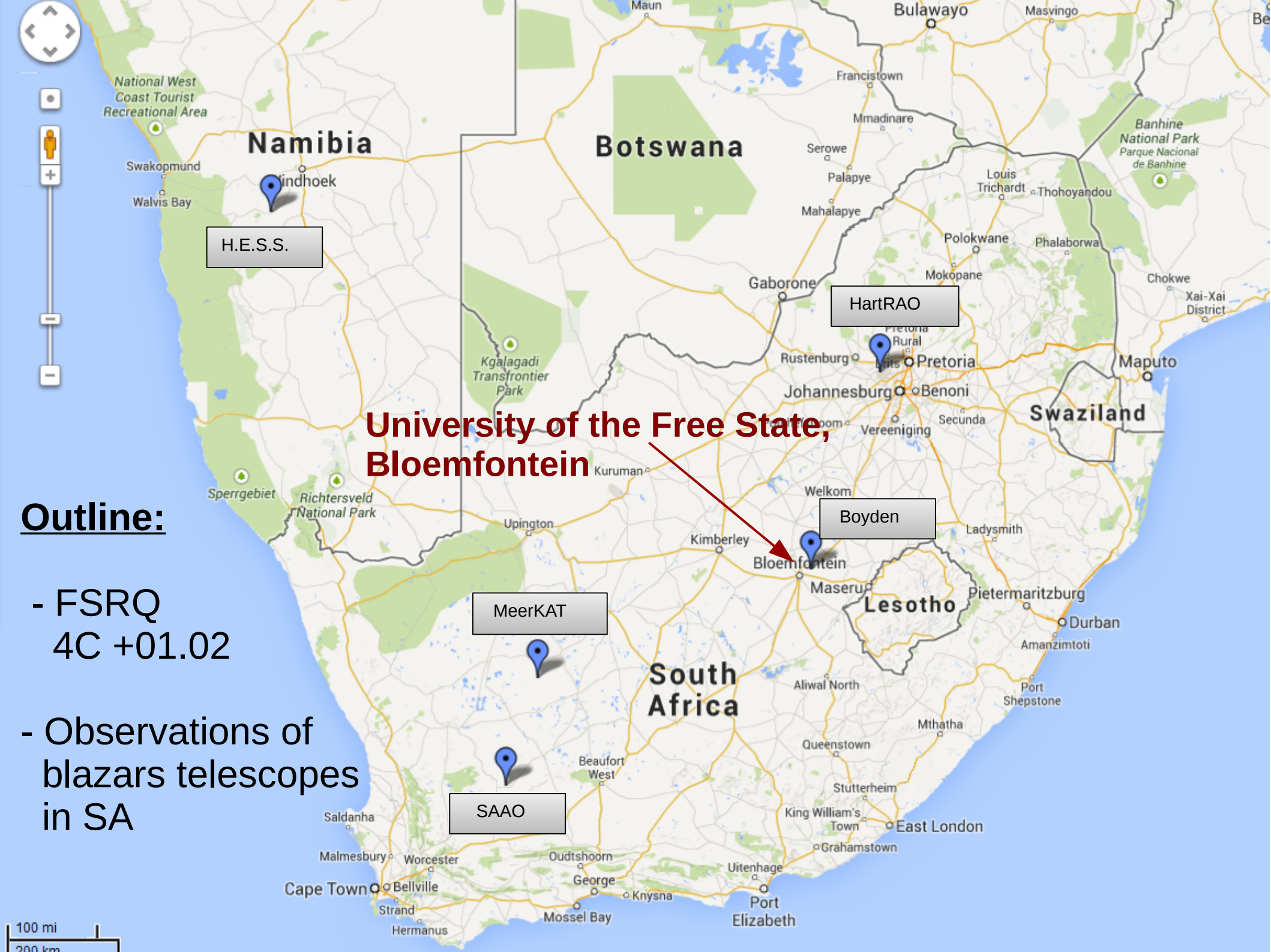
David A. H. Buckley (SAAO, SA)







6th Katmandu meeting: BH and Jets – 19 October 2016



Outline:

- FSRQ
  4C +01.02

- Observations of blazars telescopes in SA

The astronomy/astrophysics group at UFS

Photometric and spectroscopic observations

Watcher Robotic Telescope
@ Boyden Observatory (Bloemfontein)

University College Dublin
PI: Lorraine Hanlon
Antonio Martin-Carrillo
David Murphy

40 cm optical
Part of GRB afterglow follow-up network
Free time can be used for monitoring

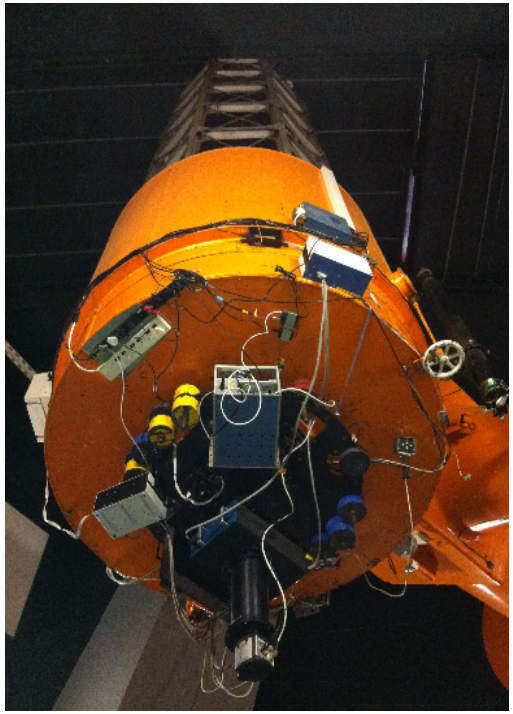
Boyden 1.5 m Telescope
@ Boyden Observatory (Bloemfontein)

University of the Free State

Robert Stobie Spectrograph (RSS) with polarimetry capability

Commissioning a new 1 m telescope @ SAAO: ***WiNCam*** (Wide-field Nasmyth Camera): ~**40x40 arcmin FOV**

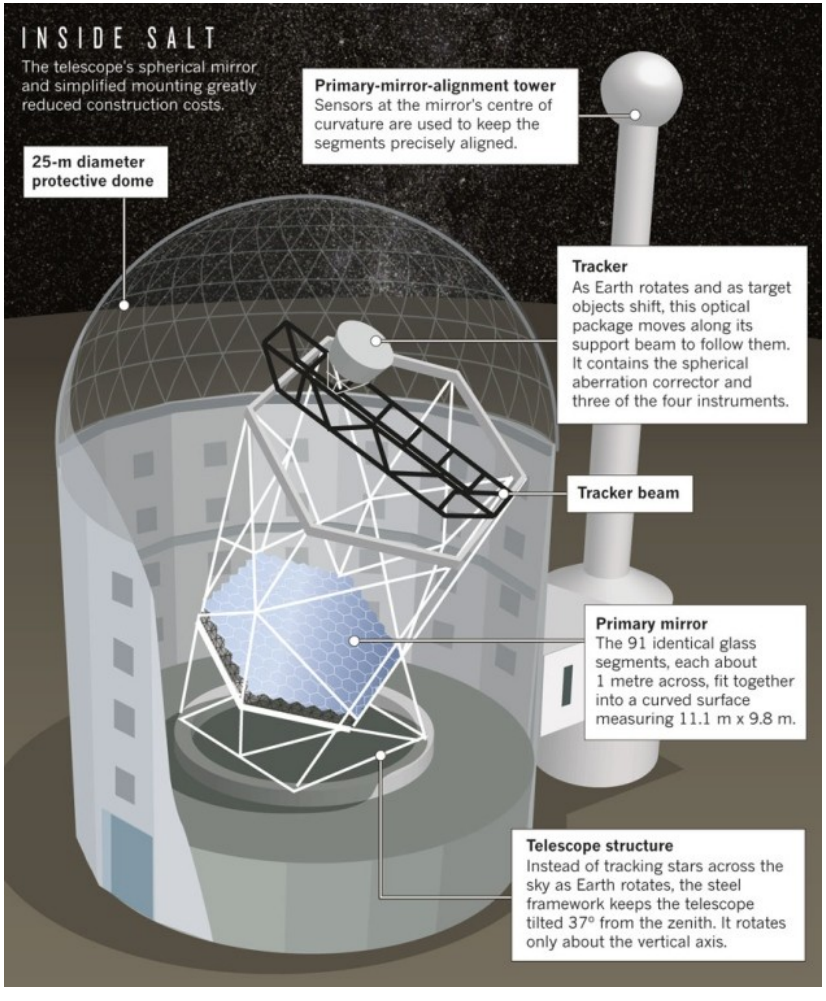
First light expected by end 2017



SAAO 1.9-m Telescope @ Sutherland

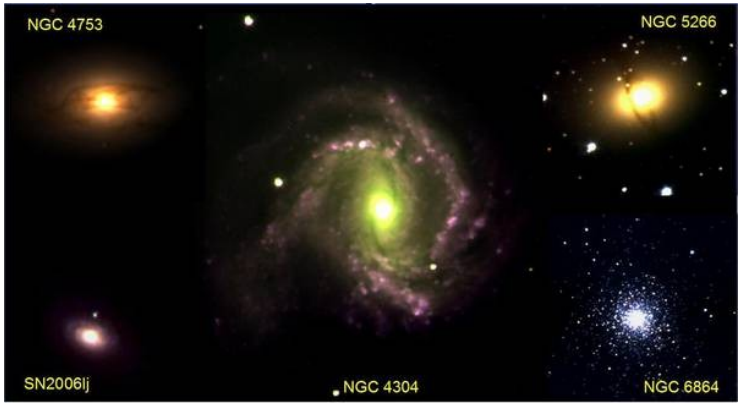
SHOC (Sutherland High-speed Optica Camera) (up to ~0.1 sec)

SpUpNIC spectrometer
HIPPO polarimeter

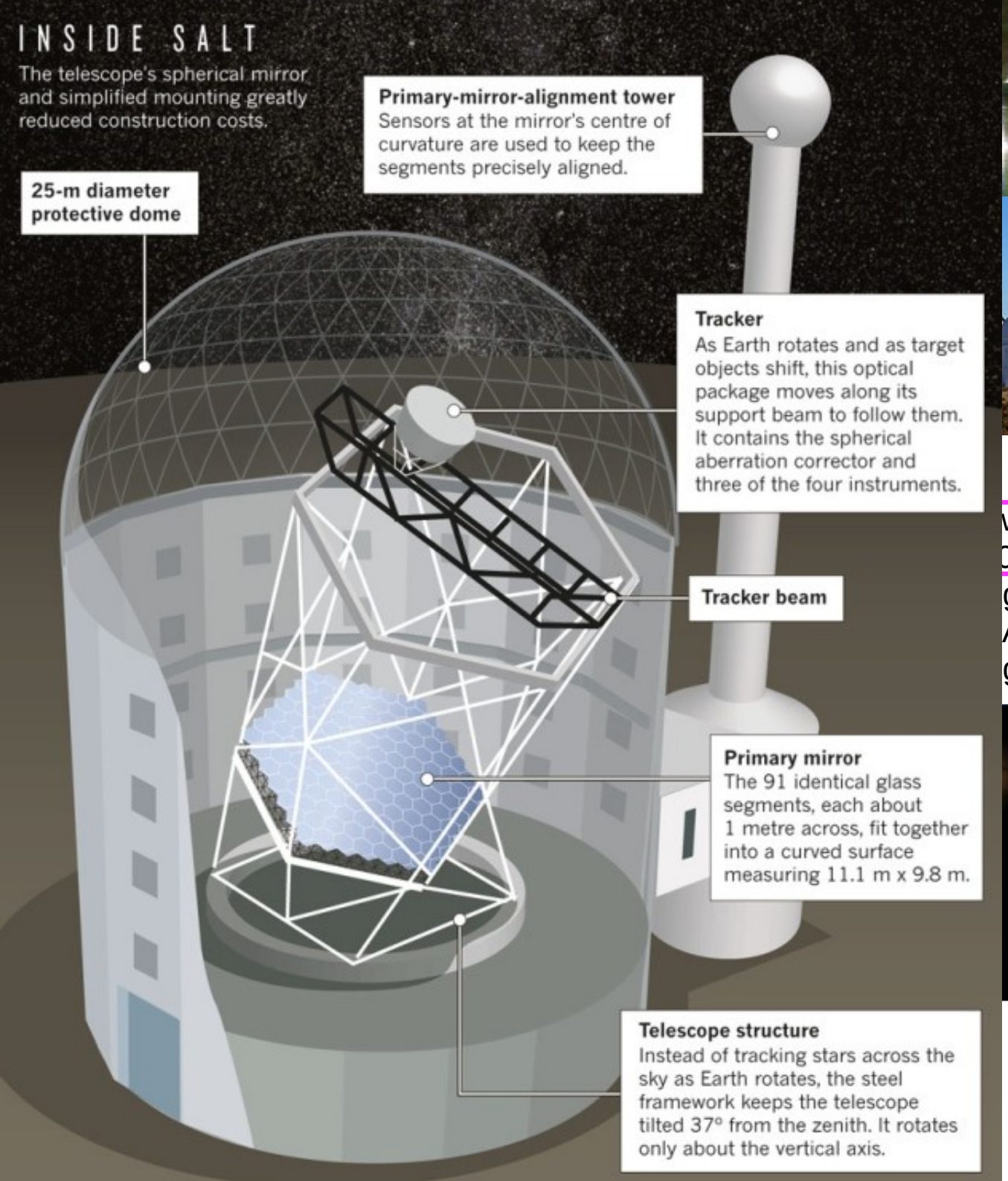


10 metre class telescope

- RSS: low-medium resolution spectrograph (R~5000-9000) with polarimetry capability
- HRS: high resolution spectrograph
- SALTICAM: imaging/photometry
- BVIT: high time resolution camera

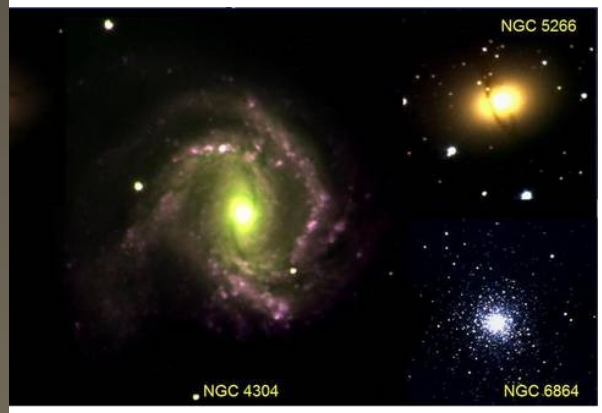


International consortium with South Africa, the United States, Germany, Poland, India, the United Kingdom and New Zealand



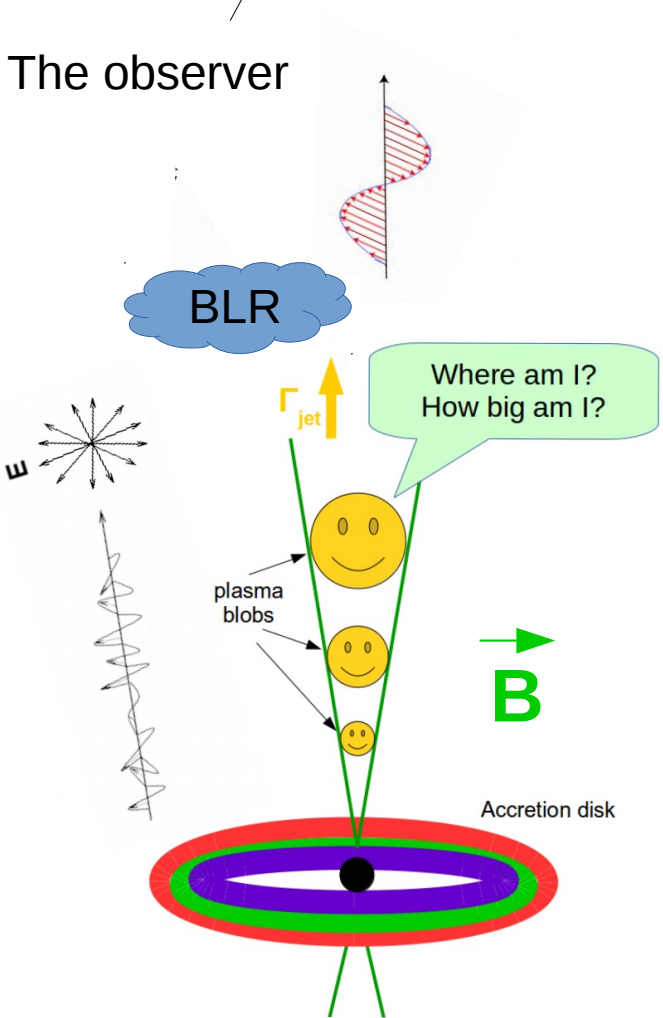
metre class telescope

w-medium resolution spectrograph
0-9000) with polarimetry capability
gh resolution spectrograph
AM: imaging/photometry
gh time resolution camera



Flaring blazars

The observer



- What powers blazar jets?
- Where is radiation emitted/absorbed?
- Photometry, spectroscopy and polarimetry:
  - Magnetic fields
  - Radiation emission mechanisms
- Monitoring possible variation of the BLR spectrum

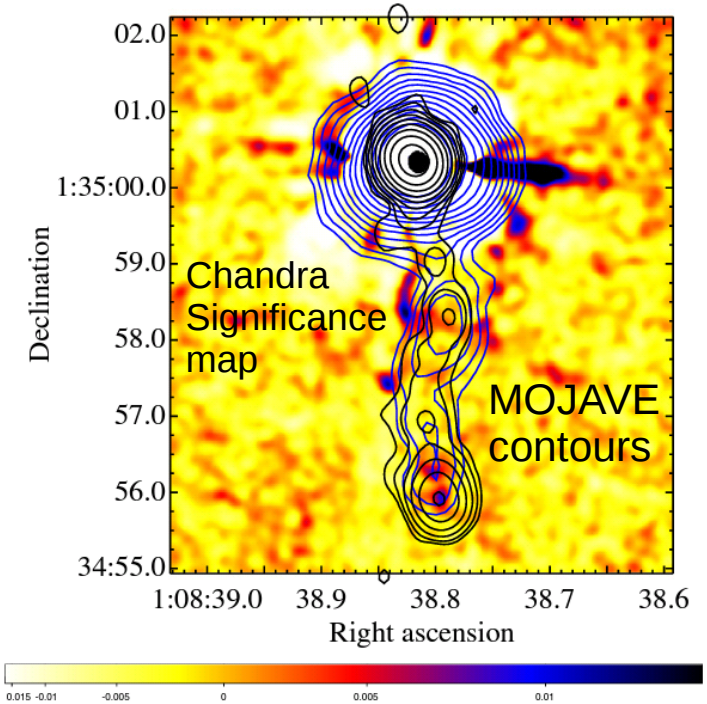
Measuring LE polarisation:

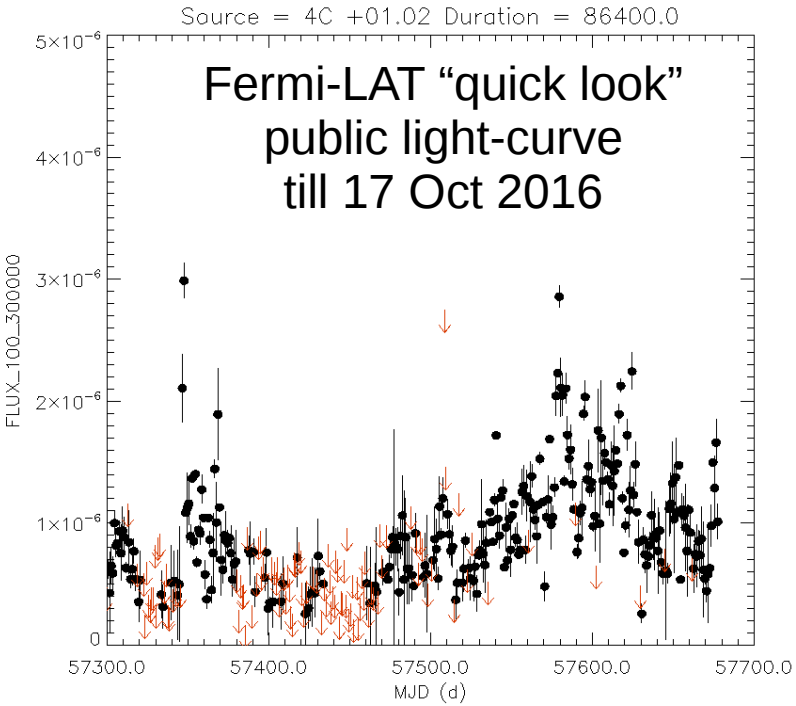
- **Linear polarisation:** constraint on the strength and geometry of magnetic fields
- **Polarisation angle change:** constraint on the location of the gamma-ray emiting region

FSRQ 4C +01.02 (PKS B0106+013)

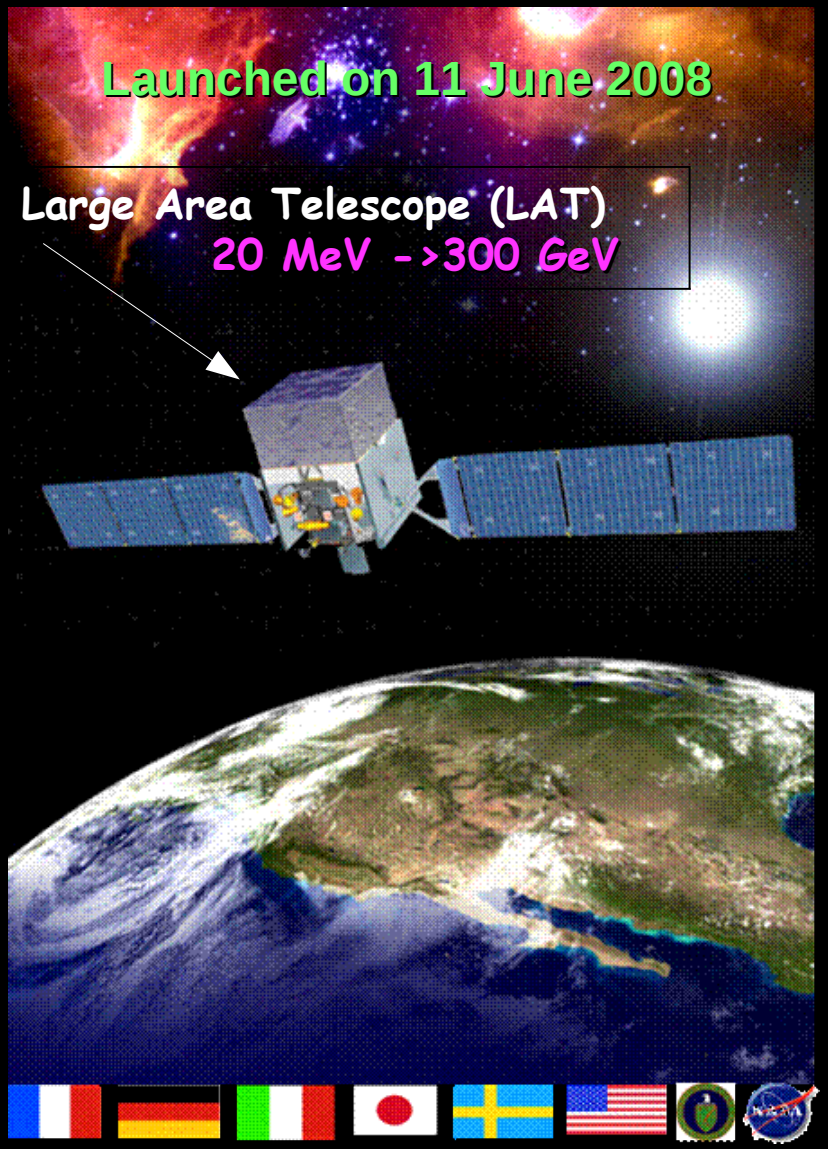
- Bright outburst – Redshift z ~ 2.1
- Fermi-LAT and MOJAVE source
- A radio quasar without radio lobe

Kharb et al, 748:81 (13pp), 2012





The *Fermi* Gamma-Ray Space Telescope

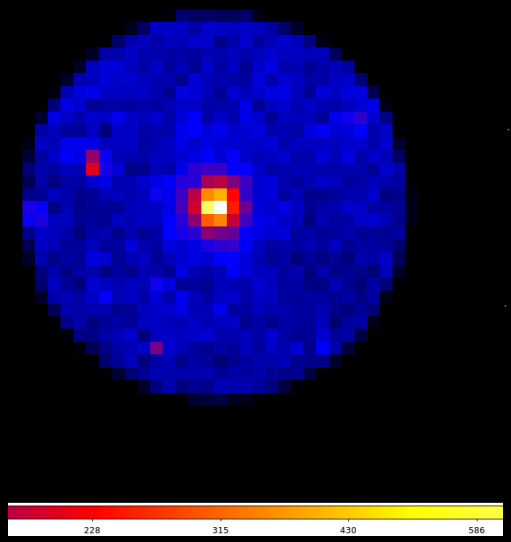


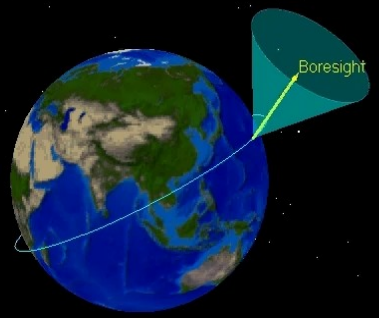
5 countries and many Universities and Institutes all around the World.

Data from 4C +01.02 collected between 11 March and 12 September 2016.

- Pass 8 unbinned likelihood analysis
- 100 MeV - 300 GeV
- Zenith angle < 90°
- Source event class
- DATA_QUAL==1 && LAT_CONFIG==1
- Science Tools version v10r0p5
- Diffuse emission:
  - gll_iem_v06.fits
  - iso_P8R2_SOURCE_V6_v06.txt
- Souces modeled from 3FGL up to 35° radius

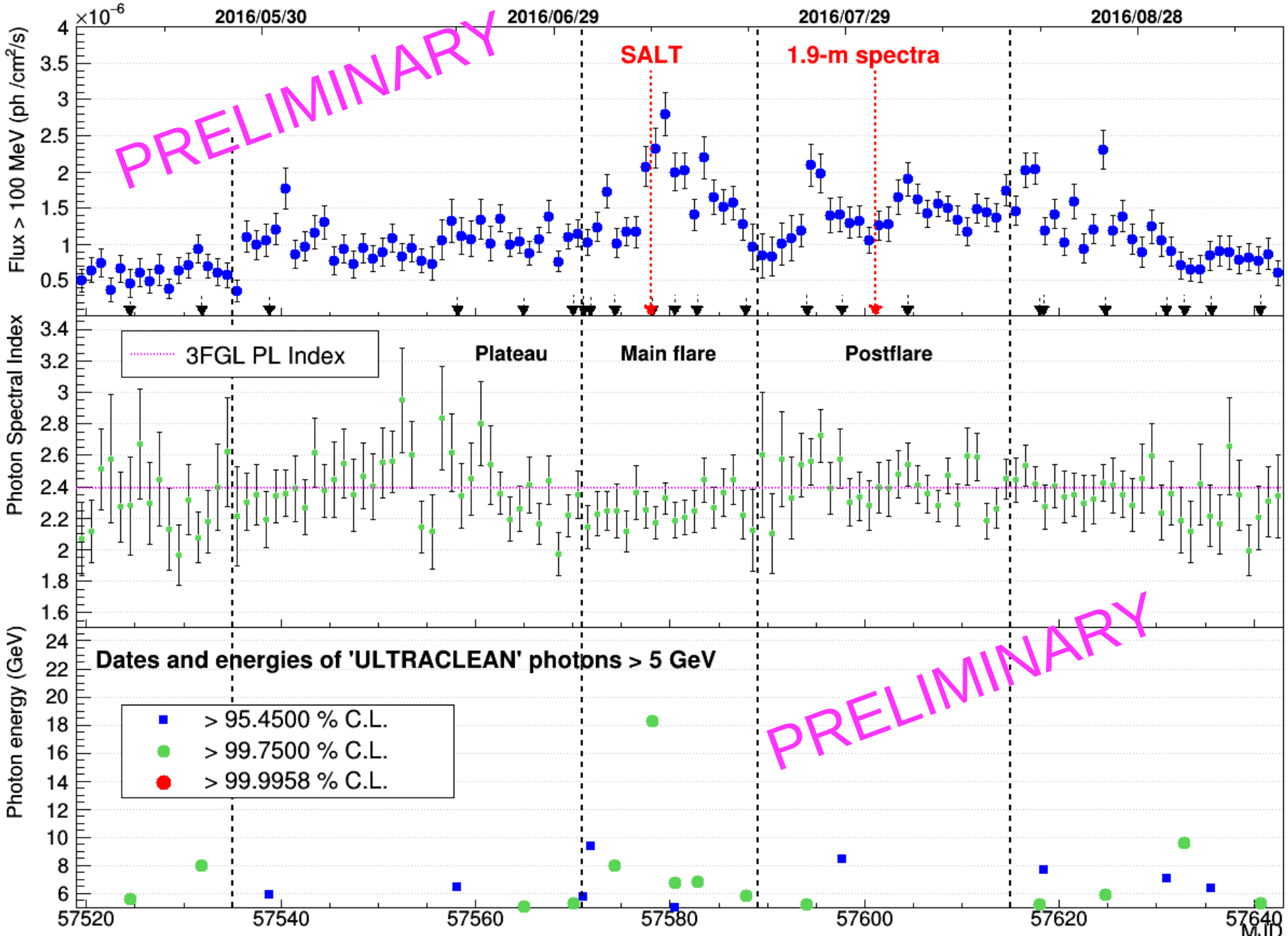
ROI = 15°





Fermi-LAT light-curve of 4C +01.02

11 May – 12 Sep 2016 – 1-day binning



Fermi-LAT light-curve of 4C +01.02

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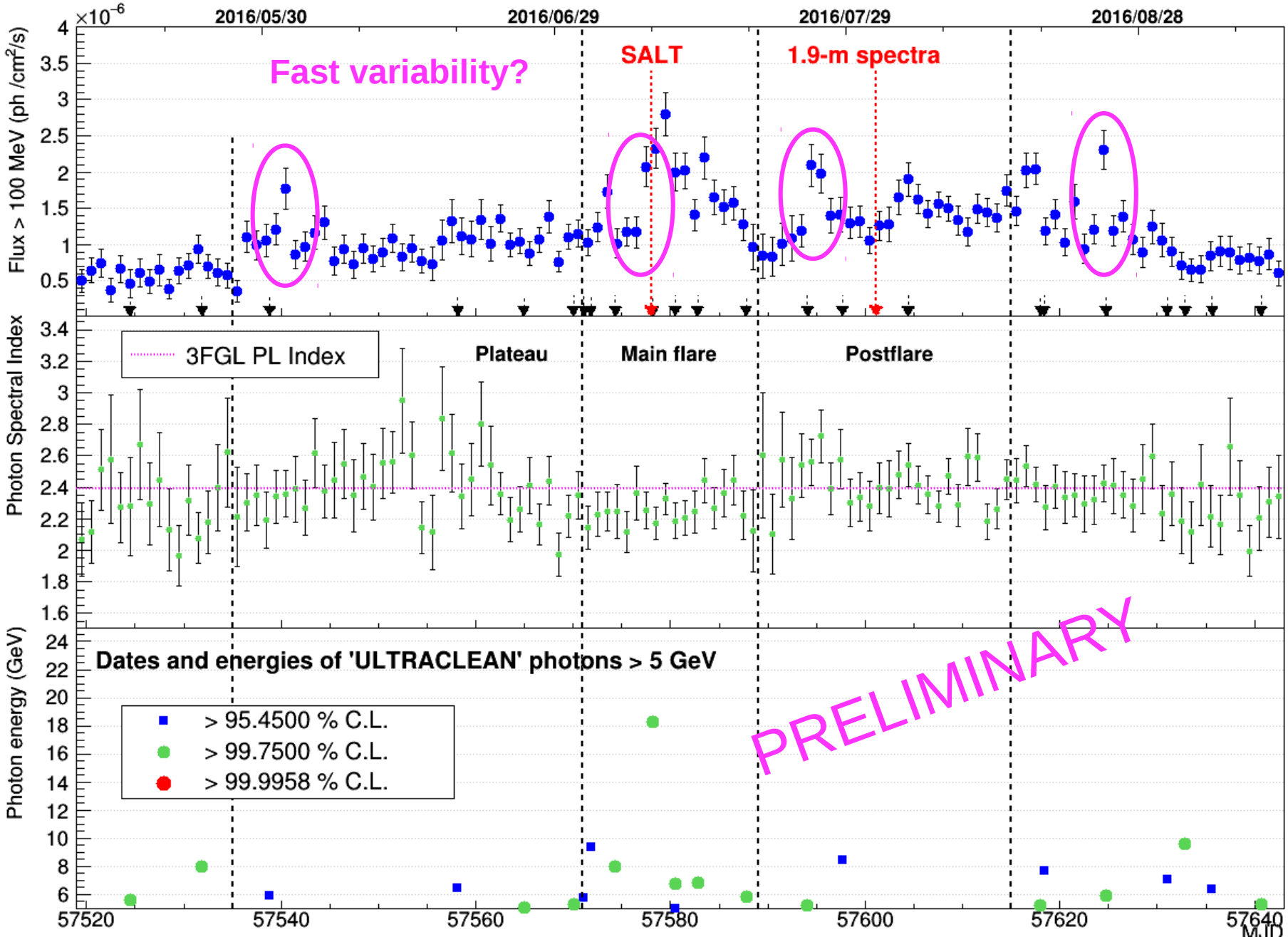
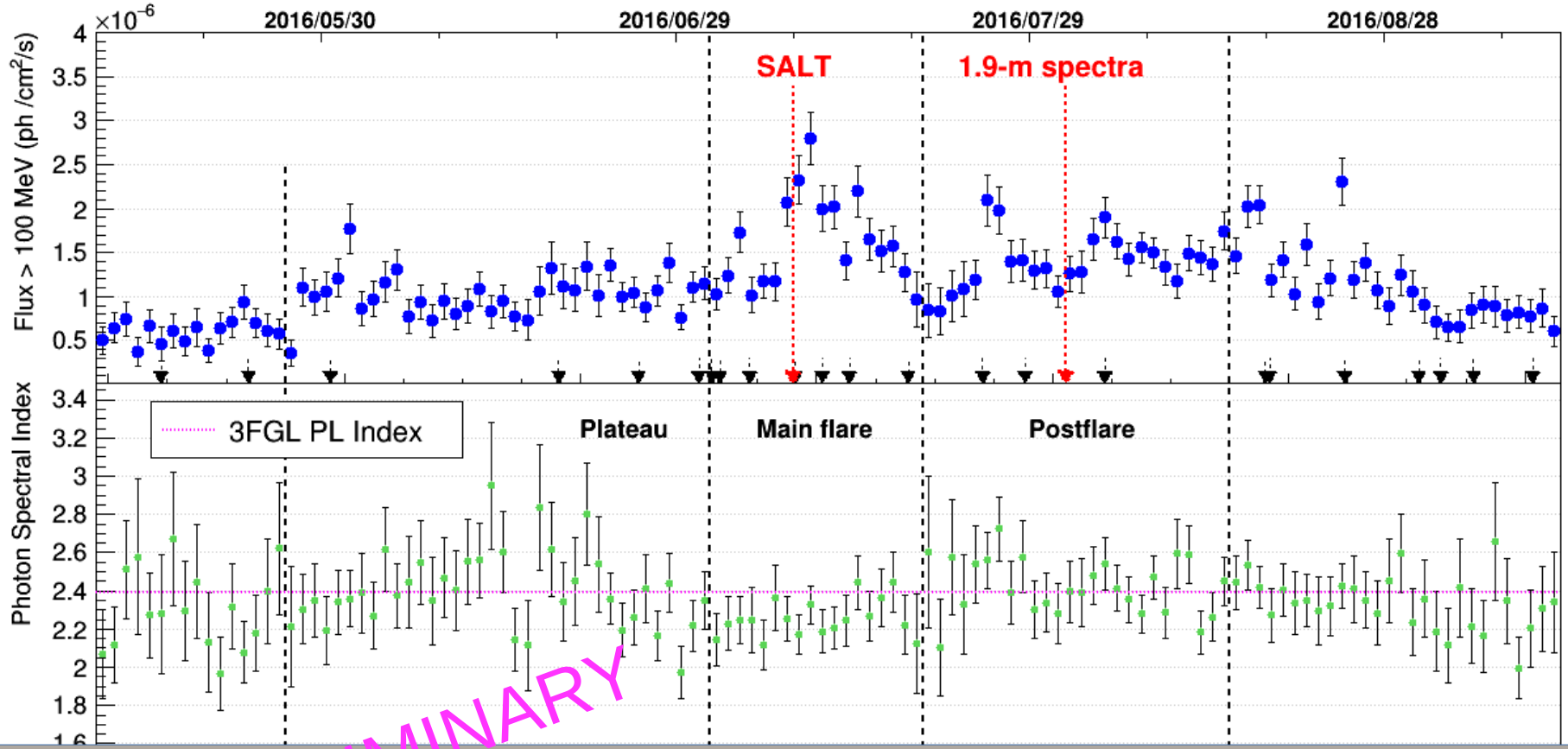


Fermi-LAT light-curve of 4C +01.02

11 May – 12 Sep 2016 – 1-day binning

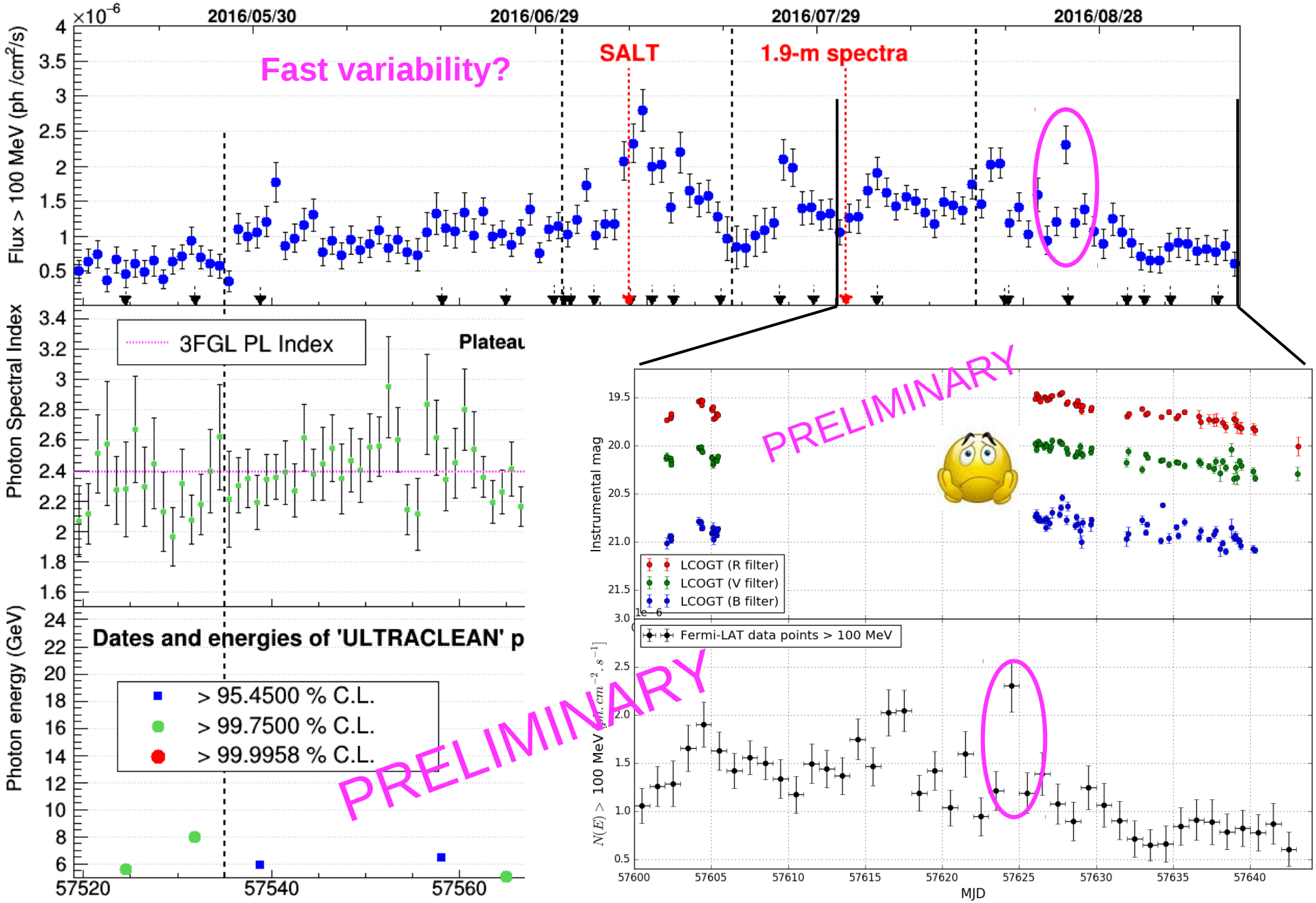


PRELIMINARY

Period	Γ	α	β	Flux (ph cm^{-2} s^{-1})
11 May-28 May (Pre-flare)	2.26 ± 0.06	2.04 ± 0.09	0.19 ± 0.06	5.35e-07 ± 4.38e-08
28 May-02 Jul (Plateau)	2.36 ± 0.03	2.27 ± 0.04	0.11 ± 0.03	9.94e-07 ± 3.50e-08
02 Jul -20 Jul (Flare)	2.26 ± 0.03	2.11 ± 0.04	0.16 ± 0.03	1.56e-06 ± 5.71e-08
20 Jul -15 Aug (Postflare)	2.41 ± 0.03	2.32 ± 0.04	0.12 ± 0.03	1.38e-06 ± 4.40e-08

Fermi-LAT light-curve of 4C +01.02

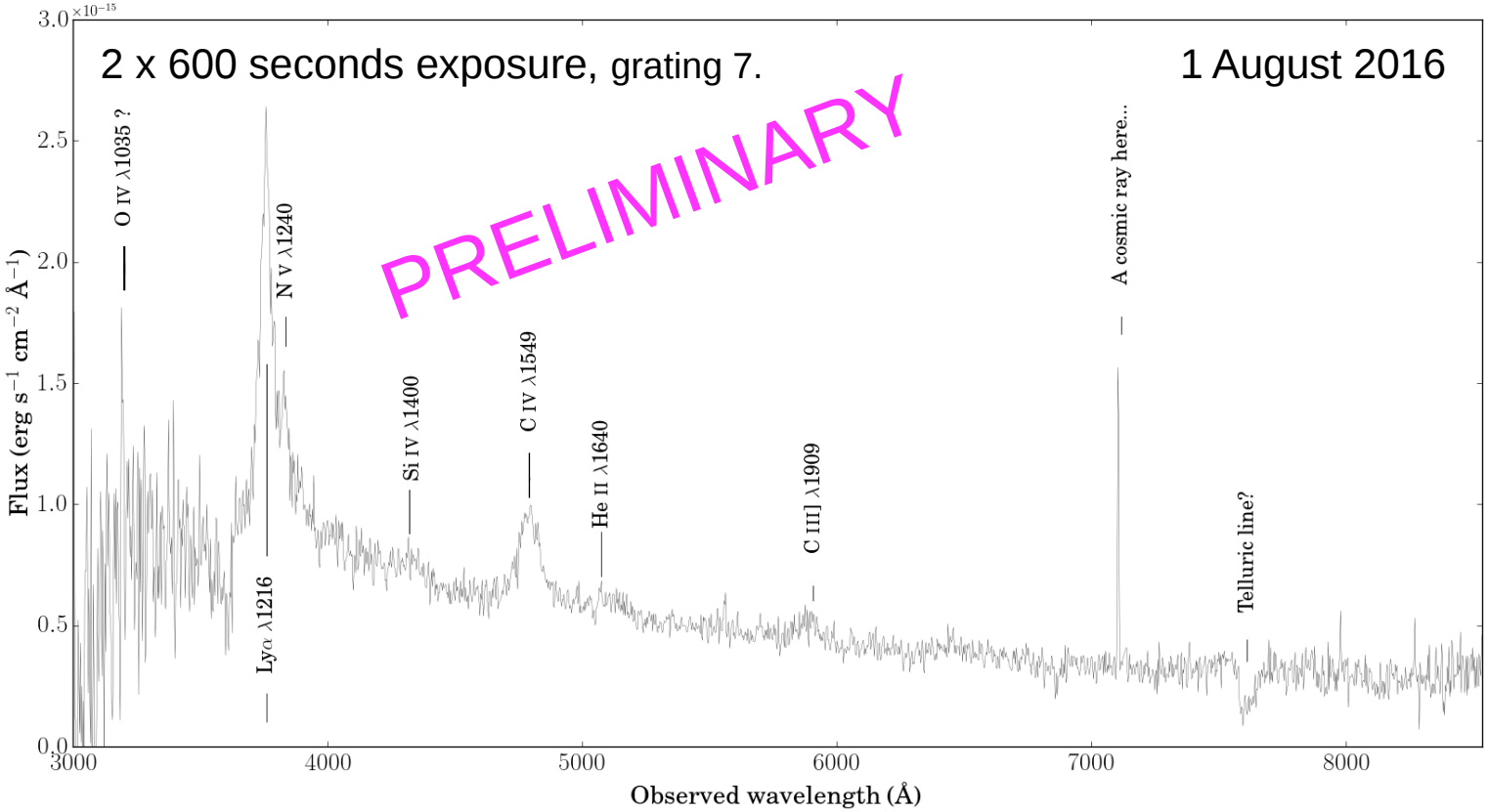
11 May – 12 Sep 2016 – 1-day binning



Work in progress

- Trying smaller time bins
- Discrete Correlation Function (DCF)
- Split into two gamma-ray bands:
  - 0.1 – 0.5 GeV
  - 0.5 – 100 GeV

Preliminary spectrum of 4C +01.02 from SpUpNIC
(1.9 m telescope/SAAO/Sutherland)

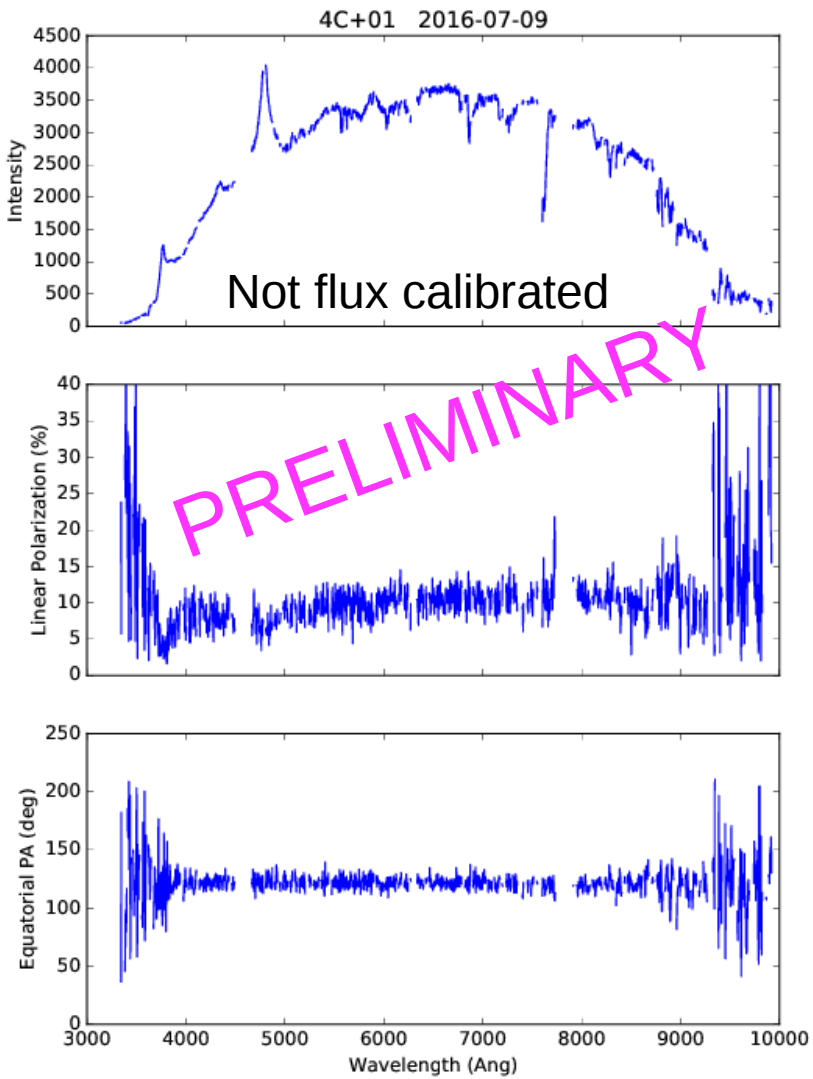


Spectrum reduction: Andry Rajoelimanana

- Typical spectrum of a radio-loud quasar.
- Several acquisitions at different flux levels would allow the probing of eventual feature changes.
- We have found a redshift z = 2.095 (versus z = 2.099 in Simbad).

SALT-RSS spectrum (grating PG 300) and polarised parameters.

9 July 2016



Same features than in the SpUpNIC spectrum but extended to IR. Better S/N – less resolution.

Exposure time: 4 x 600 s initially

Linear polarization ~ 5-10 %

One dip in the polarisation
in the 3700-3800 A range
(= rest frame around 1200 A)

But most probably an instrumental artefact.

Measuring LE polarisation:

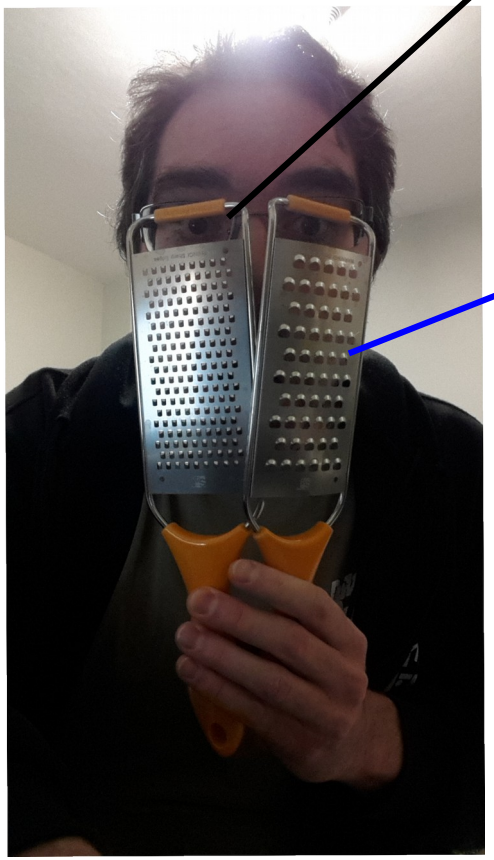
- **<u>Linear polarisation:</u>** constraint on the strength and geometry of magnetic fields
- **<u>Polarisation angle change:</u>** constraint on the location of the gamma-ray emiting region

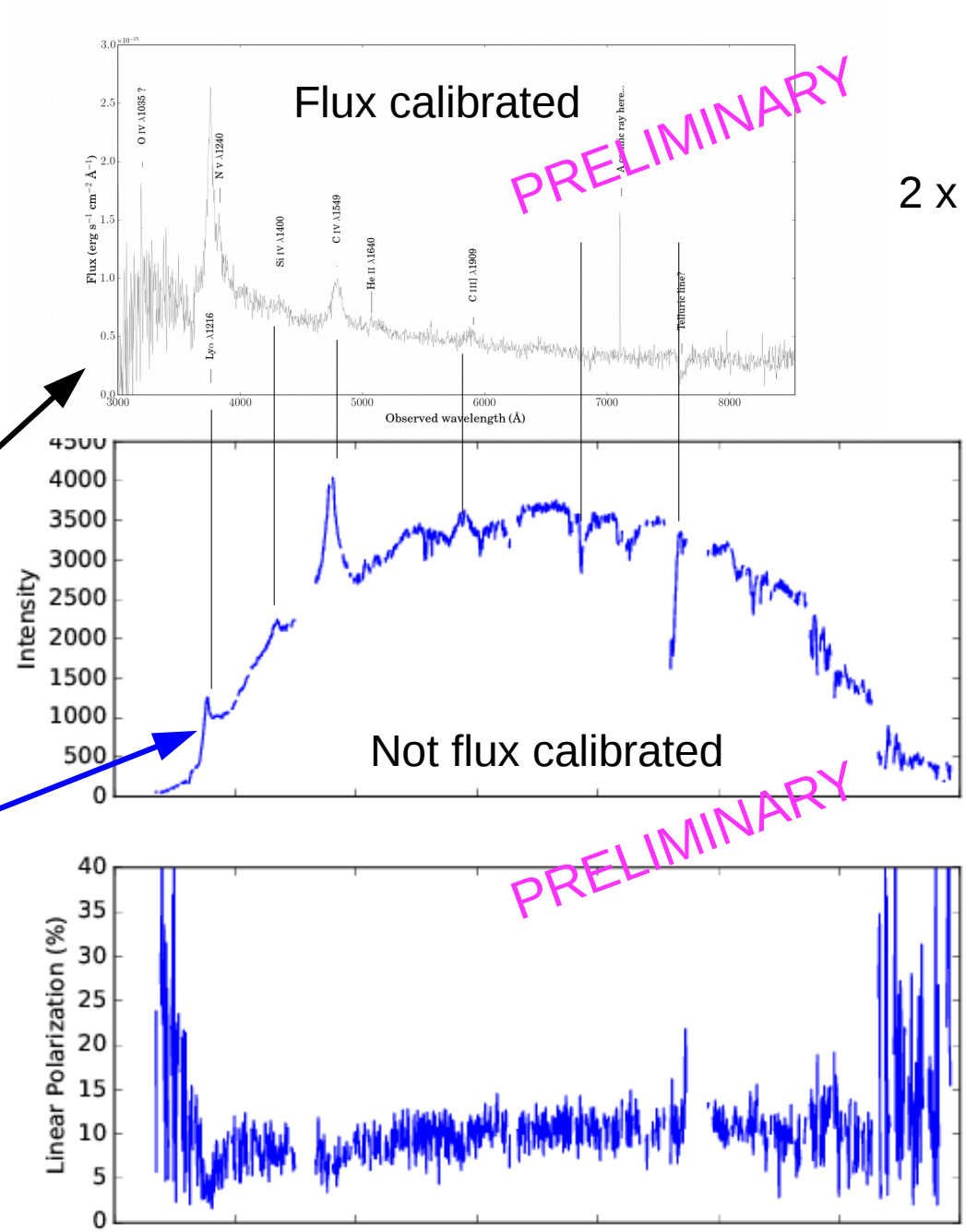
Spectrum reduction: Steve Crawford

SpUpNIC on 1.9 m telescope

versus

SALT-RSS spectra





2 x 600 s

4 x 600 s

Summary on 4C +01.02

- Dramatic variability in both optical and gamma-ray bands – some visible correlation
- Illustrate well the potential for Fermi-LAT / SA-based telescope combined studies of flaring blazars

<u>In the “to do” LIST:</u>

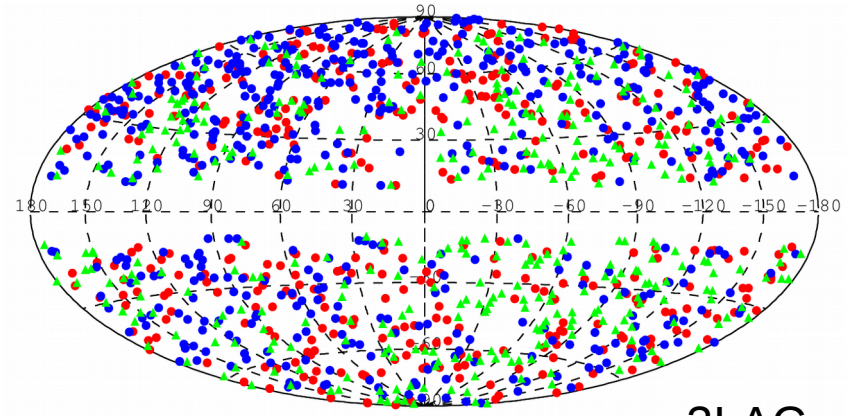
- Collecting more optical data (photometric and spectrometric) is expected for monitoring spectral variability
- White magnitudes and V, R , I from less sensitive telescopes still under process
- Checking the fast variability pattern
- Compute time lags between light-curves

Classification of BCUs

L. Klindt's M Sc project

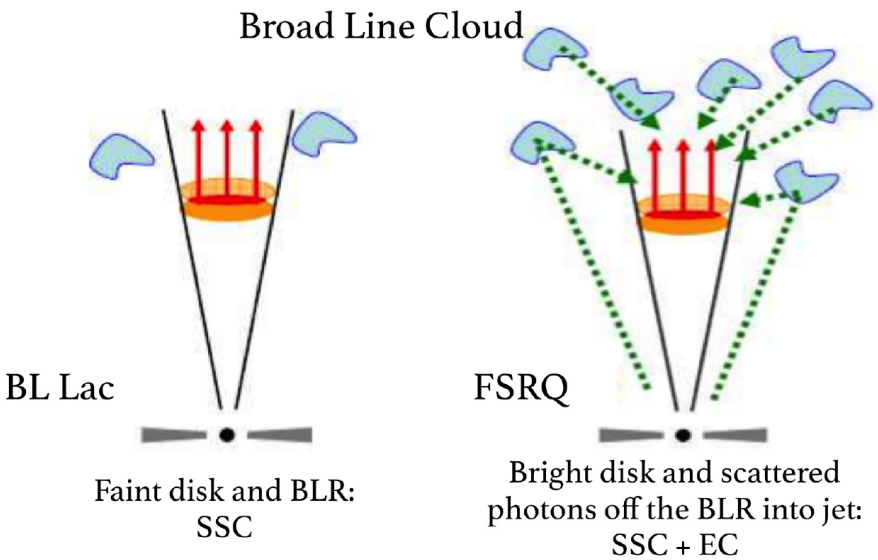
Blazars can be divided into FSRQs or BL Lacs based on their spectral properties.

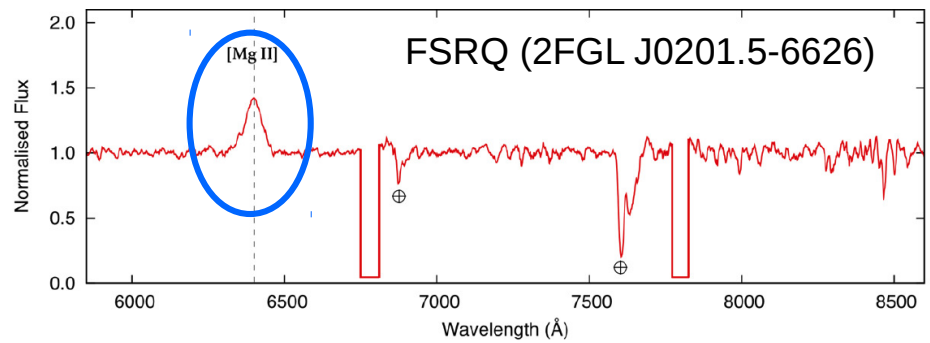
- FSRQs show strong emission lines
  - EW > 5 Å
- BL Lacs show mainly featureless spectra
  - EW < 5 Å

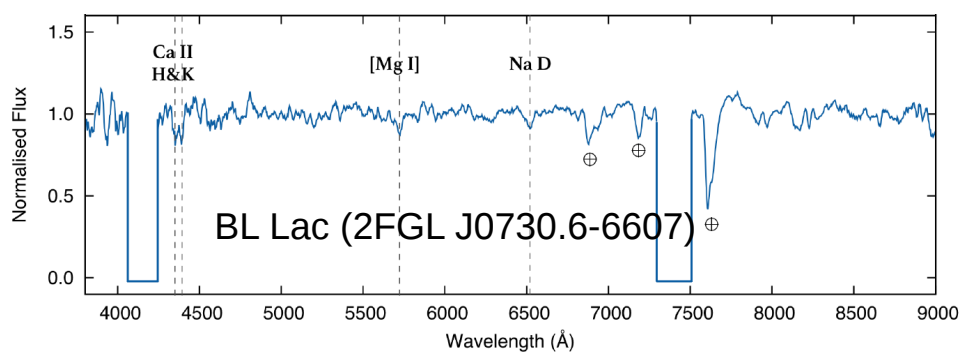


Red: FSRQs, blue: BL Lac objects, magenta: radio galaxies, and green: **blazar candidates of uncertain type (BCU)** – 402 objects in the clean sample)

Ackermann et al. 2015, ApJ, 810, 14



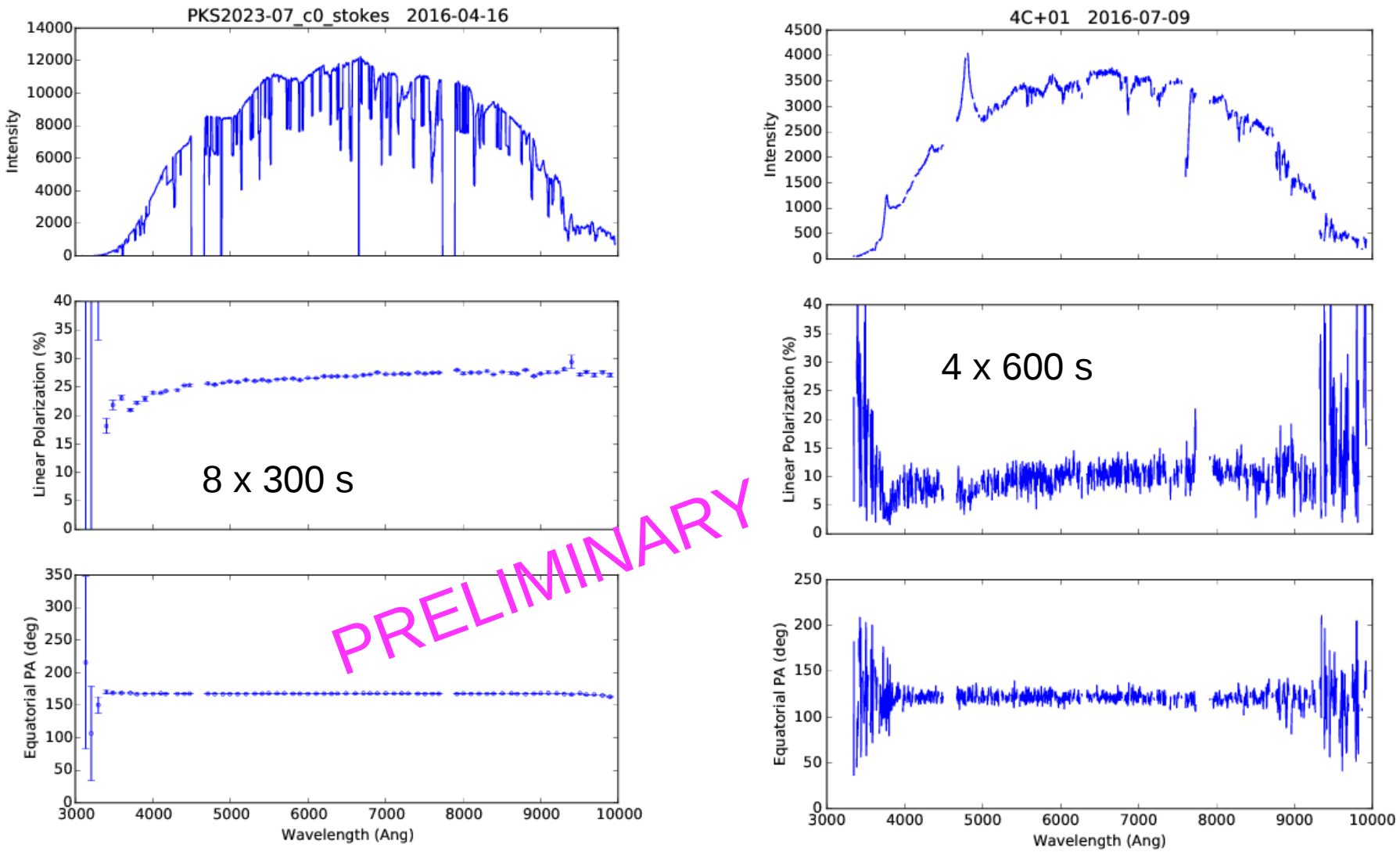




Comparison to ANN predictions

2FGL name	3FGL name	ANN class	SPEC class	
2FGLJ0044.7-3702	3FGLJ0045.2-3704	FSRQ	FSRQ	
2FGLJ0201.5-6626	3FGLJ0200.9-6635	Uncertain	FSRQ	
2FGLJ0644.2-6713	3FGLJ0644.3-6713	FSRQ	FSRQ	
2FGLJ0730.6-6607	3FGLJ0730.5-6606	BL_Lac	BL_LAC	
2FGLJ1106.3-3643	3FGLJ1106.4-3643	BL_Lac	BL_Lac?	Featureless spectrum
2FGLJ1154.1-3242	3FGLJ1154.0-3243	BL_Lac	BL_Lac	
2FGLJ1218.8-4827	3FGLJ1218.8-4827	Uncertain	BL_Lac	
2FGLJ1407.5-4257	3FGLJ1407.7-4256	BL_Lac	BL_Lac	
2FGLJ1617.6-2526c	3FGLJ1617.3-2519	FSRQ	BL_Lac?	Featureless spectrum
2FGLJ1955.0-5639	3FGLJ1954.9-5640	BL_Lac	BL_Lac?	Featureless spectrum
2FGLJ2049.8+1001	3FGLJ2049.7+1002	Uncertain	BL_Lac	

In coll. with G. Chiaro et al – see Chiaro et al (2016) arXiv:1607.07822 [astro-ph.HE]



Spectra reduction: Steve Crawford

Spectropolarimetry of PKS 1510-089 still to be reduced

धन्यवाद्!

Backup slides

Leptonic *versus* hadronic discrimination

- **Light-curves:**
  - Correlation or non-correlation
    radio (or optical) *versus* gamma rays
  - Fast variability

VERY EASY

- **Broadband SED:**
  - Fitting of the HE bump
  - Polarisation in the X-ray and gamma-ray domain

Hmm…

Probably not in 2016…

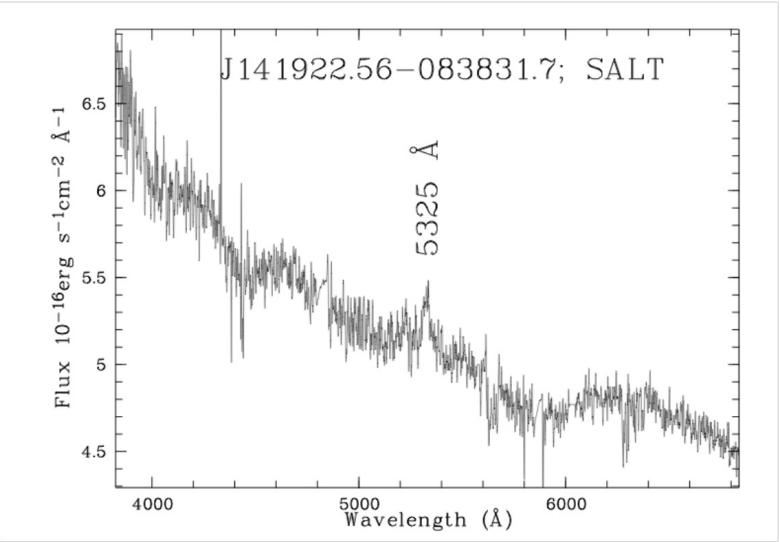
- **Neutrinos detections**

We need to narrow time coincidence…

- Spectrum of one MASTER-OT/Fermi-LAT source:
  - NVSS J141922-083830 (Buckley et al, in preparation)

z = 0.903
if the 5325 Å line
is the Mg II 2798 Å line

ATel #7167; D. A.H. Buckley et al. (2015)



- Observing the Transient Universe
  - PI: David A. H. Buckley (proposal currently running)
  - Includes ToO on flaring blazars
  - Spectropolarimetry of FSRQs

    PKS 2023-07 and 4C +01.02

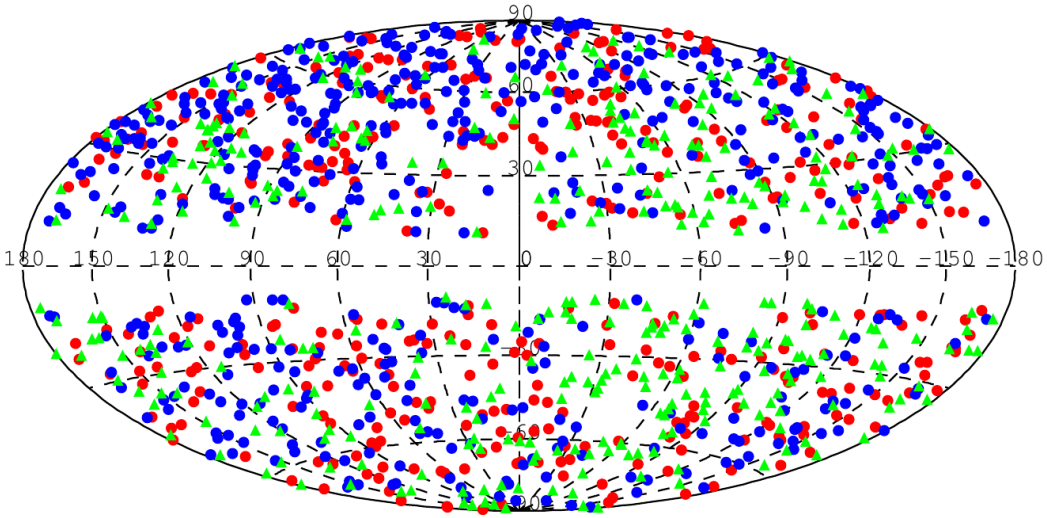
Fermi-LAT – Catalog of Active Galactic Nuclei

- 402 of the sources are listed as *blazars of uncertain type* (BCUs)
  - BCU I: published optical spectrum but not sensitive enough classification
  - BCU II: no optical spectrum but a reliable evaluation of the SED synchrotron-peak position
  - BCU III: no optical spectrum nor an estimated synchrotron-peak position but shows a blazar-like broadband emission and a flat radio spectrum;

- Furthermore, 60 of these BCUs are included in the 2nd catalogue of Hard *Fermi*-LAT sources; (2FHL, Ackermann et al. 2016)

AGN type	Entire 3LAC	Clean sample	Low-latitude sample
FSRQ	467	414	24
BL Lac	632	604	30
BCU	460	402	125
Other	32	24	3
Total	**1591**	**1444**	**182**

Ackermann et al. 2015, ApJ, 810, 14



Red: FSRQs, blue: BL Lac objects, magenta: radio galaxies, and green: AGNs of unknown type

Spectral classification/Redshift

2FGL name	Counterpart	Source classification	Redshift from optical spectra
J0044.7-3702	PKS 0042-373	FSRQ	1.0331 ± 0.0004
J0201.5-6626	PMN J0201-6638	FSRQ	1.28 ± 0.01
J0644.2-6713	PKS 0644-671	FSRQ	1.930 ± 0.004
J0730.6-6607	PMN J0730-6602	HSP BL Lac	0.106 ± 0.001
J1154.1-3242	PKS 1151-324	LSP BL Lac	0.224 ± 0.019
J1218.8-4827	PMN J1219-4826	ISP BL Lac	0.150 ± 0.006
J1407.5-4257	CGRaBS J1407-4302	LSP BL Lac	0.124 ± 0.009
J2049.8+1001	PKS 2047+098	LSP BL Lac	0.226 ± 0.001

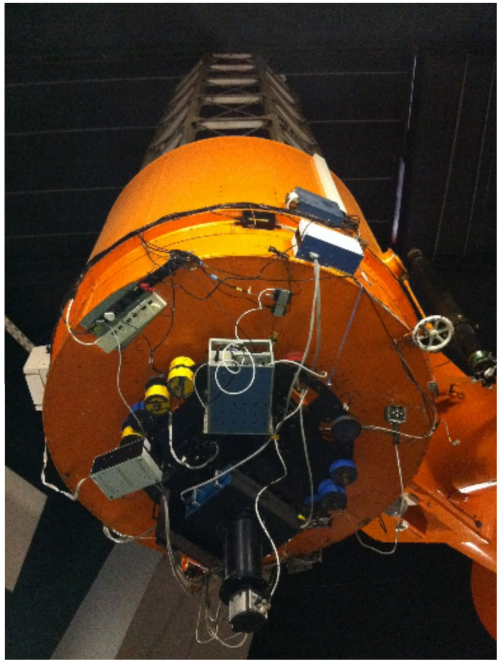
Klindt et al *in prep*

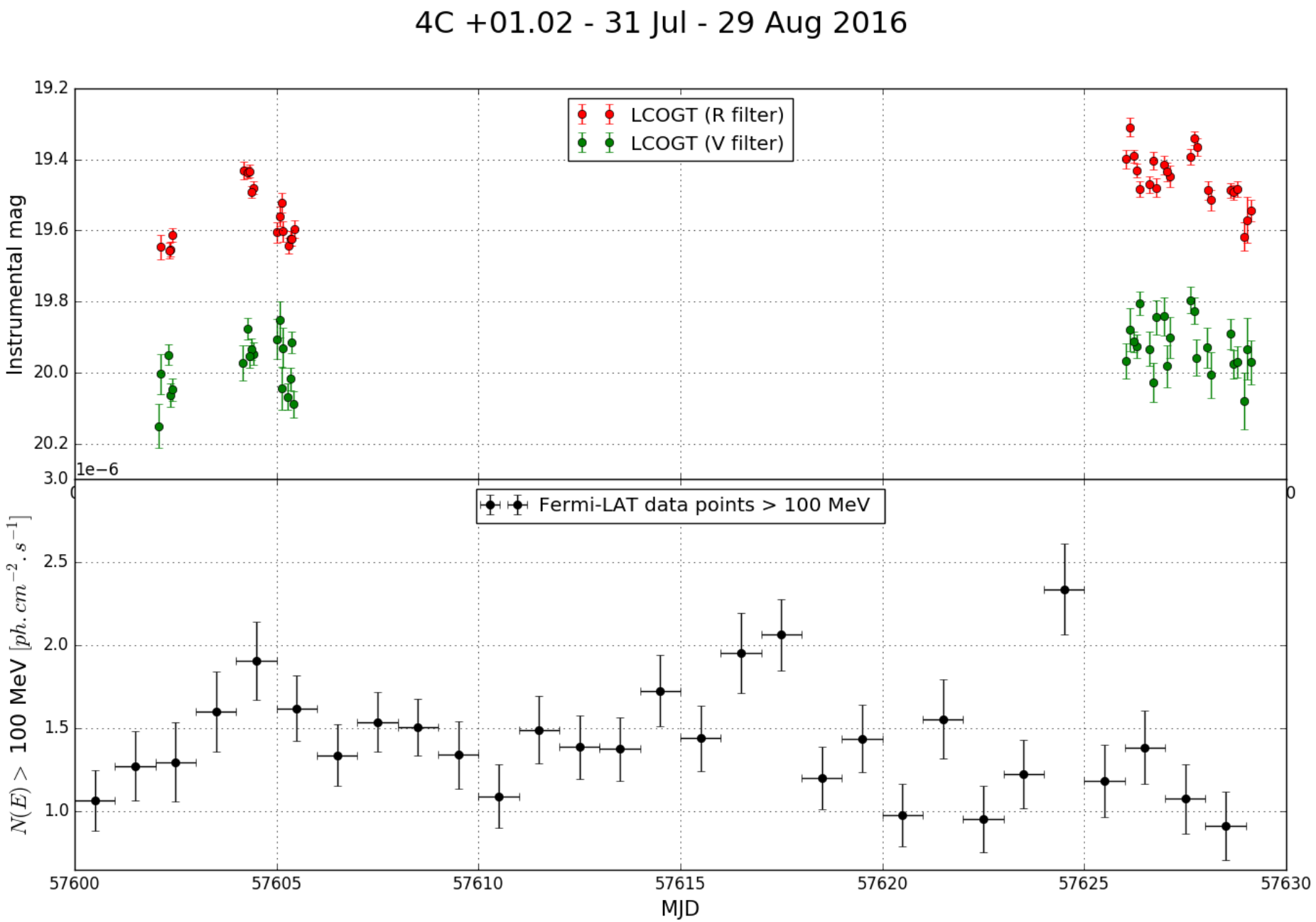
Future Plans

- In order to continue the BCU searchers and improve the ANN calibration we are undertaking more observations of BCUs

- During July/August we have undertaken spectroscopy of 11 new sources with the SpUpNIC/SAAO 1.9-m
  - Selection focused on
    - 2FHL sources – (TeV candidates)
    - Important sources identified from the BCU-ANN method

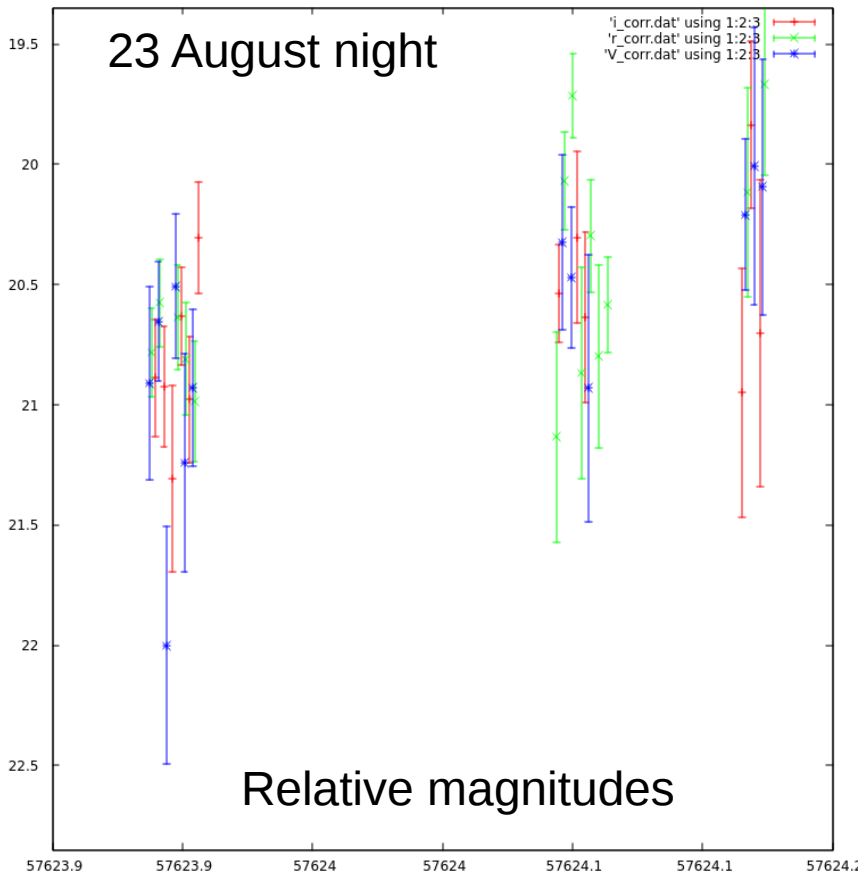
We are open to suggestions of sources and observation setups to continue this quest!




4C +01.02 - 31 Jul - 29 Aug 2016
LCOGT (R filter)
LCOGT (V filter)
Instrumental mag
19.2
19.4
19.6
19.8
20.0
20.2
1e−6
3.0
Fermi-LAT data points > 100 MeV
$N(E) >$ 100 MeV $[ph.cm^{-2}.s^{-1}]$
2.5
2.0
1.5
1.0
57600
57605
57610
57615
57620
57625
57630
MJD

Watcher data from the last two nights

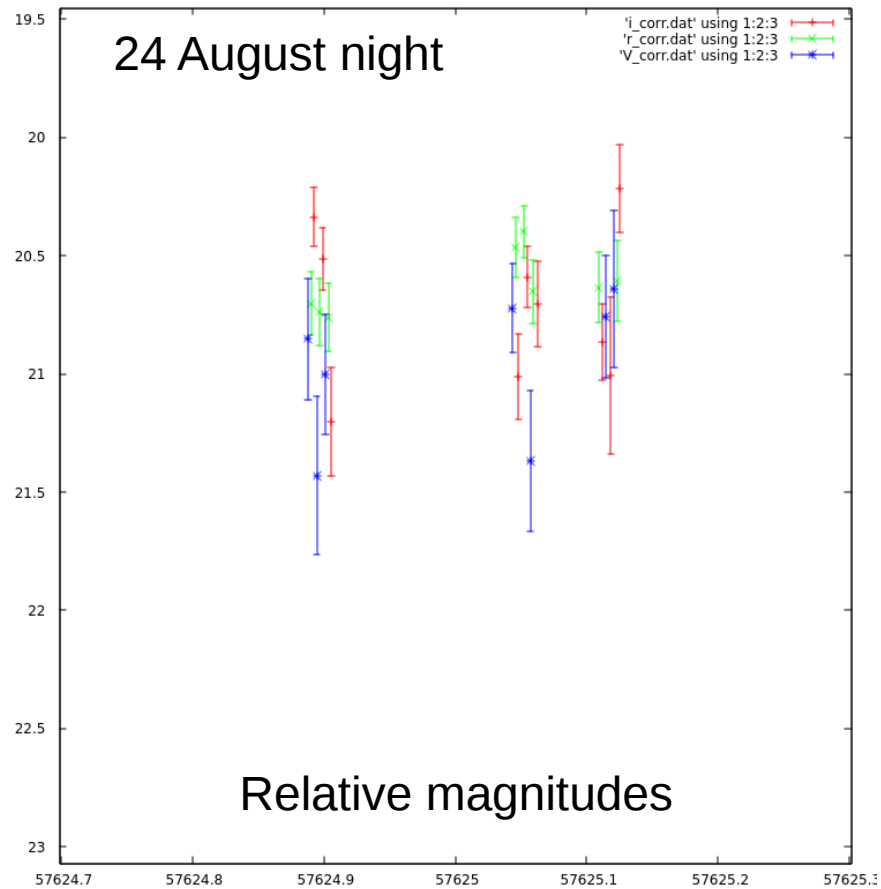
4C +01.02



r

i

V



Exposure: 3 x 30 s

Exposure: 6 x 30 s

Data extraction: J. P. Marais