Fermi Gamma-ray Space Telescope

Evidence of quasi periodic modulation in the gamma-ray blazar PG1553+113

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PG 1553+113: introduction

- PG 1553+113 is an optically-selected BL Lac object in Palomar-Green Bright Quasar Catalog.

- First citations of this blazar dates back to mid '80s (source seen by IRAS Neugebauer et al. 1986, ApJ 308, 815).

- BL Lac object classification (featureless optical spectrum, Miller & Green 1983)

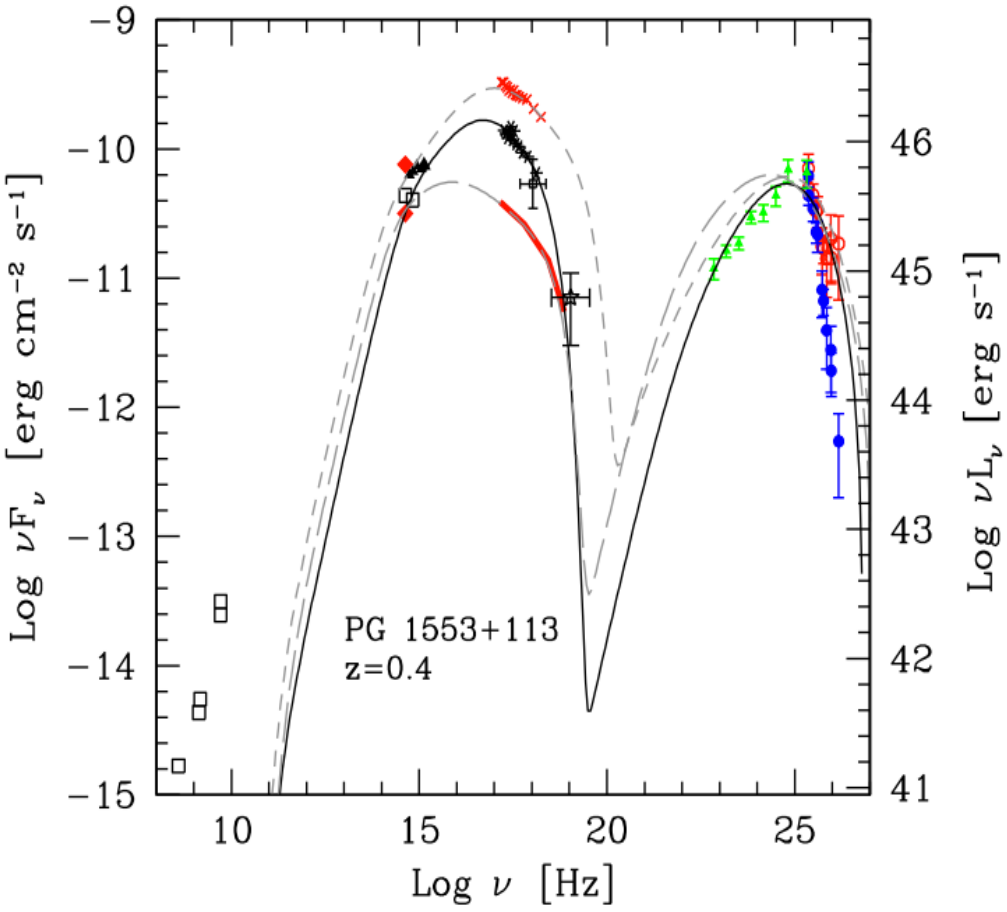
- The X-ray counterpart is discovered by the Einstein Observatory (1ES catalog, Einstein satellite, 1981 March with count rate 1.27 cts/s), putting it among the brightest BL Lac objects in the X-ray band.

- Host galaxy remains unresolved and optical observations of the spectrum no reveal any spectral features ➔ Limits to the PG 1553+113 redshift value based on indirect measurements Recent/best estimation of the limits constrain the redshift between $0.395 < z < 0.62$ (Danforth et al 2010 and Aliu et al. 2015)

PG 1553+113: in gamma rays

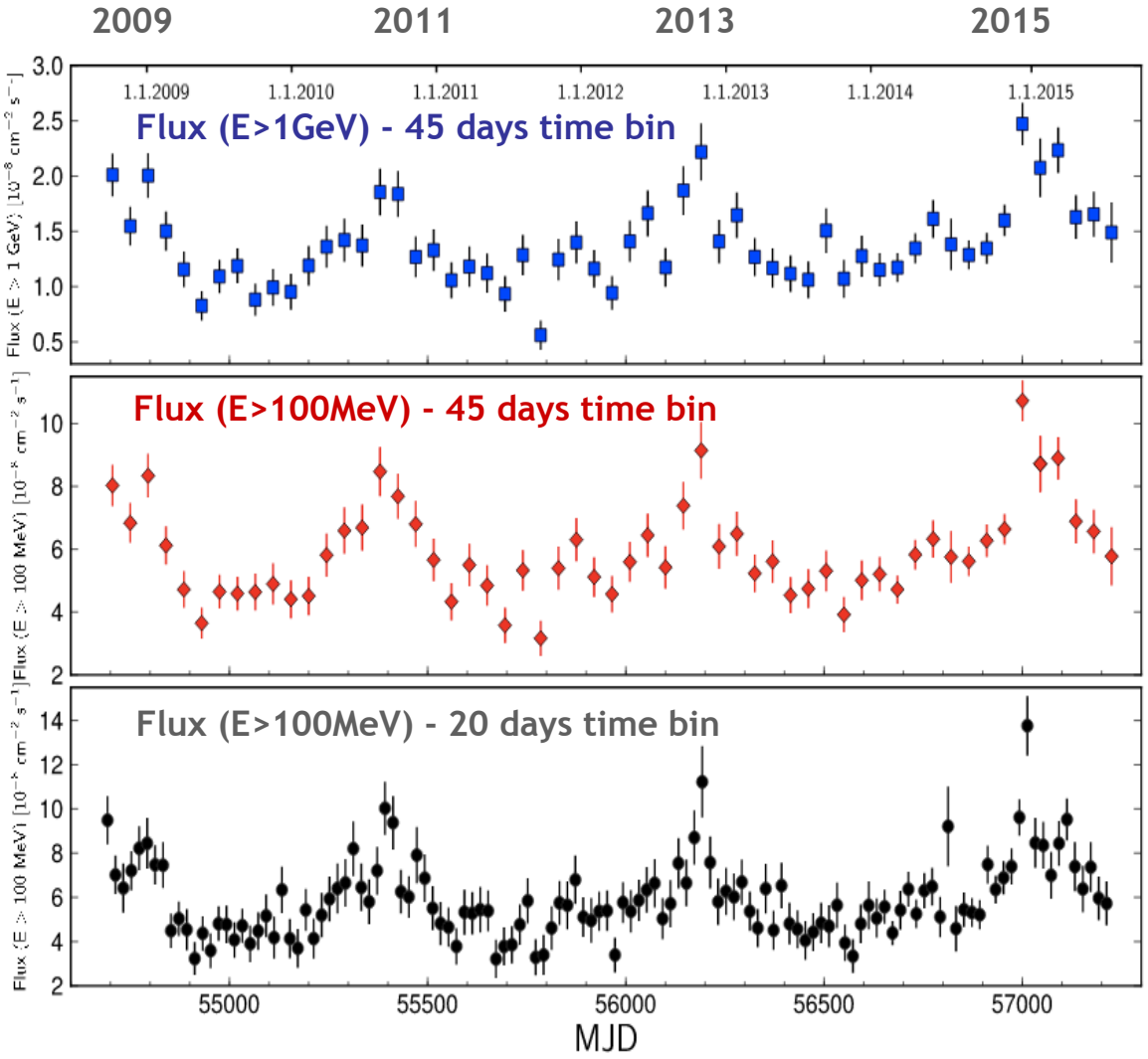
- VHE (E>100GeV) gamma-ray emission from PG 1553+113 discovered independently and almost simultaneously by H.E.S.S. (Aharonian et al. 2006, A&A, 448, L19), and by MAGIC (Albert et al. 2007, ApJL., 654, L119, Aleksic et al. 2012 ApJ, 748, 46).

- In the 3FGL (3FGL 1555.7+1111) the spectrum can be well fitted by a power-law with a hard spectral photon index of 1.60+/-0.02 and F(E>100MeV)=(1.32+/-0.03)X10^-8 ph cm^-2 s^-1. The source has found variable in GeV gamma-rays based on 1-month bin light curve.



PG 1553+113: Fermi-LAT gamma-ray light curves

- *Fermi* LAT gamma-ray flux (E>100MeV and E>1GeV) light curves of PG 1553+113 based on Pass 8 dataset up to July 2015, produced in regular time bins of 45-day and 20-day size.
- A long-term oscillating trend is visually evident from these LAT gamma-ray light curves.
- Modulation of the light curve is visually identified ➔Next period peak is foreseen between the end of 2016 and beginning of 2017.



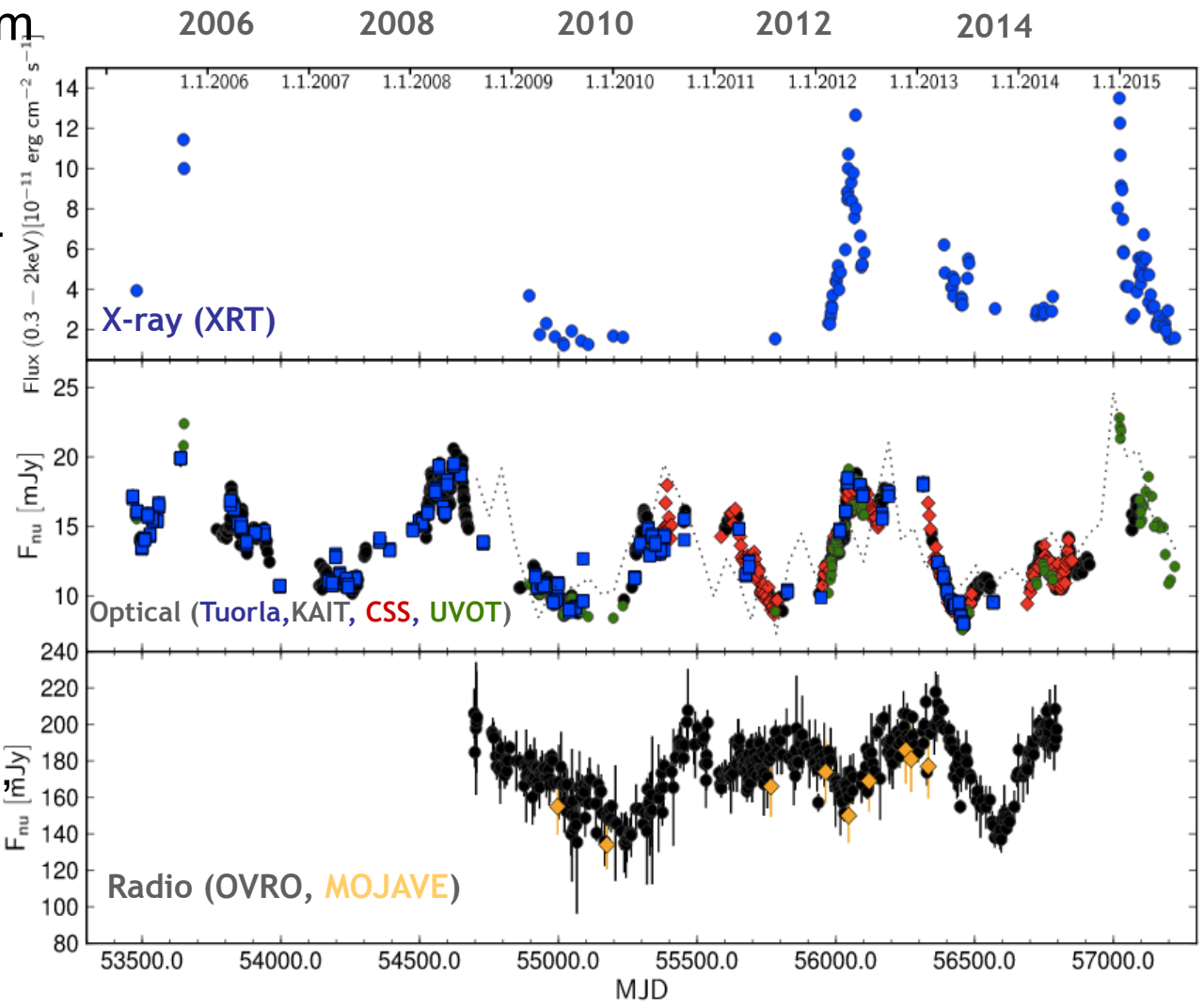
Fermi/LAT Coll.+AS, ApJL, 2015, 816, 41

PG1553+113: MWL light curves

➔X-ray data obtained with Swift-XRT dedicated follow-up program of Target of Opportunity

➔Optical band assembled with Tuorla monitoring program KAIT monitoring data Catalina Sky Survey data and Swift-UVOT

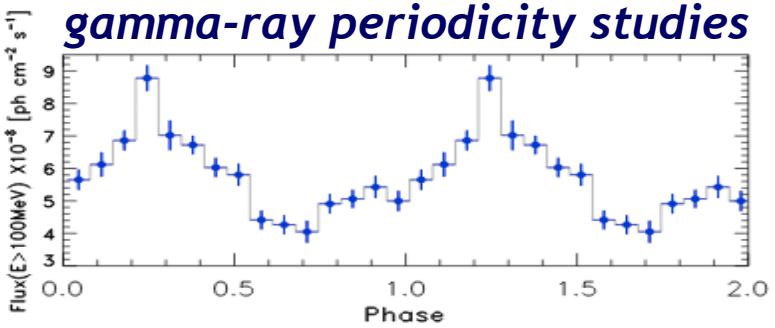
➔Radio band at 15 GHz is assembled with OVRO Fermi blazars follow-up program (Richards et al. 2011, ApJ, 194, 29) and MOJAVE Fermi monitoring program (Lister et al., 2009, AJ, 137, 3718)

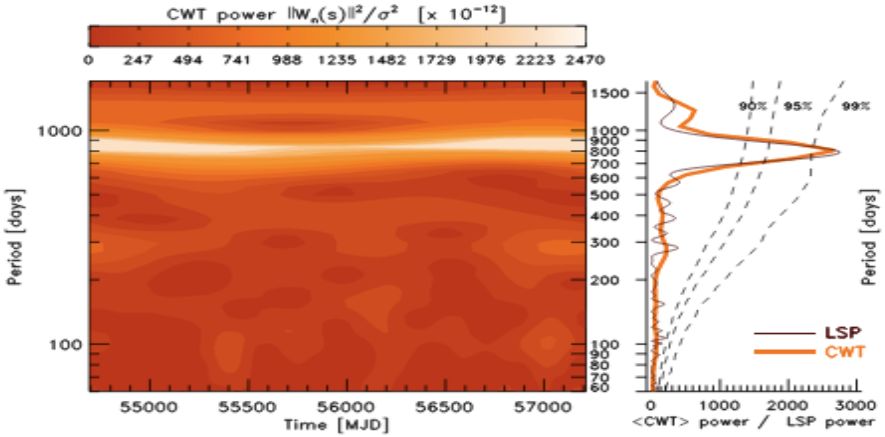


PG1553+113: periodicity studies

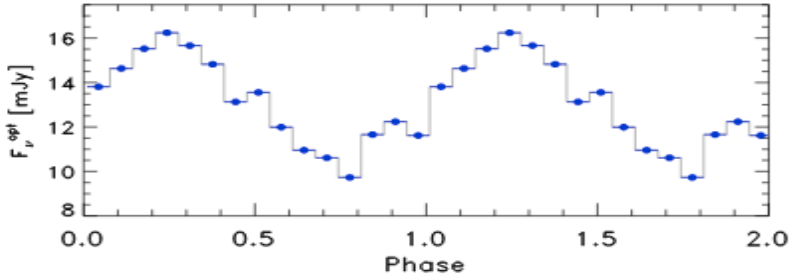
- Gamma-ray period evaluation (7 yr of data): 2.18+/-0.08 yr
  - <1% random fluctuation from LSP (red noise bkg)
  - ~1% chance probability of random line up of 3.5 cicles
- Optical period evaluation (10 yr of data): 2.05+/-0.05yr
  - <5% random fluctuation from LSP (red noise bkg)

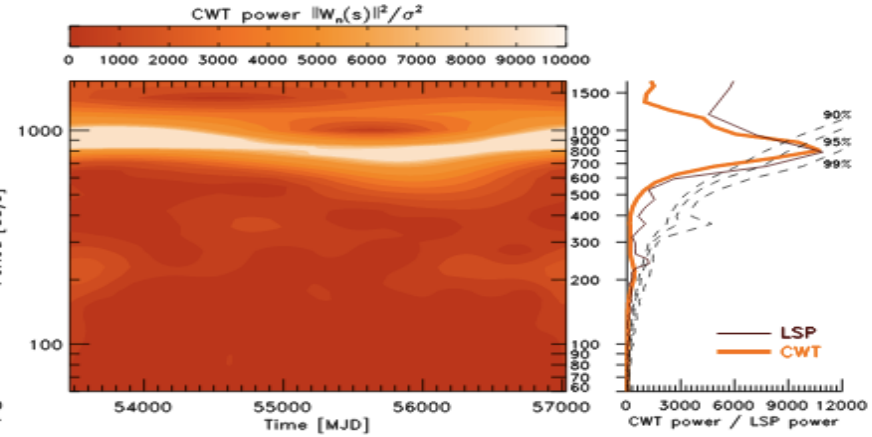
gamma-ray periodicity studies



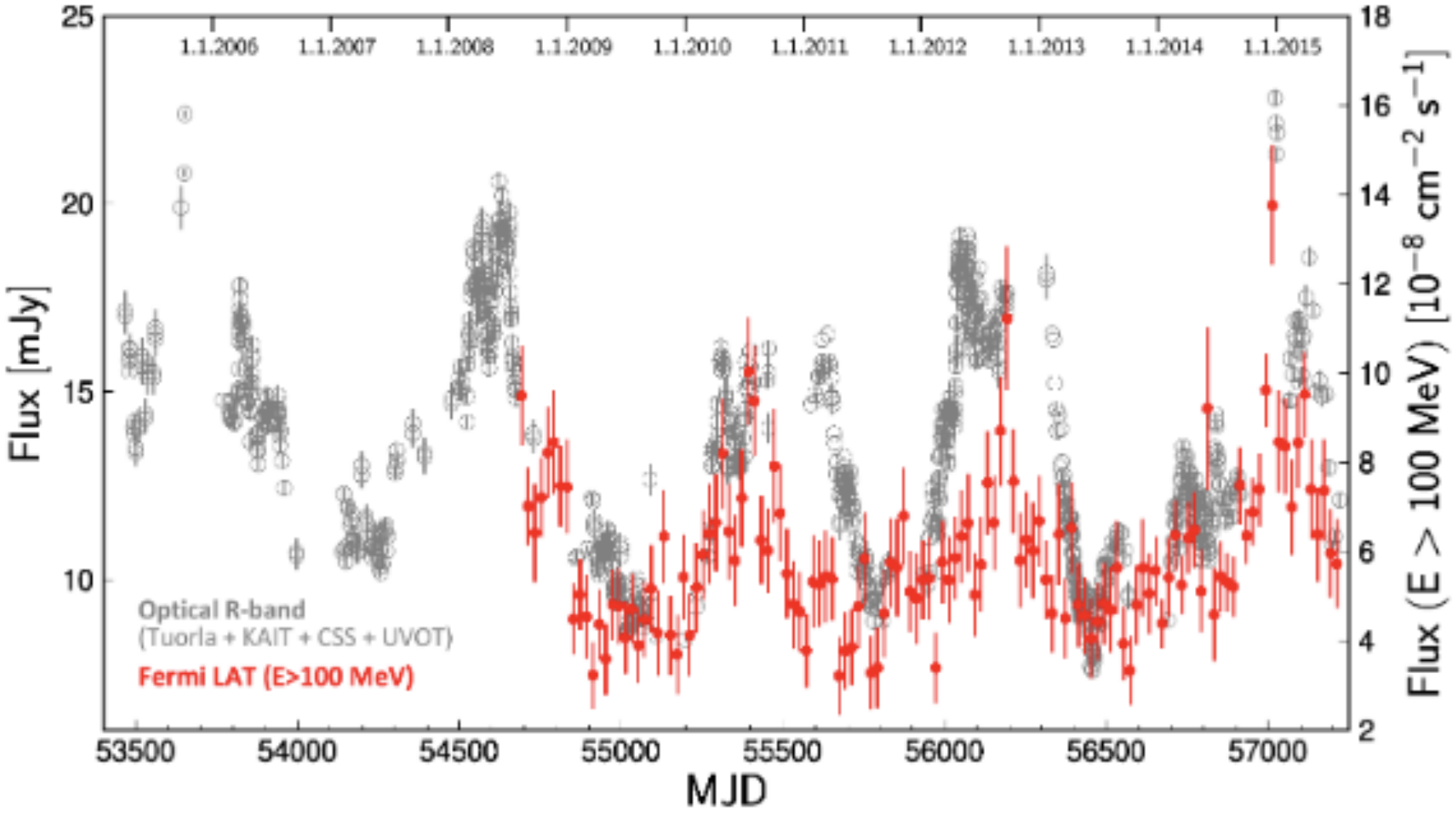


optical periodicity studies





PG 1553+113: composite light curve



PG1553+113 light curves: time lags

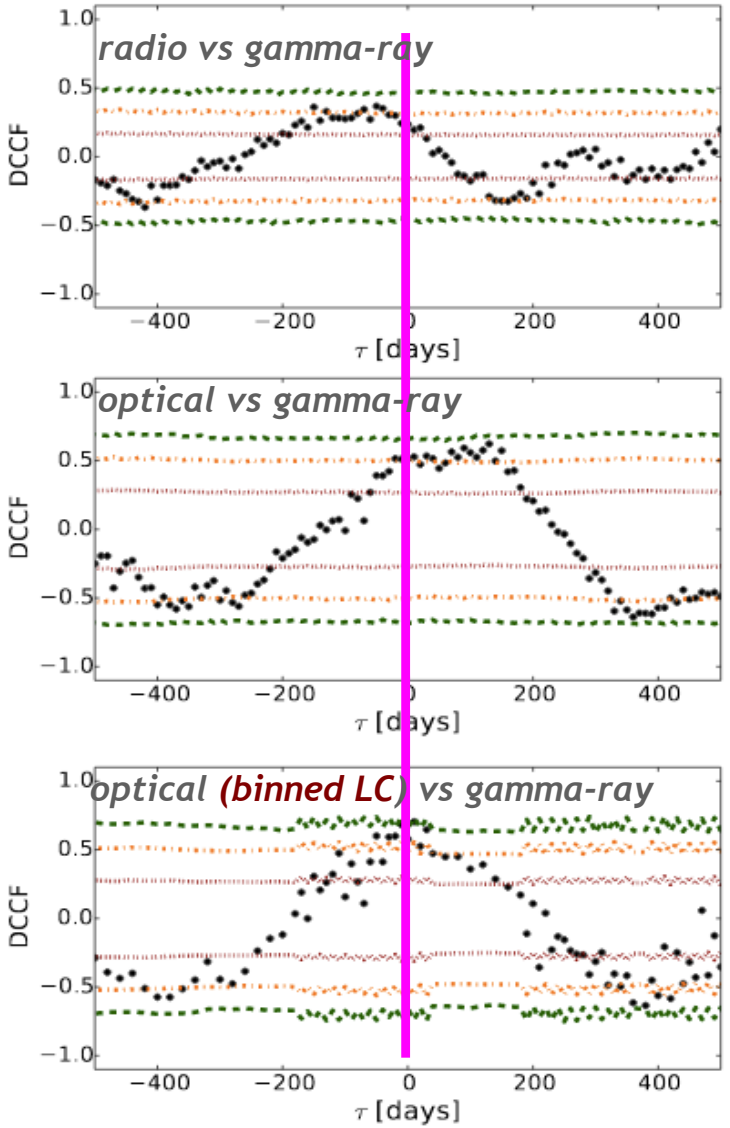
Discrete Cross Correlation Function (DCCF): to investigate the correlation between gamma-ray, optical and radio flux LC:-

Possible clues on underlying the periodic process

- -radio to gamma-ray: 50+/-10days
- -optical to gamma-ray:75+/- 27 days
- -rebinning the optical LC vs gamma-ray: time lag is consistent with 0 within the errors

Time lags depend on the short structure of the LC

- - e.g. Fermi-LAT cannot resolve the double peak seen in the optical band



PG 1553+113: Possible interpretations

PG1553+113 is dominated by non-thermal emission from the jet binary and single SMBH can be invoked

❑ **Processes at the base of the jet inducing quasi-periodic oscillations →** Accretion rate perturbations model due to the presents of a second SMBH milli-pc separation in the early inspiral gravitational-wave driven regime

- already invoked for OJ 287 (Sillampää et al 1988 and Letho, Valtonen 1996)

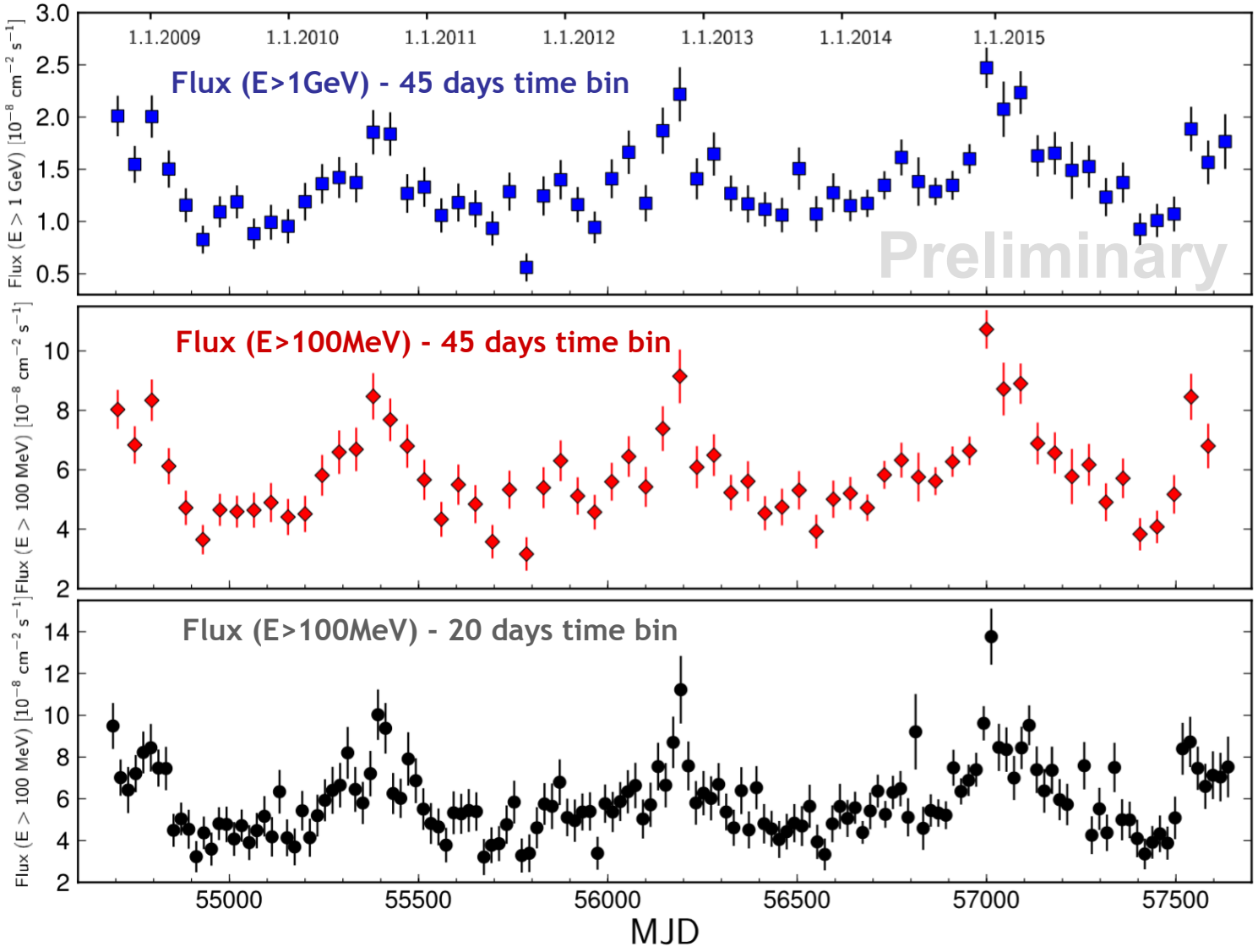
❑ **Pulsational accretion flow instabilities**

- MADF in the inner portion are able to efficently impart energy to the particles in the jet→periodic instabilities order of years for slow spinning SMBH

❑ **Geometrical effects on the jet**

- Variation of the viewing angle and jet precession →doppler factor magnification (40%, 1deg). **See A. Stamerra talk**

Updated Fermi light curves



Summary

- First clear evidence of gamma-ray periodic emission from an AGN confirmed in optical, hint in radio
- Interpretation is still open:
  - -possible milli-pc SMBH binary system
  - -QPO from helical path or flow instabilities
- Regular MWL observations:
  - -disentangle fast flaring episodes from the long term modulation
  - -TeV (MAGIC and VERITAS), optical polarization and other MWL campaigns to cover the next maximum foreseen January 2017