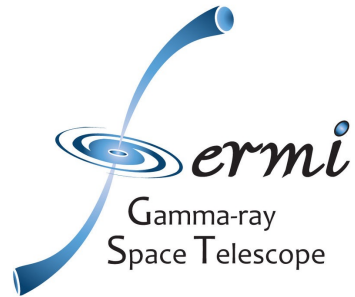




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## Evidence of quasi periodic modulation in the gamma-ray blazar PG1553+113

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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)

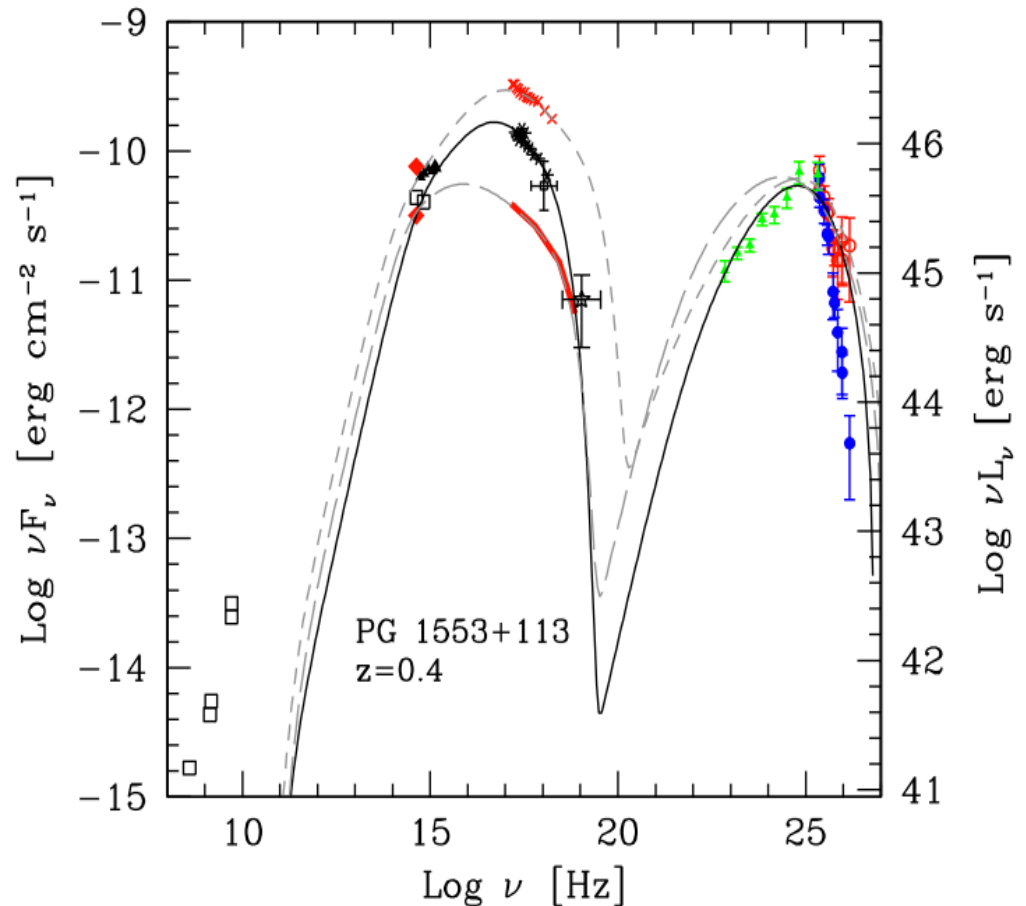


# PG 1553+113: in gamma rays



□ VHE ( $E > 100 \text{ GeV}$ ) 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  $1.60 \pm 0.02$  and  $F(E > 100 \text{ MeV}) = (1.32 \pm 0.03) \times 10^{-8} \text{ ph cm}^{-2} \text{ s}^{-1}$ . The source has found **variable** in GeV gamma-rays based on 1-month bin light curve.





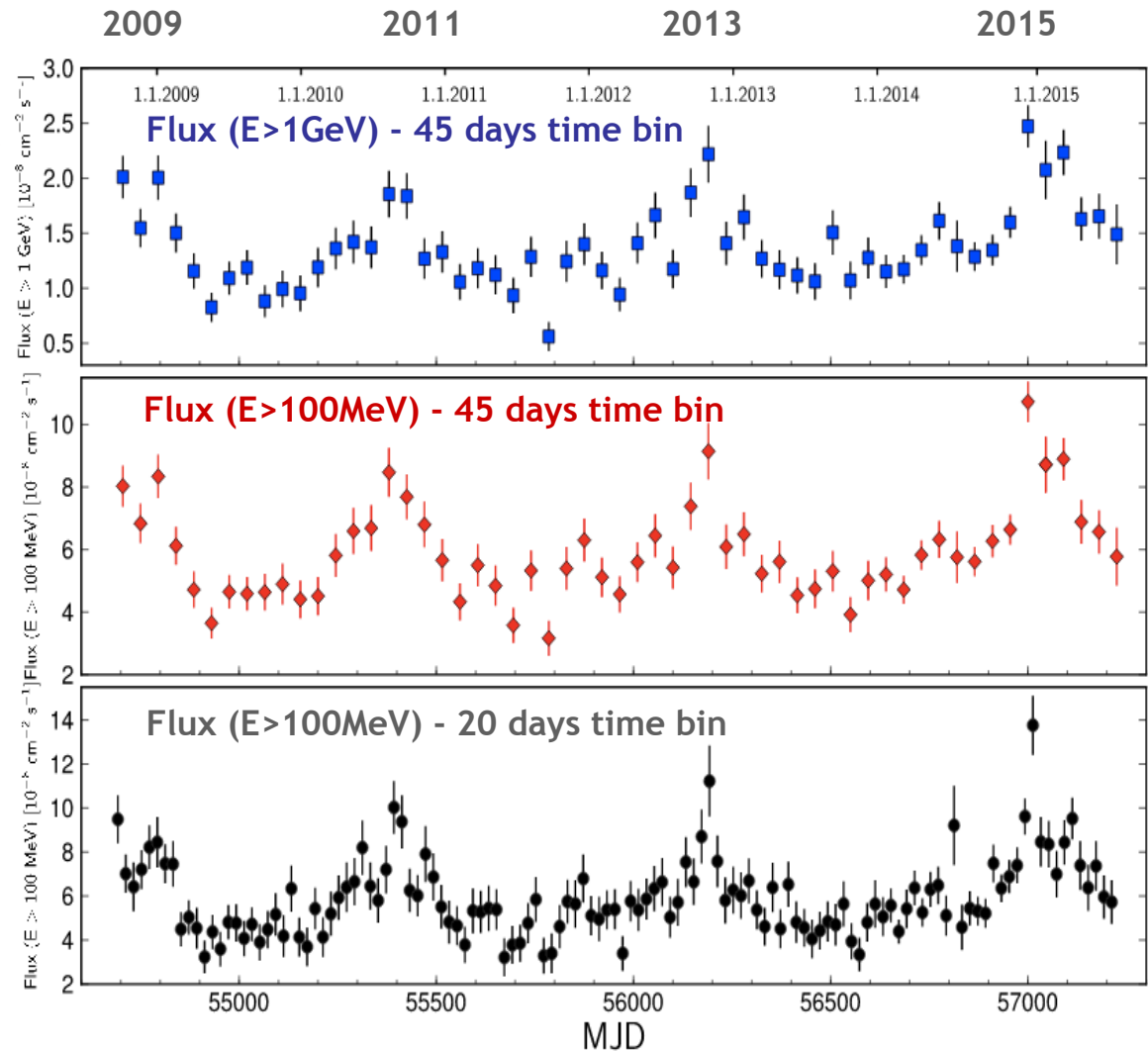
# PG 1553+113: Fermi-LAT gamma-ray light curves



□ *Fermi* LAT gamma-ray flux ( $E > 100\text{MeV}$  and  $E > 1\text{GeV}$ ) 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



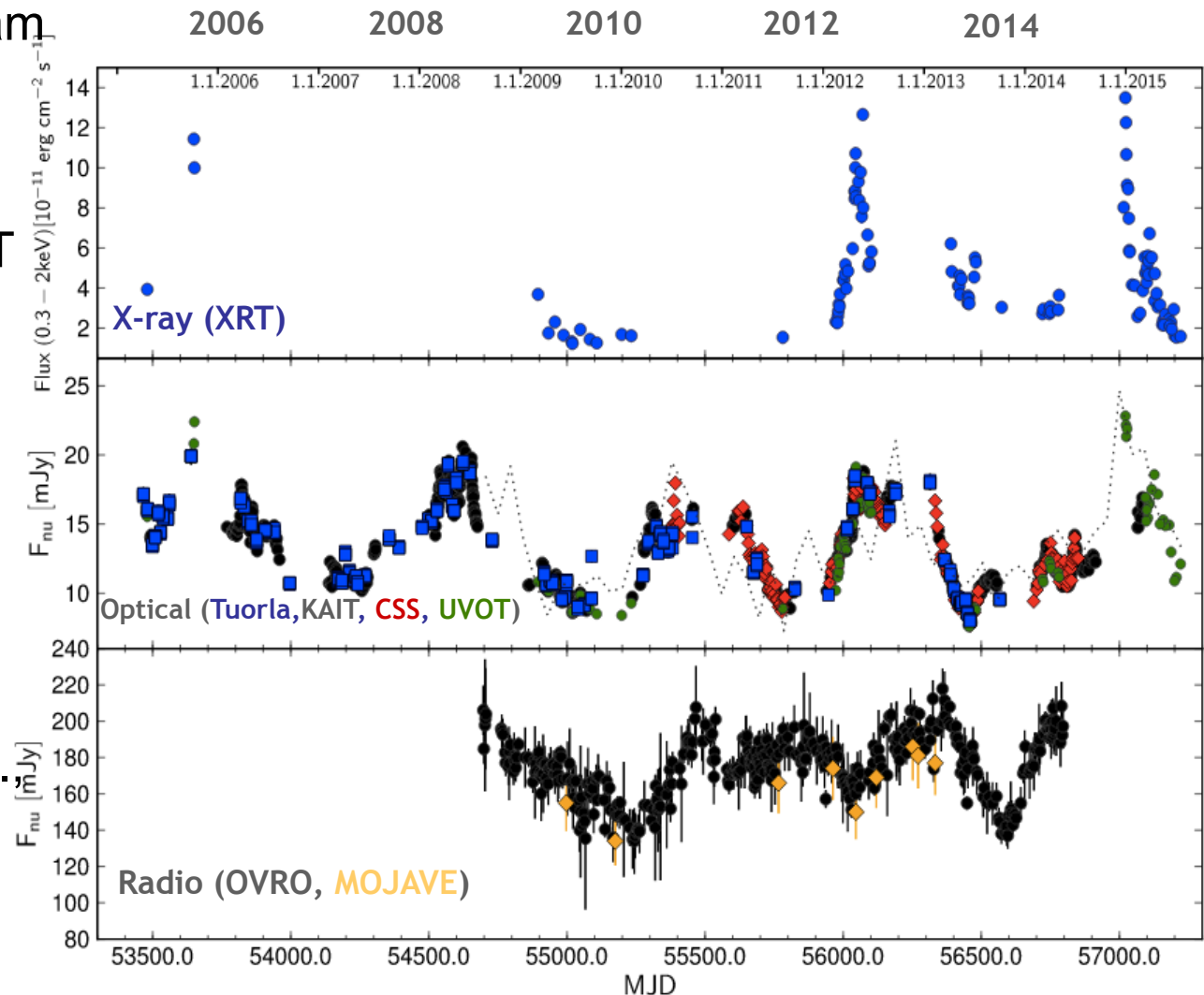
# PG1553+113: MWL light curves



→ 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)

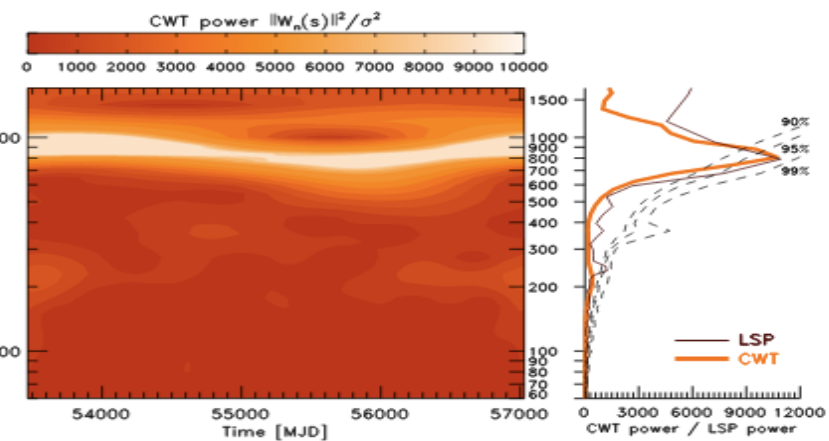
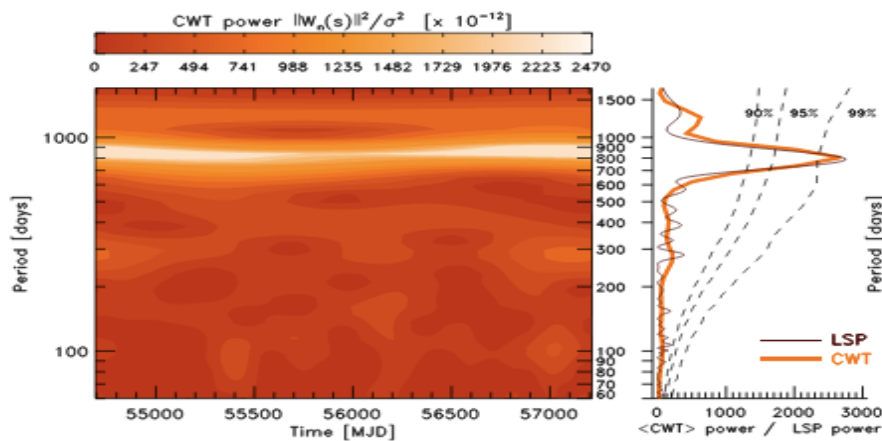
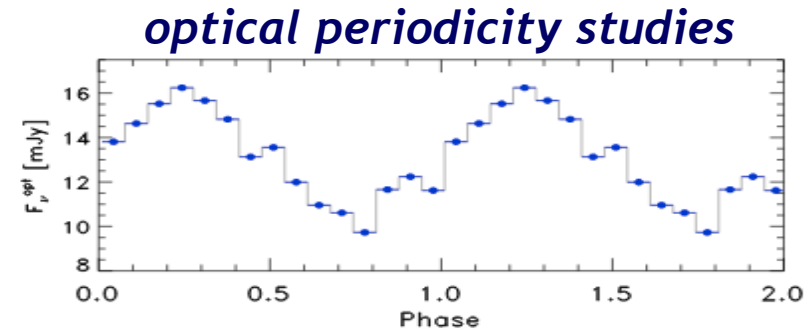
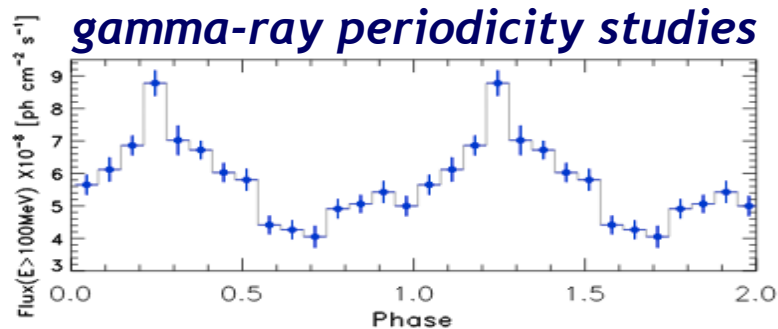




# PG1553+113: periodicity studies

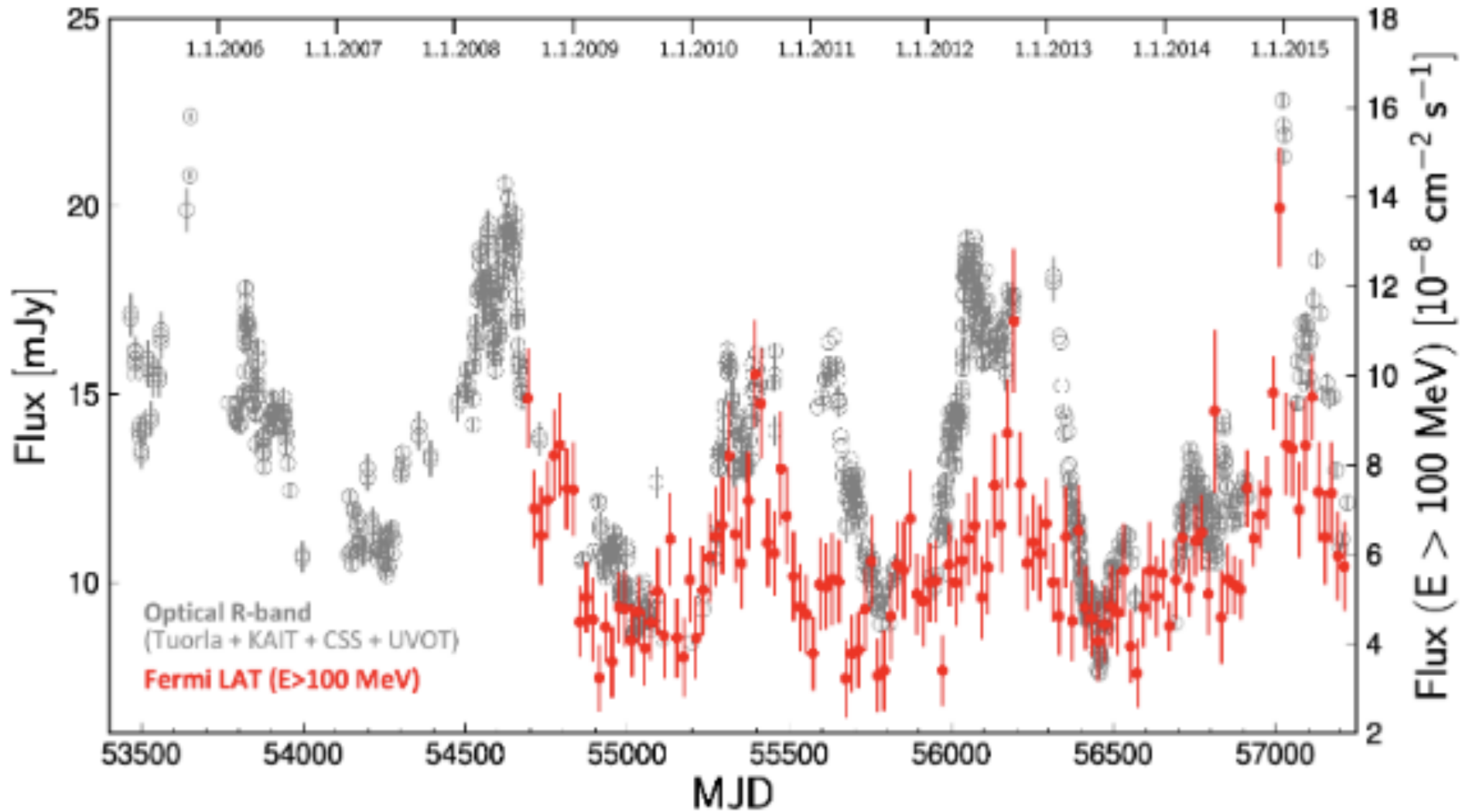


- Gamma-ray period evaluation (7 yr of data):  $2.18 \pm 0.08$  yr  
<1% random fluctuation from LSP (red noise bkg)  
~1% chance probability of random line up of 3.5 cycles
- Optical period evaluation (10 yr of data):  $2.05 \pm 0.05$  yr  
<5% random fluctuation from LSP (red noise bkg)





# PG 1553+113: composite light curve







# PG1553+113 light curves: time lags



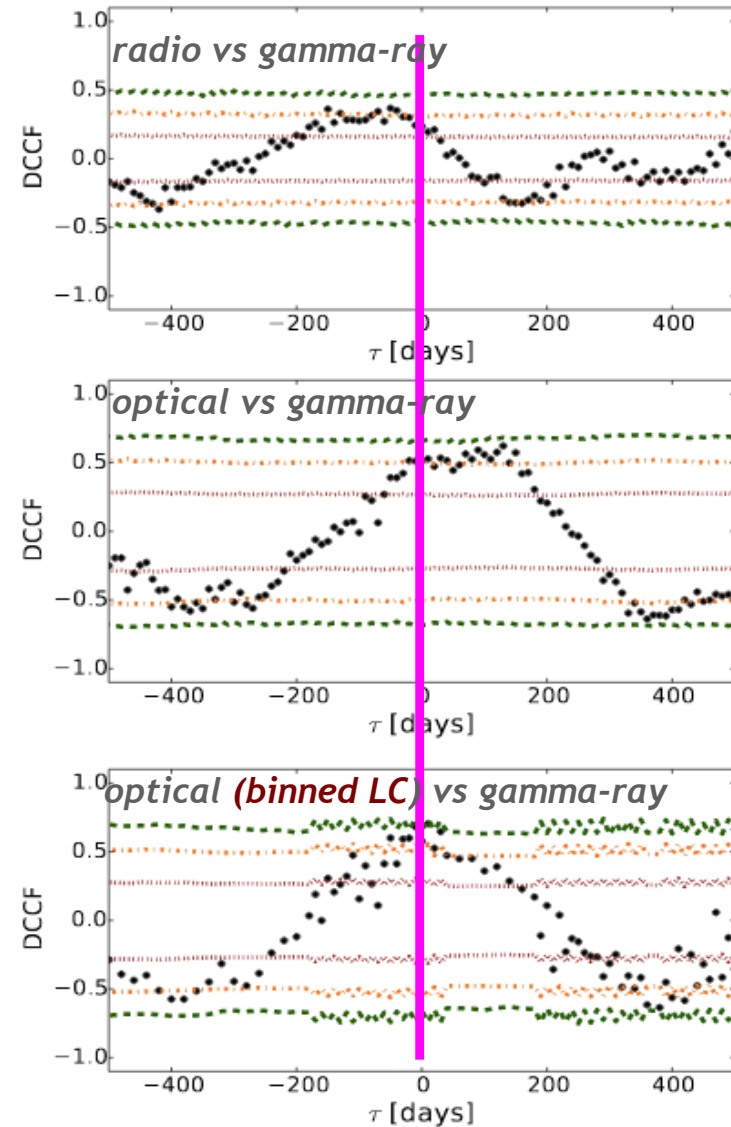
Discrete Cross Correlation Function (DCCF):  
to investigate the correlation between gamma-ray,  
optical and radio flux LC:-

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

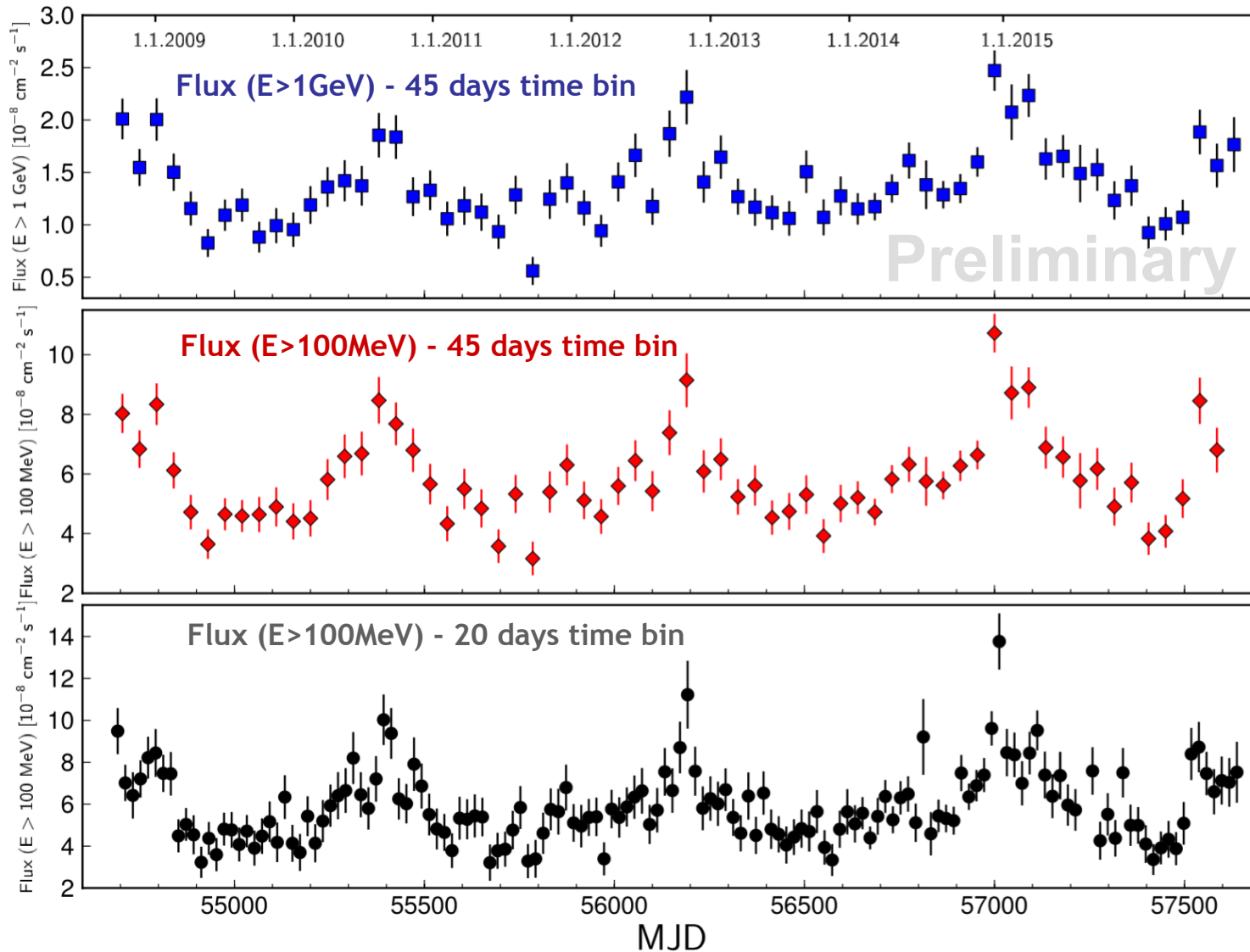


PG1553+113 is dominated by non-thermal emission from the jet **binary** and single **SMBH** can be invoked

- **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 efficiently 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

