Misaligned Active Galactic Nuclei in *Fermi* Era

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Abstract: Observational γ-ray astronomy got a massive growth after the launch of *Fermi* γ-ray Space Telescope (*Fermi*). Majority of the identified sources in the γ-ray sky is a class of active galactic nuclei called blazars. In case of blazars, the jet makes a very small angle to the line of sight and hence, their emission is jet dominated. However, jet emission falls rapidly with increasing jet to line-of-sight angle. Therefore, misaligned AGN (MAGN) are not expected to be strong γ-ray emitters. EGRET on board the Compton γ-ray observatory detected two MAGNs (Cen A and NGC 6251) during its lifetime. However, *Fermi* already detected $\sim$20 MAGN during the first four years of observation and this number is expected to increase in coming years. Therefore, it is an opportune time to study the properties of MAGN. The prime objective of this work is to understand the properties of Fermi detected MAGN by studying their multiband flux variability and broadband spectral energy distribution. The preliminary results of this study are presented here.

Introduction

• Misaligned Active Galactic Nuclei (MAGN): They are a class of AGN with their relativistic jets not closely aligned with the observer, having jet inclination angle $>10°$. At radio wavelengths, they display both FRI (weaker sources with $P_{178MHz} < 10^{25}$ W/Hz) and FRII (stronger sources with $P_{178MHz} > 10^{25}$ W/Hz) morphology. The broad band spectral energy distribution of aligned AGN (blazar) has two distinct humps, with the low energy hump attributed to synchroton emission processes and the high energy hump attributed to inverse Compton (IC) processes. FRI and FRII are believed to be the parent population of BL Lacs and FSRQs, which are a sub-class of blazars. In the case of BL Lacs, the seed photons for the IC process are the synchrotron photons themselves (synchrotron self Compton) whereas in the case of FSRQs, the seed photons for the IC process are from sources exterior to the jet and can come from the accretion disk, the torus and/or the broad line region.

Census of γ-ray emitting MAGN

• MAGNs detected in γ-ray:
• Two sources known from EGRET era: NGC 6251(FRI) and Cen A(FRI).
• Nine sources known from Fermi 1st catalog (11 months): 6 FRIs and 3 FRIIs.
• Ten sources known from Fermi 2nd catalog (24 months): 8 FRIs and 2 FRIIs.
• Nineteen sources known from Fermi 3rd catalog (48 months) 12 FRI and 7 FRIIs.

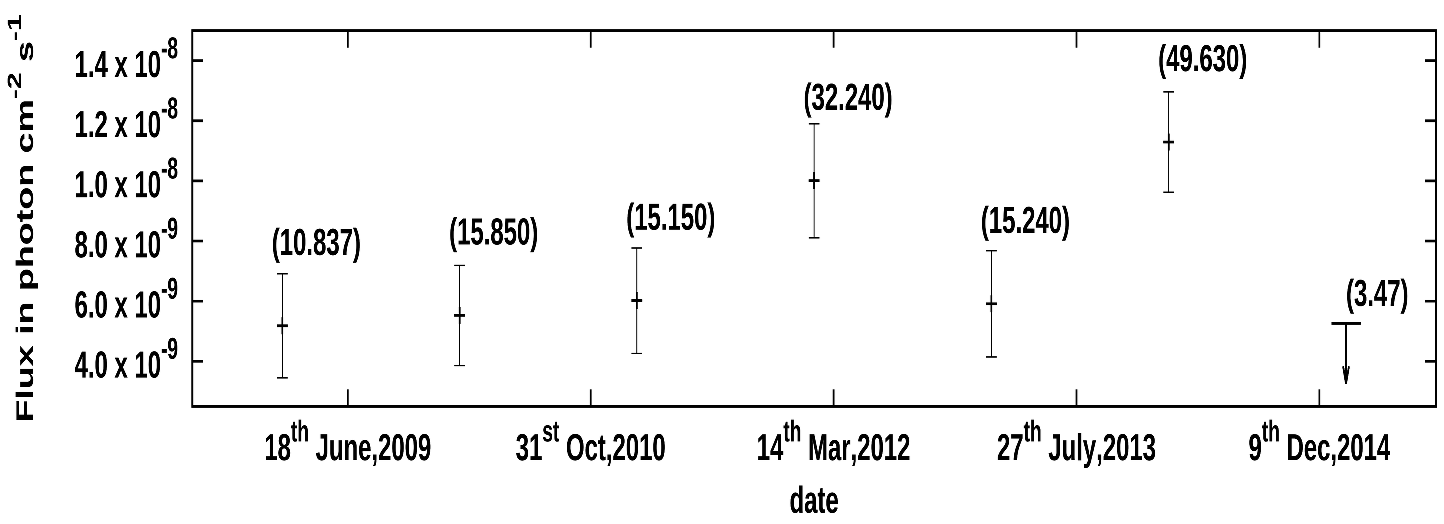
Majority of MAGNs detected in are FRIs

Motivation:

• How the flux variability properties of MAGN compare to that of blazars?
• Are there any differences in the optical and gamma-ray flux variations between FRI and FRII types of MAGN?

Data and Analysis

• γ-ray light curves have been generated for 3C 111 and NGC 1218 using 7 years of Fermi data. The analysis has been carried out following standard procedures. They are shown in Fig. 1 and Fig. 2.



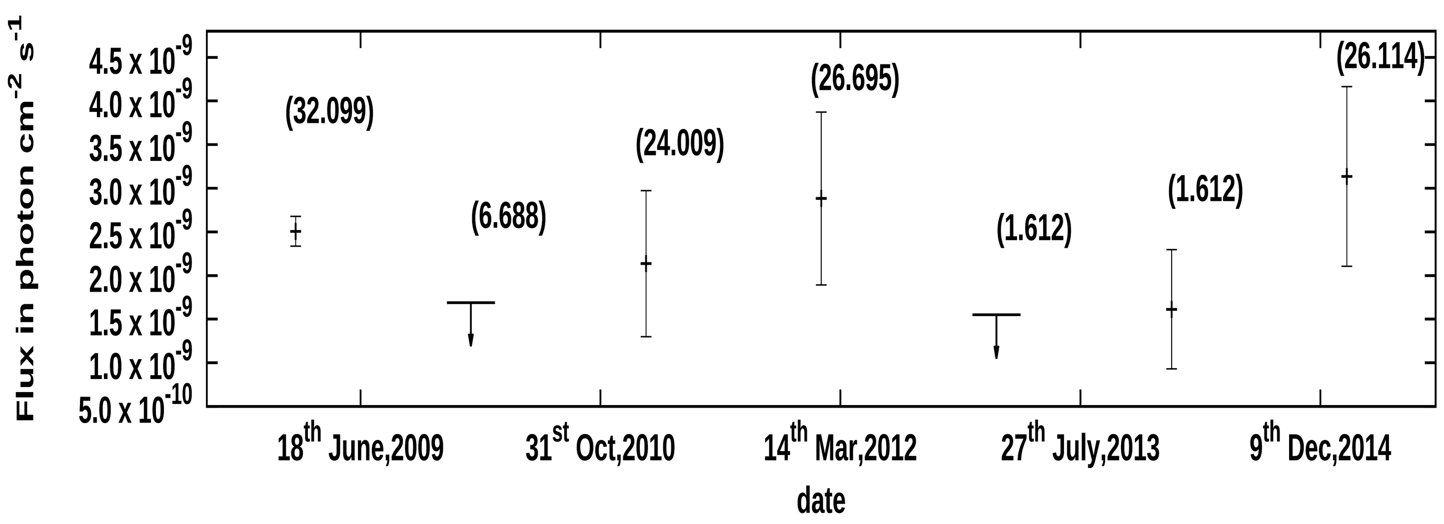


Fig.1 & Fig.2: Light curves for 3C 111 and NGC 1218 . The value in brackets is the TS of the source.

• Intranight optical monitoring observations were carried out on few sources using the 2m Himalayan Chandra Telescope and the 1.3 m JCB Telescope The observed field of 3C 303 (14th june,2015) is shown in Fig. 3 and the differential lightcurves are shown in Fig. 4.
• Four statistical test have been applied on the observations to check for the presence of variability and Fractional variance has been used to characteristic the flux variations. The results of the statistical tests are given in following table.

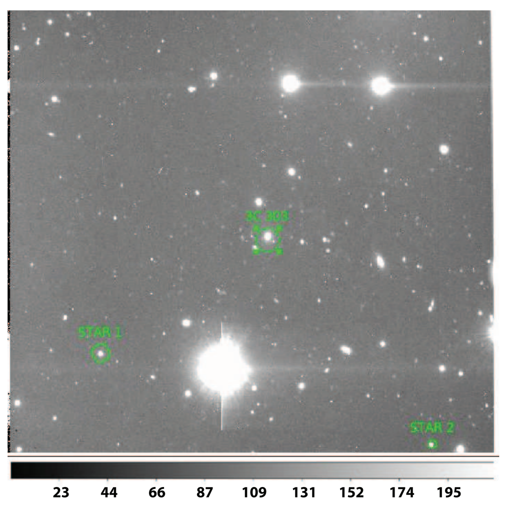


Fig.3 : Filtered sky image with comparison stars and source.

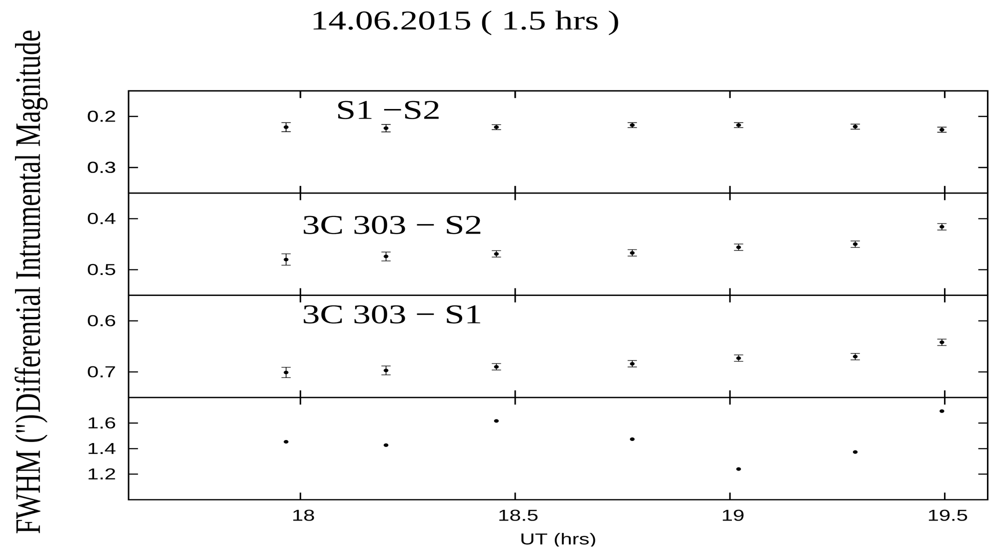


Fig.4: Light curve for 3C 303 for 14th june, 2015.

T.S. values of 3C 111 and NGC 1218 in different time bins.

Source	Reduced chi sq			F-test			C-test		Modified C-test		
	t-s1	t-s2	s1-s2	t-s1	t-s2	s1-s2	t-s1	t-s2	t-s1	t-s2	s1-s2
3C 303 14-06-2015	9.3056	10.9052	0.4403	9.6709	10.3976	0.3641	6.2995	6.7137	3.1748	3.3178	0.6219
3C 303 15-06-2015	1.4513	2.2919	0.6352	1.6437	2.9337	0.8112	1.6875	2.3818	1.2842	1.7221	0.9068
NGC 6251 15-06-2015	1.6076	0.6558	0.4610	1.3592	0.6921	0.4902	1.2137	1.1312	1.2113	0.8342	0.7044
NGC 2484 25-01-2015	0.4387	0.7570	0.1968	0.4826	0.8327	0.2164	1.7570	1.9615	0.6947	0.9125	0.4652

Summary

Variability of few Fermi detected MAGNs in γ-rays (long term) and optical wavelength (short term) are studied here.
• NGC 6251 and NGC 1218 (FRI), do not show any long term γ-ray variability.
• 3C 111, a FRII MAGN, shows long term variability (1 year averaged light curve) in γ-ray with fractional variance of 26.7 %. This is the first signature of observed long term variability in MAGN.
• Previous variability studies of 3C 111 limited to the first two years of LAT data showed only one bin detection (3 months bin). The source spends not more than two months flaring and then disappears (fast variability of 60 days)[2].
• INOV was tested for a sample of MAGNs (NGC 6251, NGC 2484, 3C 264, 3C 303). One of the source (3C 303) shows significant intranight optical variability.
• We aim to study the γ-ray variability of all Fermi detected MAGNs to investigate any possible difference between FR I and FR II sources.
• Detection of INOV in one MAGN puts an important question on the possible origin of INOV. However, one needs to carry out many more observations to strenthen this result, which is in progress.
• To better understand the emission mechanism in FR I and FR II, we plan to model the broad band spectral energy distributions (SED) of these sources utilizing multi-wavelength observations.

References

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