The Gamma-Ray Blazar B0208-512, a Multi-Wavelength Investigation

Jay Blanchard – University of Tasmania

Jim Lovell, School of Mathematics & Physics, University of Tasmania, Australia.
Roopesh Ojha, NASA Goddard Space Flight Center, USA
Matthias Kadler, University of Wurzburg, Germany;
Roberto Nesci, University La Sapienza, Italy;
Philip Edwards, CSIRO Astronomy and Space Science, ATNF, Australia
Michael Dutka, Catholic University, USA
Tapio Pursimo, Nordic Optical Telescope, Santa Cruz de La Palma, Spain;
John Dickey, School of Mathematics & Physics, University of Tasmania, Australia.
Jamie Stevens, CSIRO Astronomy and Space Science, ATNF, Australia

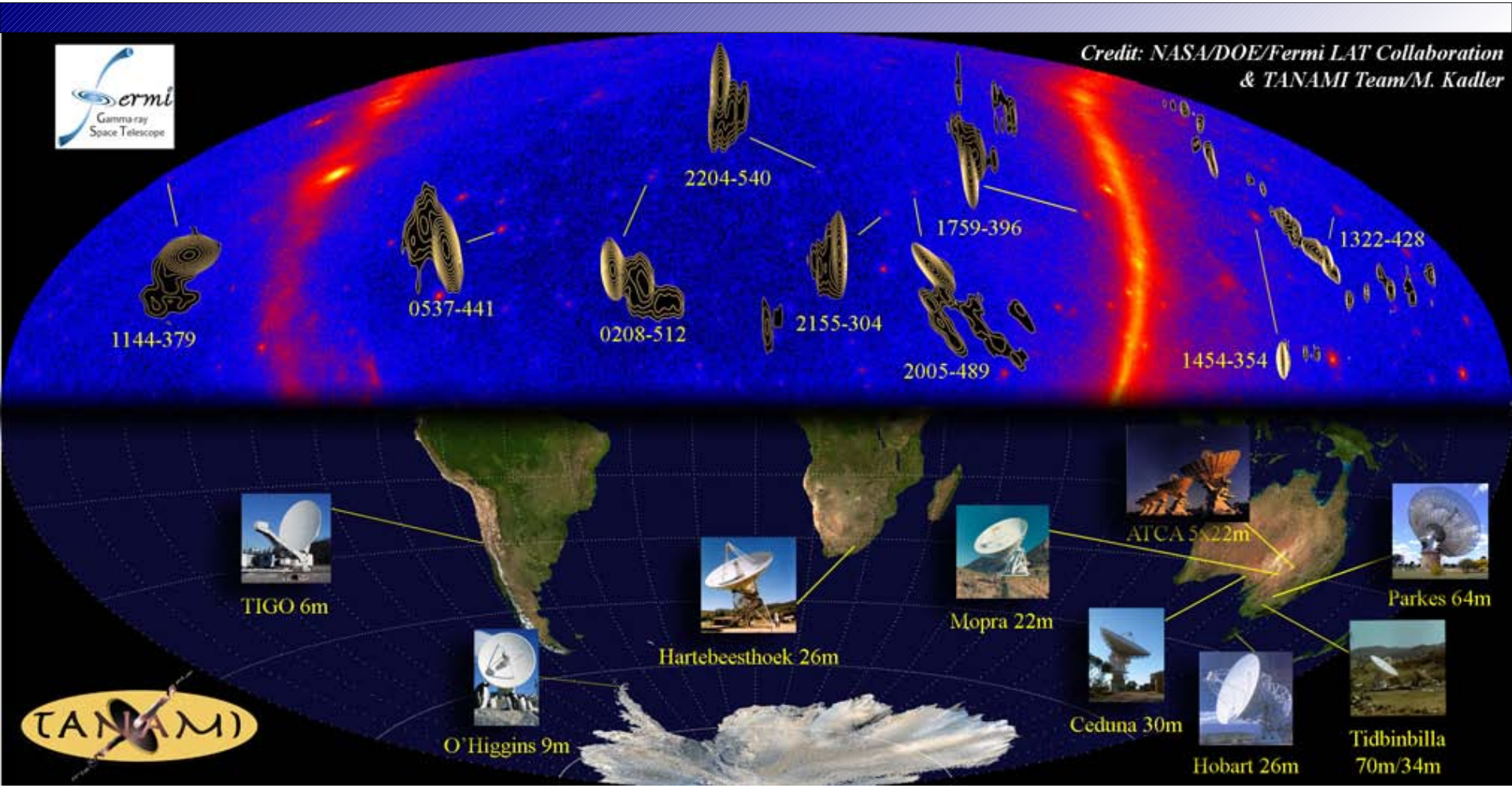
Outline

- The TANAMI project
- Introduction
- PKS 0208-512
- The Data
- Discrete Correlation Function
- Lag vs Frequency analysis
- VLBI data
- Future work.

TANAMI

- TANAMI - Tracking Active Galactic Nuclei with Austral Milliarcsecond Interferometry.
- Tracks the jets of sources south of -30 degrees declination using the Australian Long Baseline Array (LBA).
- Observes at 8.4 and 22 GHz at a cadence of about 2 months.

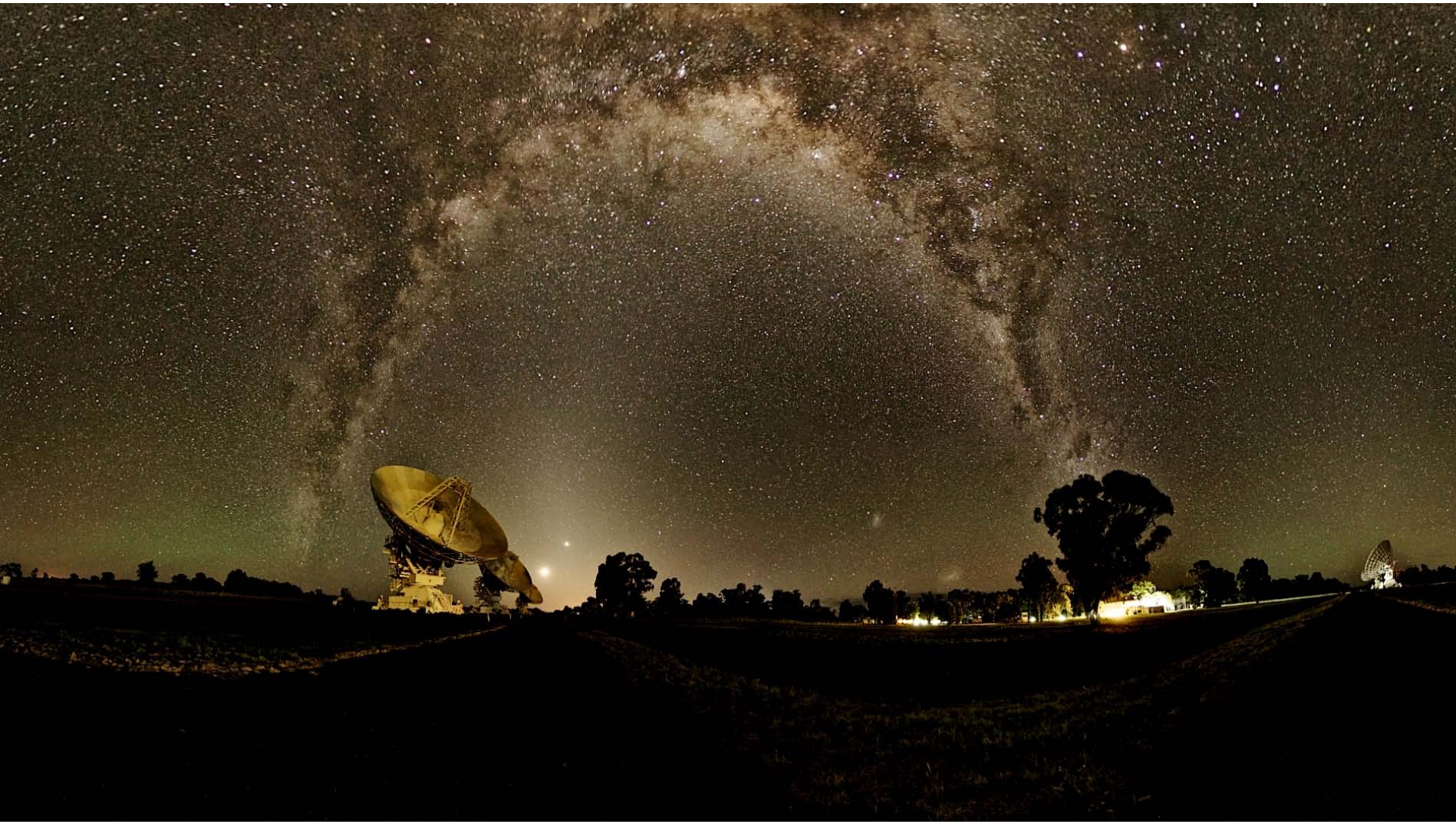
TANAMI


Credit: NASA/DOE/Fermi LAT Collaboration
& TANAMI Team/M. Kadler
Fermi
Gamma-ray
Space Telescope
2204-540
1759-396
1322-428
0537-441
0208-512
2155-304
1144-379
2005-489
1454-354
TIGO 6m
Hartebeesthoek 26m
Mopra 22m
ATCA 5x22m
Parkes 64m
O'Higgins 9m
Ceduna 30m
Hobart 26m
Tidbinbilla
70m/34m
TANAMI

TANAMI - ATCA

- TANAMI has several facilities that are supporting the VLBI observations.
- This includes the Australia Telescope Compact Array (ATCA).
- ATCA consists of six 22m dishes.
- The ATCA observes the TANAMI sources at frequencies between 1.3 and 44 GHz for a 12 hour block every 6 weeks.
- See poster by Jamie Stevens!

TANAMI - ATCA



Credit: Emil Lenc -CSIRO Astronomy and Space Science, ATNF, Australia

TANAMI - Ceduna

- Ceduna is a 30m ex-Telstra communications dish outside Ceduna in South Australia.
- This has been repurposed by the University of Tasmania for astronomical observations.
- Can observe at frequencies between 2.4 and 22 GHz.
- Observes ~40 AGN at a cadence of 2 weeks at 6.7 GHz, as well as 12 sources at a daily cadence.

TANAMI - Ceduna

Introduction

- The emission mechanism of the gamma-rays observed from blazars is as yet poorly understood.
- The mechanism itself is possibly inverse Compton upscattering (see for example Acciari et al. 2010).
- The emission site (and hence the origin of the seed photons) is still uncertain.

Introduction

- Gamma-ray emission likely occurs after the formation of a shocked region in the jet (Lahteenmaki and Valtaoja 2003).
- So the delay between the radio and gamma ray emission generated by the event can be used to identify the location of the emission site.
- In the era of the Energetic Gamma Ray Experiment Telescope (EGRET), early work in the field suggested that the gamma-ray flares are preceded by high frequency radio flares (Valtaoja and Terasranta 1995).

Introduction

- More recent work, suggests the gamma-ray emission is leading the radio (Kovalev et al. 2009, Pushkarev et al 2010). But is mixed, with some showing the opposite lag.
- The expected lag using these calculations is approximately 1.2 months in the source frame, and depends on frequency.
- They suggests the emission is coming from the core of the blazar, and that the delay is due to optical depth affects.

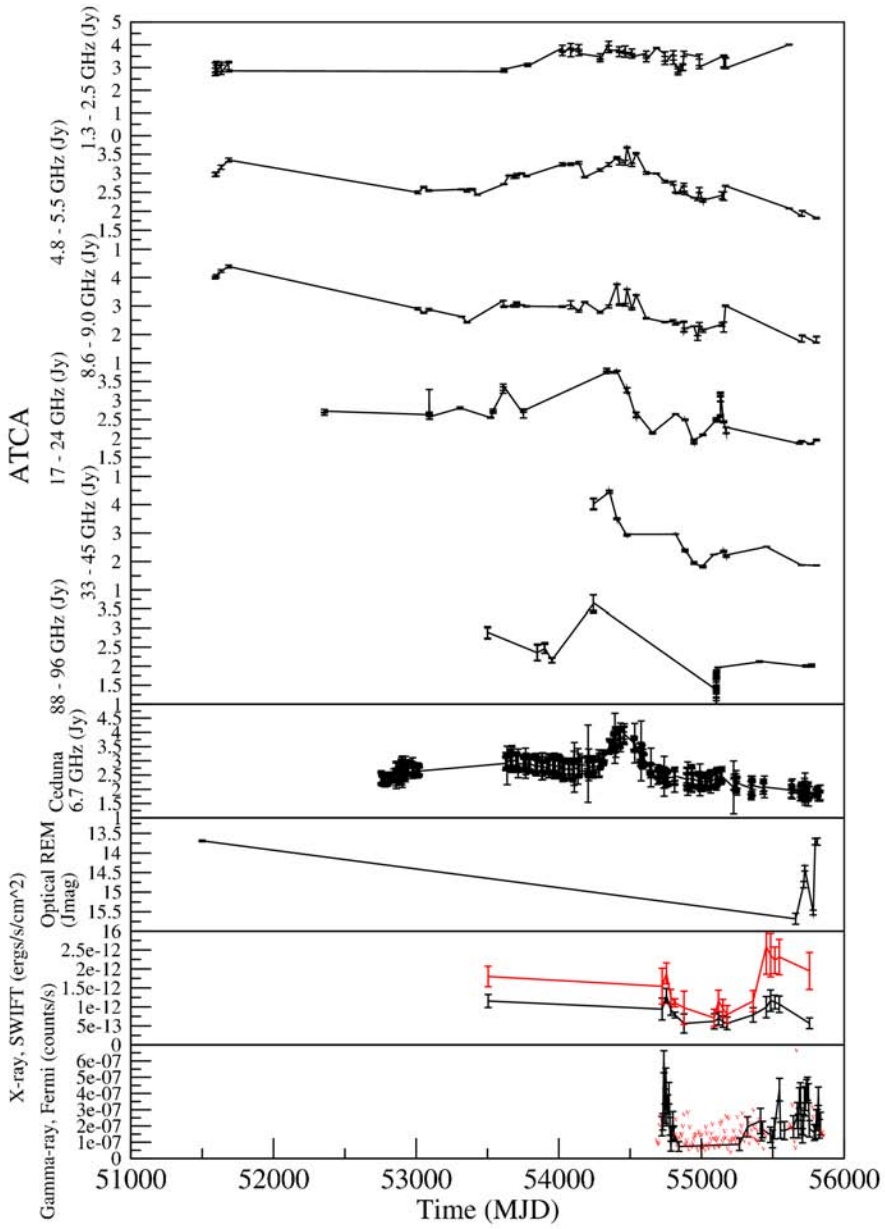
PKS 0208-512

- B0208-512 is a blazar with a redshift of 0.999.
- Shows a one sided jet at radio frequencies extending to approximately 20 mas (Tingay et al 1996).
- Strong and variable X-ray source, first detected by the Röntgen Satellite (ROSAT) (Voges et al. 1999).
- The first gamma-ray detection of the source was by EGRET (Bertsch et al. 1993).
- B0208-512 has shown flaring events in all frequencies.

The Data

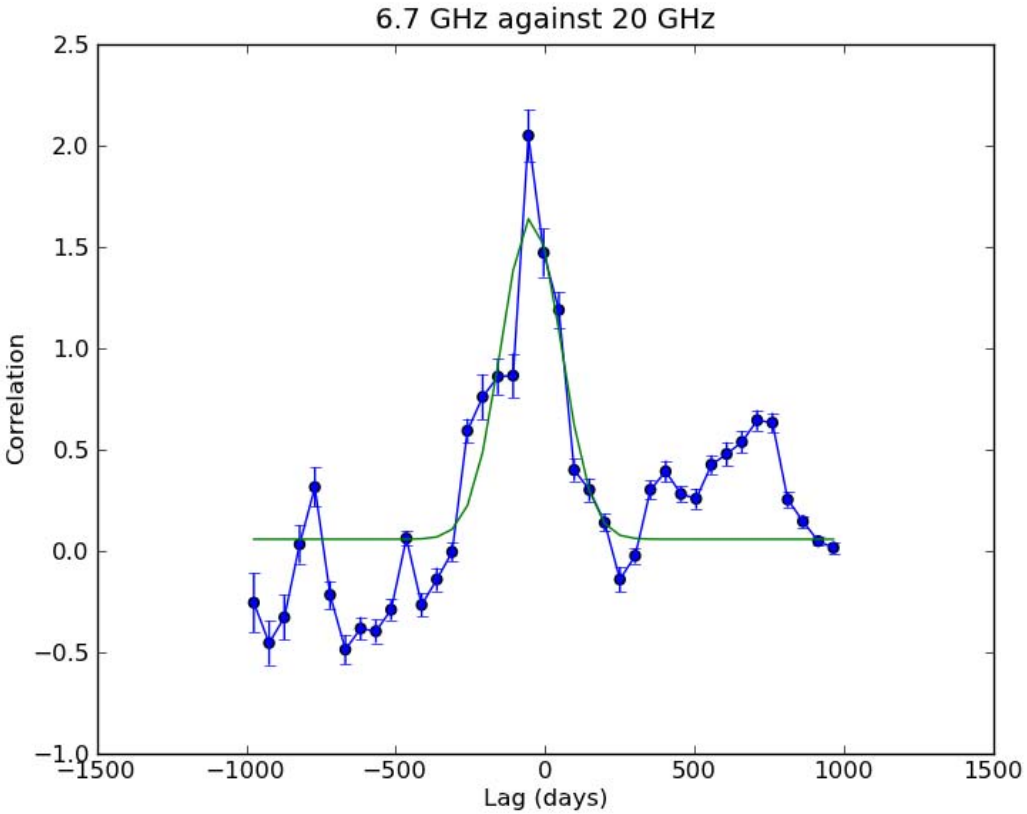
- We have multi-wavelength data going back several years including:
  - Radio data between 1.3 and 96 GHz using the ATCA.
  - Radio data at 6.7 GHz from Ceduna.
  - Optical data from REM.
  - X-ray data from SWIFT-XRT.
  - Gamma-ray data from Fermi

B0208-512


ATCA
1.3 - 2.5 GHz (Jy)
4.8 - 5.5 GHz (Jy)
8.6 - 9.0 GHz (Jy)
17 - 24 GHz (Jy)
33 - 45 GHz (Jy)
88 - 96 GHz (Jy)
Ceduna 6.7 GHz (Jy)
Optical REM (Jmag)
X-ray, SWIFT (ergs/s/cm^2)
Gamma-ray, Fermi (counts/s)
Time (MJD)
51000
52000
53000
54000
55000
56000

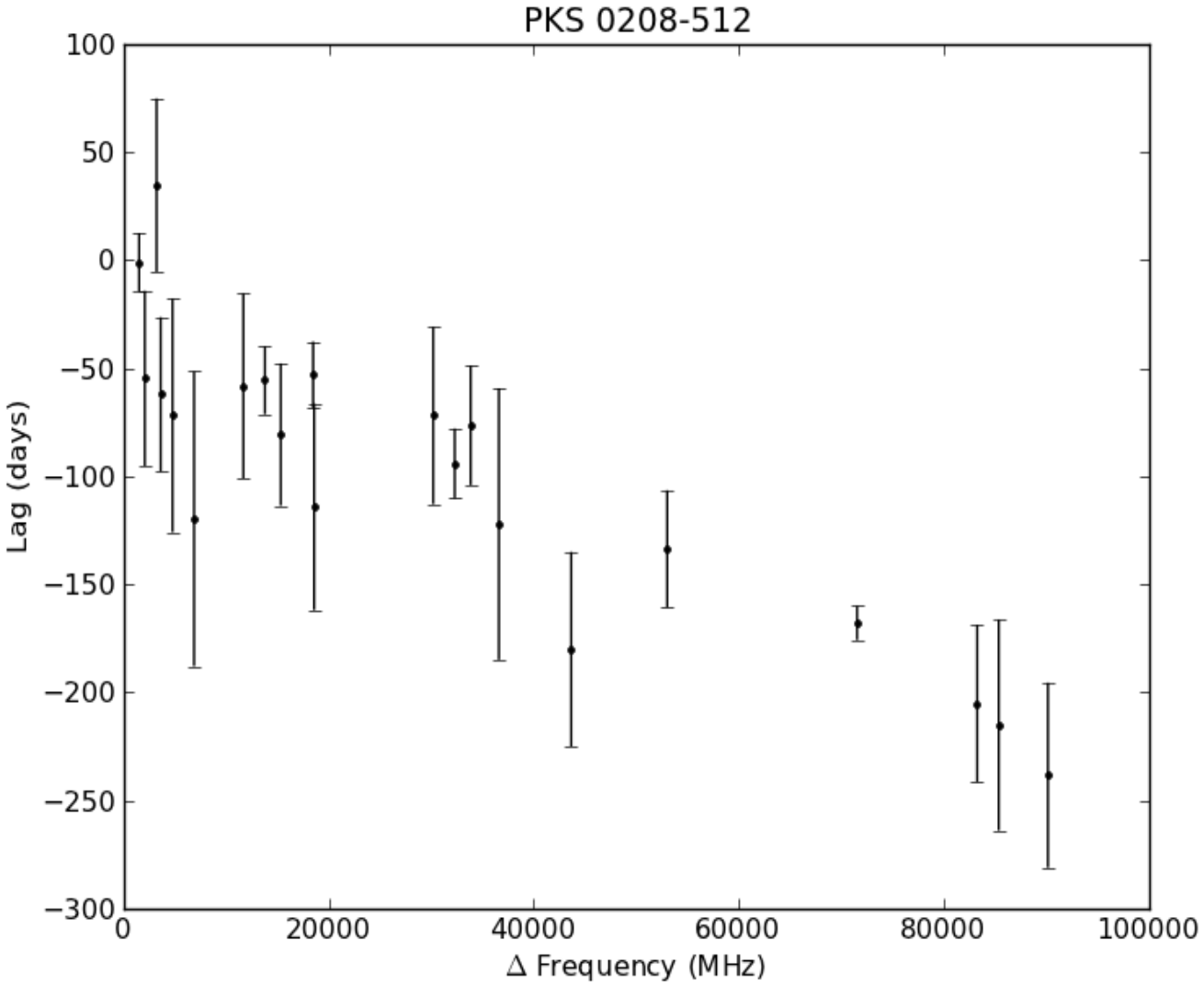
DCF

- Discrete correlation function calculated for all radio data pairs as per Edelson and Krolik (1988).
- Fitted with Gaussian using least mean squared.
- Covariance matrix gives error in the fit.

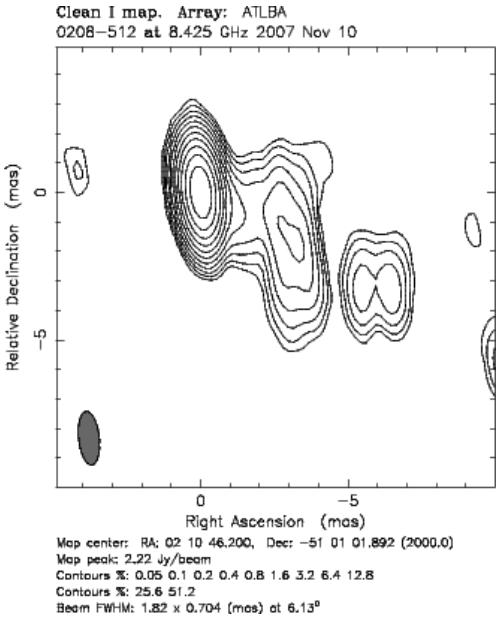


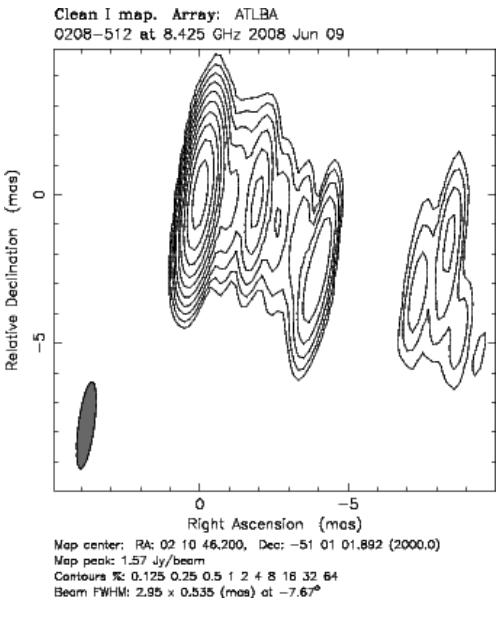
- Example gives a lag of -47 days +- 16.

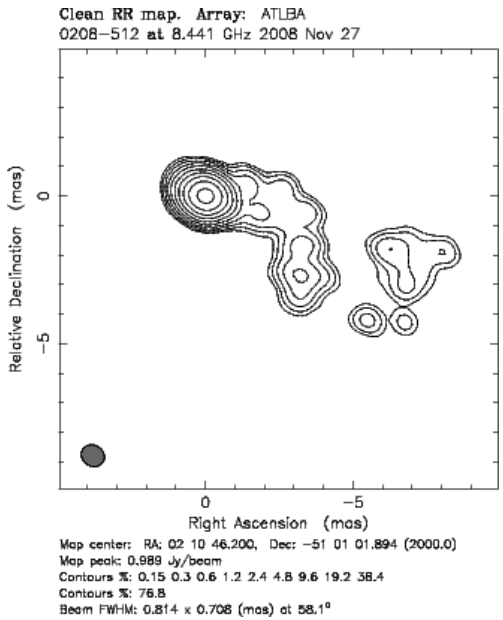
Lag vs Δ Frequency

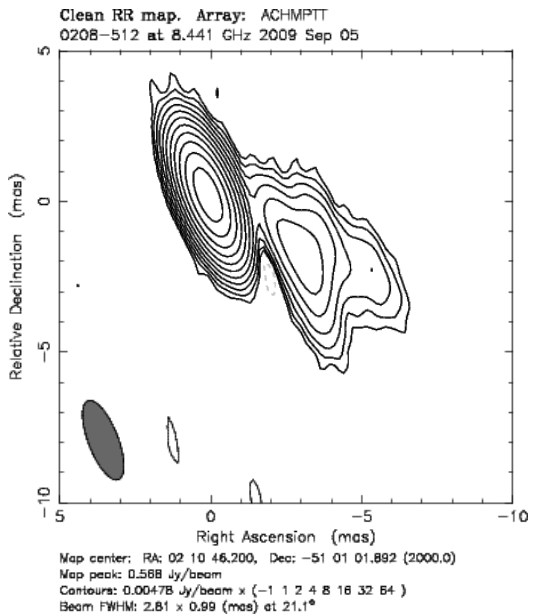


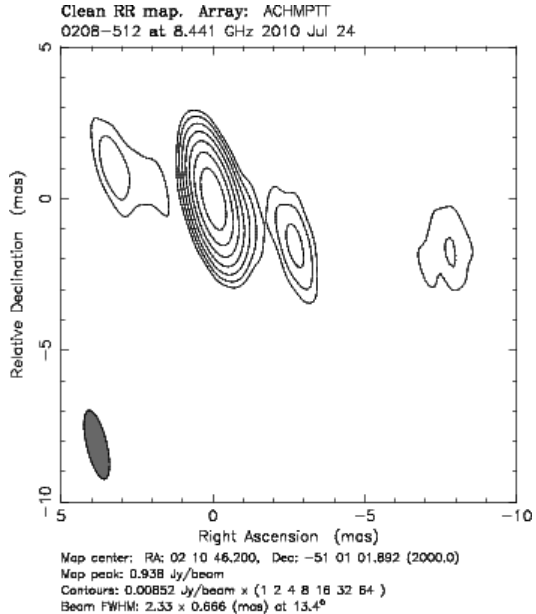
VLBI


Clean I map. Array: ATLBA
0208−512 at 8.425 GHz 2007 Nov 10
Relative Declination (mas)
Right Ascension (mas)
Map center: RA: 02 10 46.200, Dec: −51 01 01.892 (2000.0)
Map peak: 2.22 Jy/beam
Contours %: 0.05 0.1 0.2 0.4 0.8 1.6 3.2 6.4 12.8
Contours %: 25.6 51.2
Beam FWHM: 1.82 x 0.704 (mas) at 6.13°

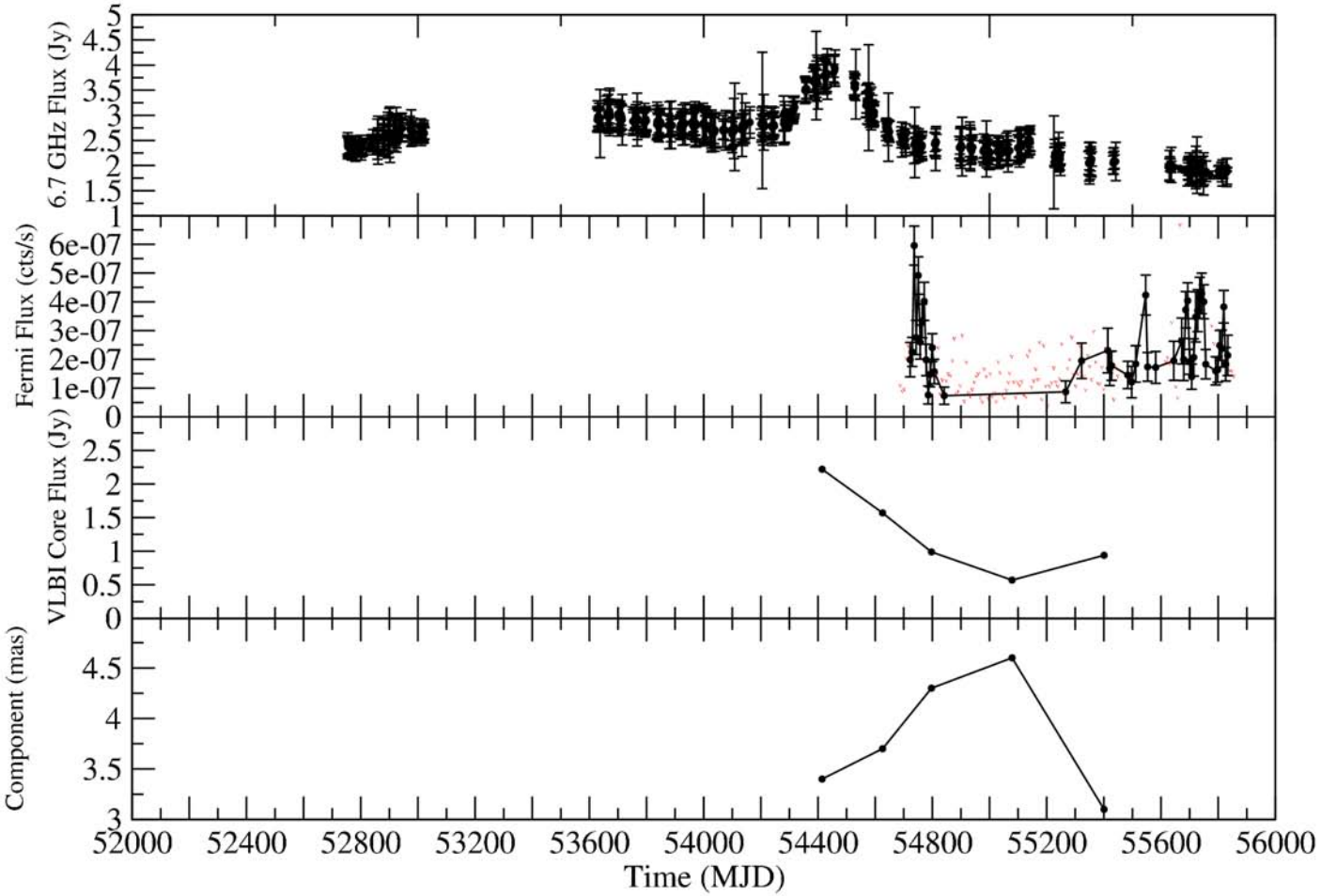

Clean I map. Array: ATLBA
0208−512 at 8.425 GHz 2008 Jun 09
Relative Declination (mas)
Right Ascension (mas)
Map center: RA: 02 10 46.200, Dec: −51 01 01.892 (2000.0)
Map peak: 1.57 Jy/beam
Contours %: 0.125 0.25 0.5 1 2 4 8 16 32 64
Beam FWHM: 2.95 x 0.535 (mas) at −7.67°


Clean RR map. Array: ATLBA
0208−512 at 8.441 GHz 2008 Nov 27
Relative Declination (mas)
Right Ascension (mas)
Map center: RA: 02 10 46.200, Dec: −51 01 01.894 (2000.0)
Map peak: 0.989 Jy/beam
Contours %: 0.15 0.3 0.6 1.2 2.4 4.8 9.6 19.2 38.4
Contours %: 76.8
Beam FWHM: 0.814 x 0.708 (mas) at 58.1°


Clean RR map. Array: ACHMPTT
0208−512 at 8.441 GHz 2009 Sep 05
Relative Declination (mas)
Right Ascension (mas)
Map center: RA: 02 10 46.200, Dec: −51 01 01.892 (2000.0)
Map peak: 0.568 Jy/beam
Contours: 0.0047B Jy/beam x (−1 1 2 4 8 16 32 64)
Beam FWHM: 2.81 x 0.99 (mas) at 21.1°


Clean RR map. Array: ACHMPTT
0208−512 at 8.441 GHz 2010 Jul 24
Relative Declination (mas)
Right Ascension (mas)
Map center: RA: 02 10 46.200, Dec: −51 01 01.892 (2000.0)
Map peak: 0.938 Jy/beam
Contours: 0.00852 Jy/beam x (1 2 4 8 16 32 64)
Beam FWHM: 2.33 x 0.666 (mas) at 13.4°

VLBI


6.7 GHz Flux (Jy)
Fermi Flux (cts/s)
VLBI Core Flux (Jy)
Component (mas)
Time (MJD)
52000
52400
52800
53200
53600
54000
54400
54800
55200
55600
56000

Current and Future Work

- Currently working on significance of DCF.
- Cross correlation between radio and x-ray/gamma-ray.
- More VLBI epochs – modelling of components.
- Reduction of SWIFT-XRT UV data.
- Flaring and Quiescent SED.