Multi-wavelengths observations on the gamma-ray blazar PG1553+113 as a probe for geometrical periodical modulation.

A. Stamerra
(INAF-OATo and SNS-Pisa)

E. Prandini, S. Paiano, P. Da Vela, H. Gareth, S. Covino
*on behalf of the MAGIC collaboration

and

S. Cutini, A. Sandrinelli

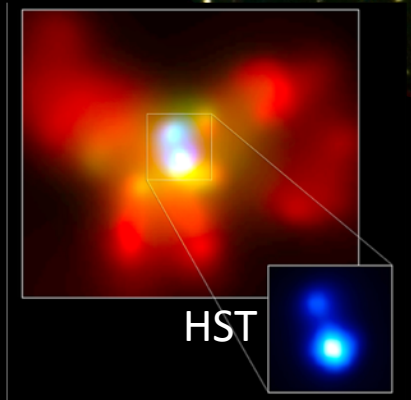
and

E. Sobacchi, M. C. Sormani

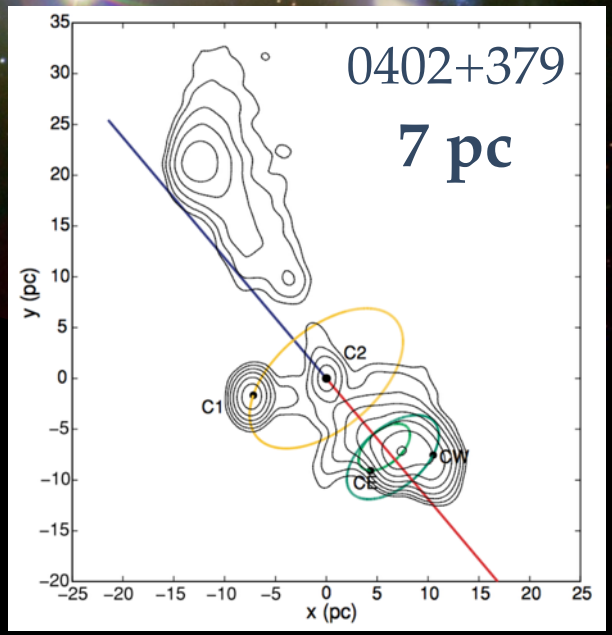
A brief history of the Universe

Hyerarchical structure formation

- Mergers
- SMBH pairs and binaries



Komossa et al. 2003

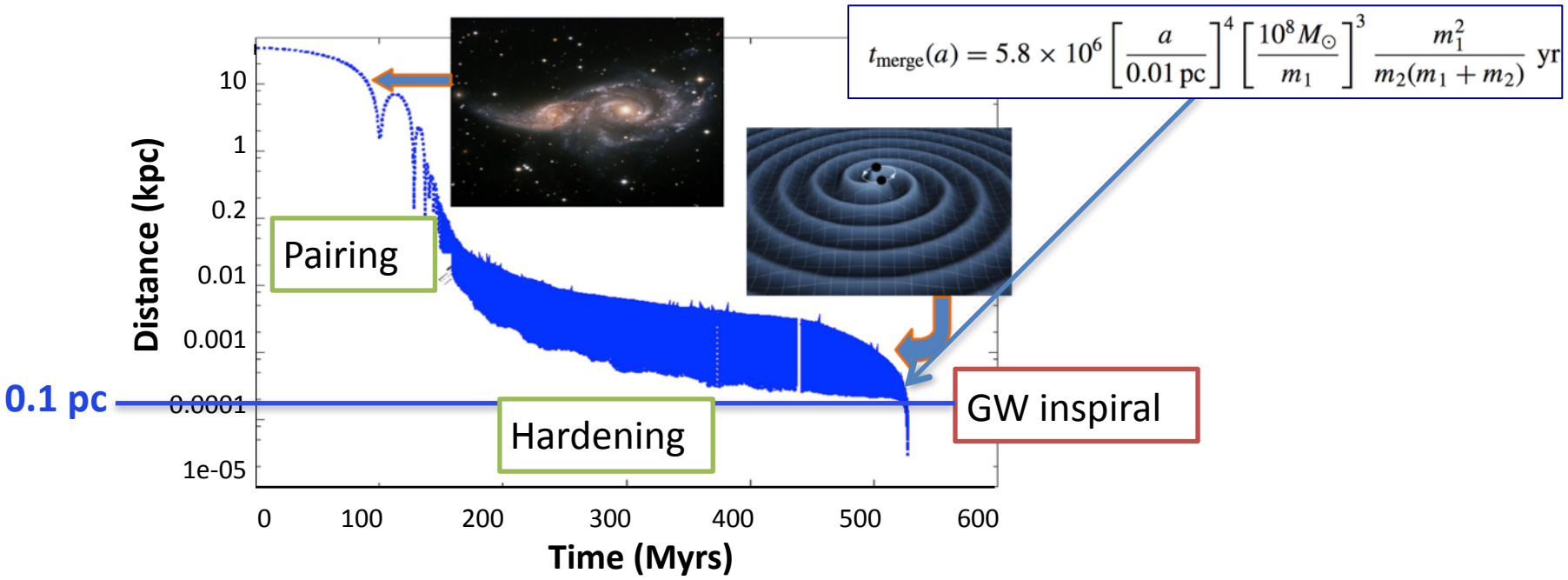


Rodriguez et al. 2006, ApJ, 697

SMBH binaries

- **Binaries (sub-pc systems): indirect search**
  - Double or asymmetric spectral lines (but Liu+2015 arXiv:1512.01825)
  - Helical, distorted jets; TDE dips in light-curve
  - **Periodic light-curve**

➢ **Observational evidence important to solve the theoretical "final pc" problem**



Periodicity and SMBH binaries

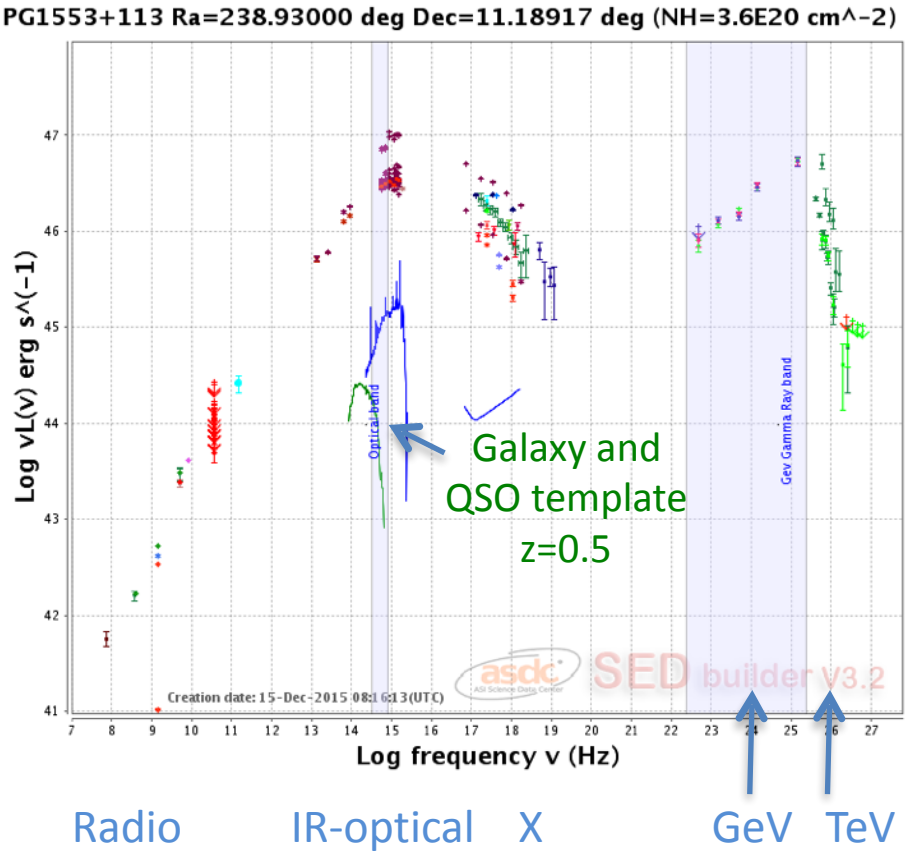
- **Reliability of AGN Periodicity**
  - Yearly periodicity over ~Myr activity
  - The significance of any apparent periodic variation depends on what assumption is made about spurious stochastic variability.
  - Measurement at different wavelength bands

- **AGN periodicity → binary BH system?**
  - Different plausible models with single SMBH
  - interpretation needs support by observations

Multi-wavelength (MWL) observations are key in the interpretation!

PG 1553+113

- **Blazar, radio-loud, HBL**
  - **Uncertain redshift z~0.5**
    Danforth et al. 2010, also Abramwoski et al. 2015
- **Well established γ-ray emitter and TeV source**
- **Dominant non-thermal emission from the jet**



→ *Raiteri, AS, et al. MNRAS 2015*

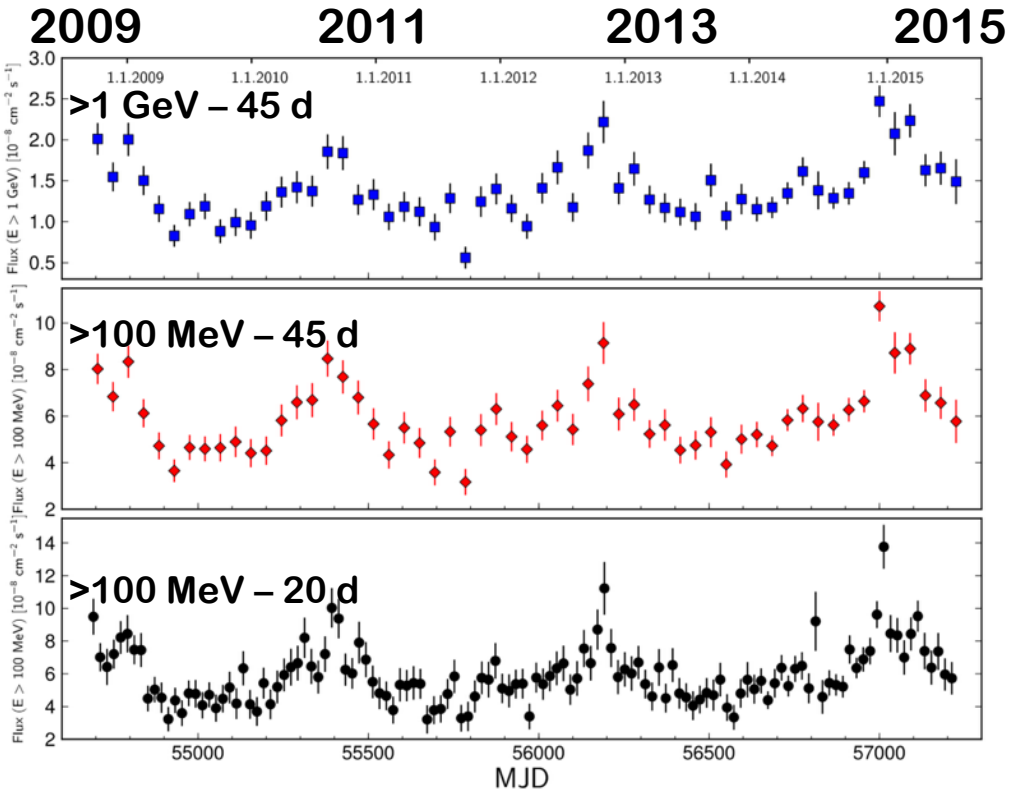
PG1553 periodicity in Fermi/LAT

First clear detection of γ-ray periodicity in a BL Lac

- **3.5 cycles over ~7 years**
- **confirmed in optical!**

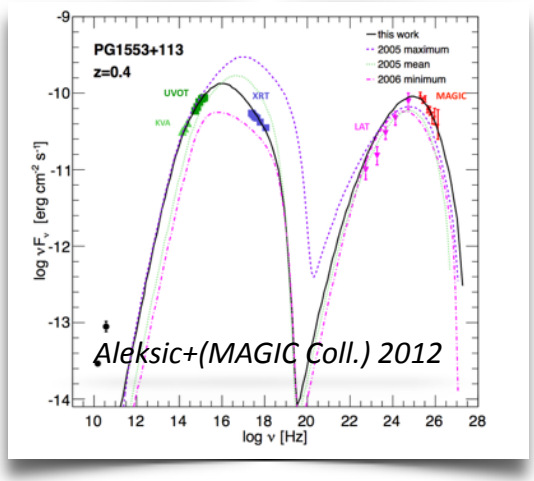
Fermi/LAT Coll.+AS, ApJL, 2015, 816, 41

➤ **S. Cutini talk**



Interpretation of periodicity

PG1553+113 dominated by non-thermal emission from the jet.



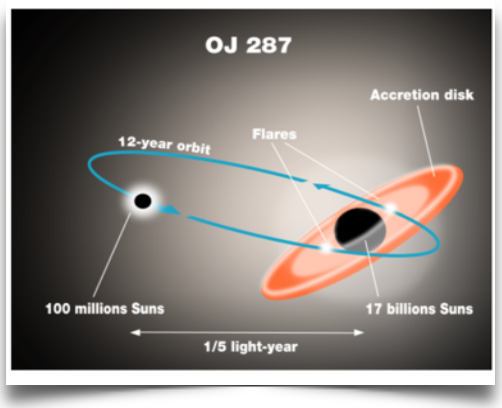
Periodicity may be the result of:

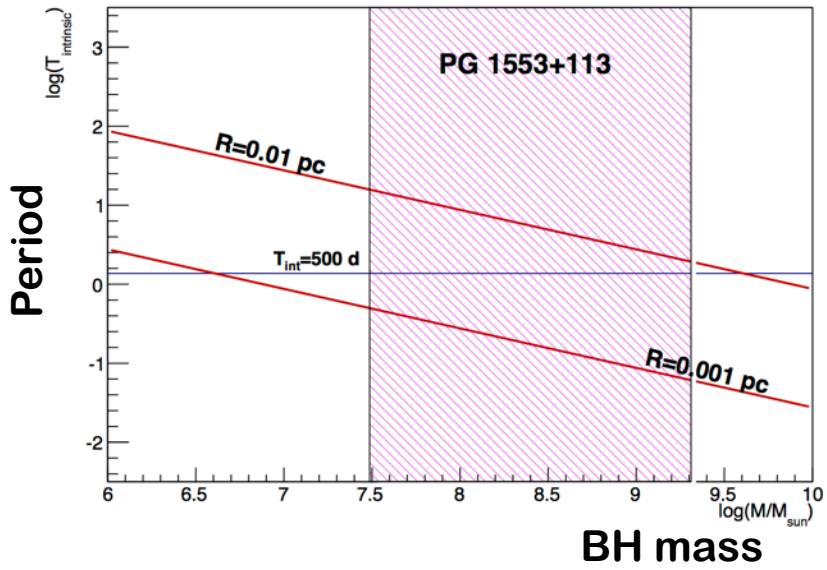
- **Processes at the base of the jet inducing quasi-periodic oscillations**
- **Geometrical effects on the jet**

◇ **Binary and single SMBH can be invoked**

Binary SMBH system

- **Accretion rate perturbations**
  - **claims on e.g. PG1302-102 Graham+2015 or OJ287 Sillampää+1988,Lehto&Valtonen 1996**
- **Variation of jet viewing angle ➜ Doppler factor** Γ~20 ~1^{o} ➜ ~40% ➜ flux ~3





milli-pc system: gravitational wave driven inspiral stage!

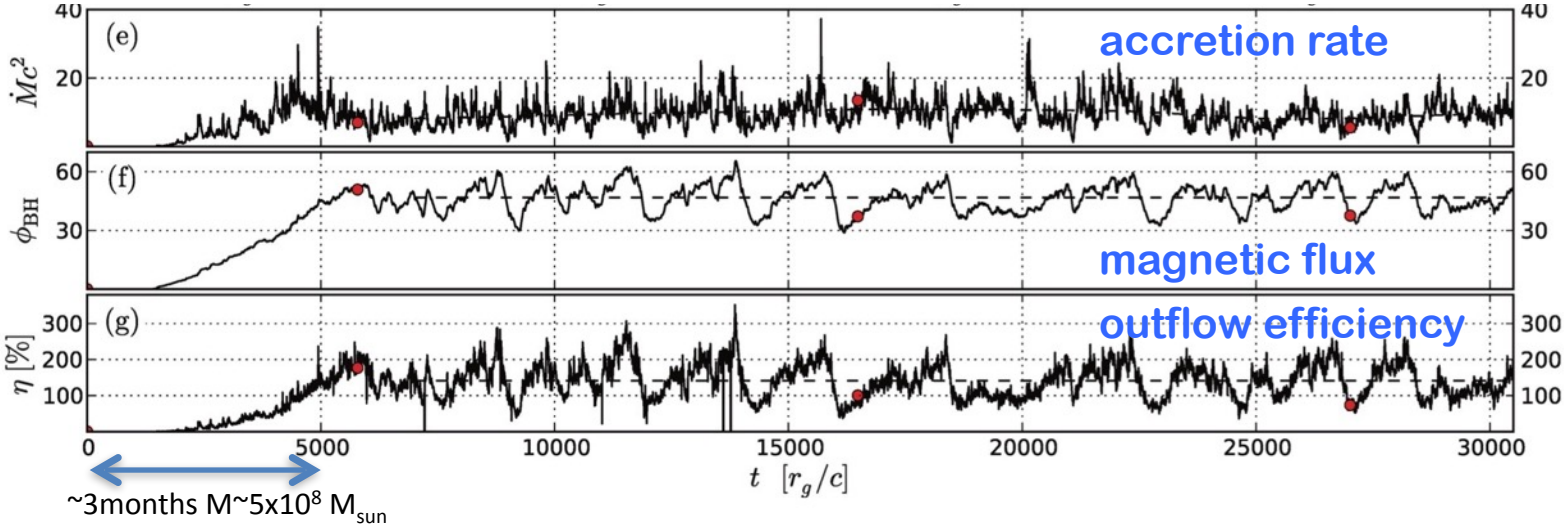
Single SMBH

Jet feeding

- **QPO from warped disk**
  e.g. Nealon+2015
- **QPO from choking of magnetic arrested disk (MAD, Tchekhovskoy et al. 2011)**

Geometrical

- **Helical jet (QPO)**
  Villata&Raiteri 1999
- **Jet precession (BH-spin, Lense-Thirring), rotation**
  Long periods expected



MAD

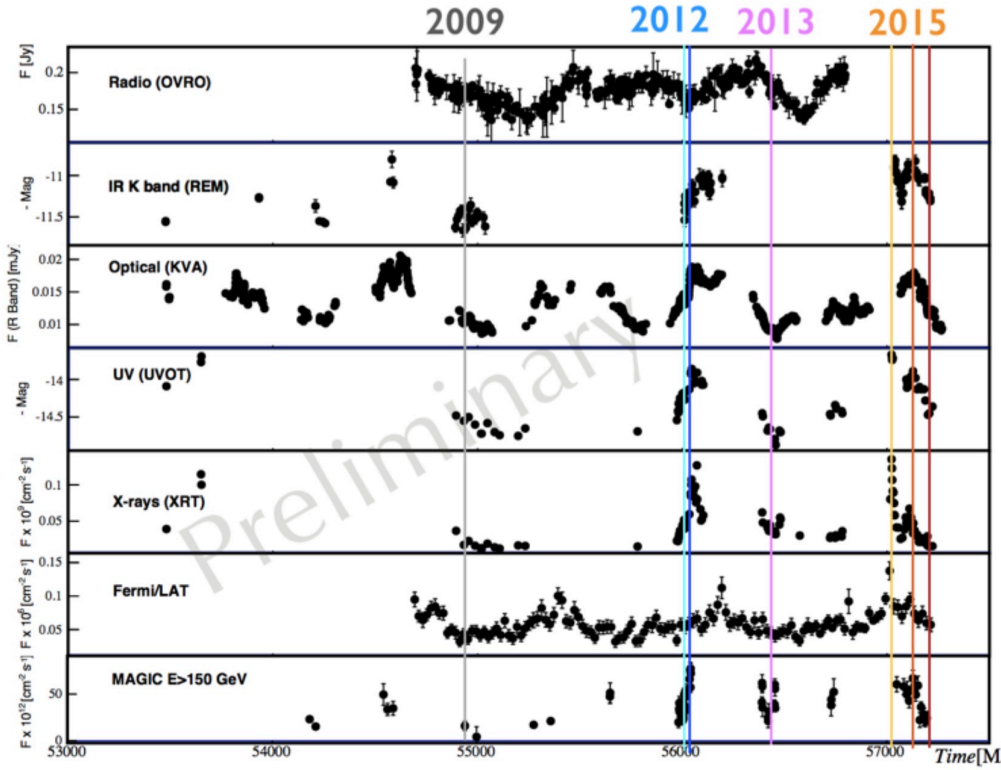
MWL campaign

- Regular MWL monitoring started at the end of 2014
  - from radio to VHE gamma-rays
- Make ready for the next high-activity; expected beginning 2017
- Led by the MAGIC collaboration

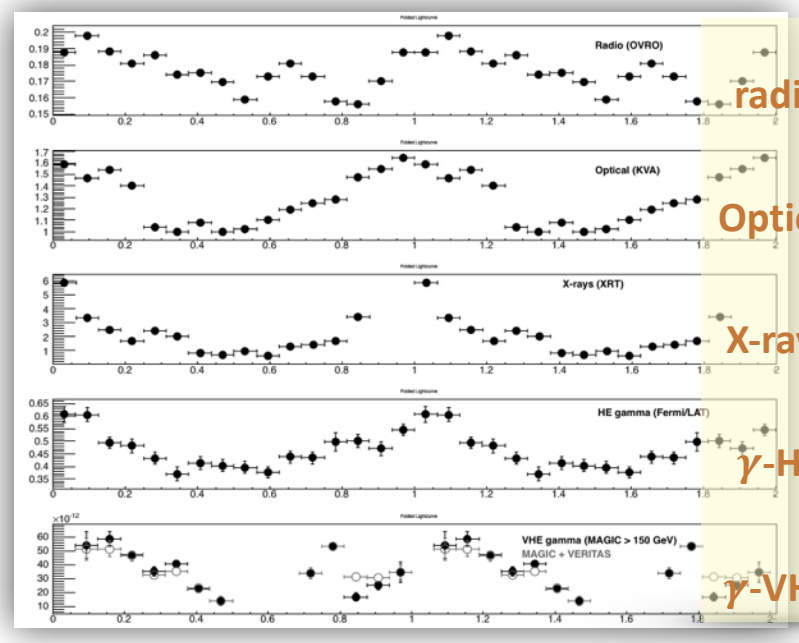
The baseline: a old MAGIC friend with a young touch on periodicity

- **Long-term observations with MAGIC since 2005**

MAGIC coll. + MWL partners, in prep.



Folded light curves P=783 days



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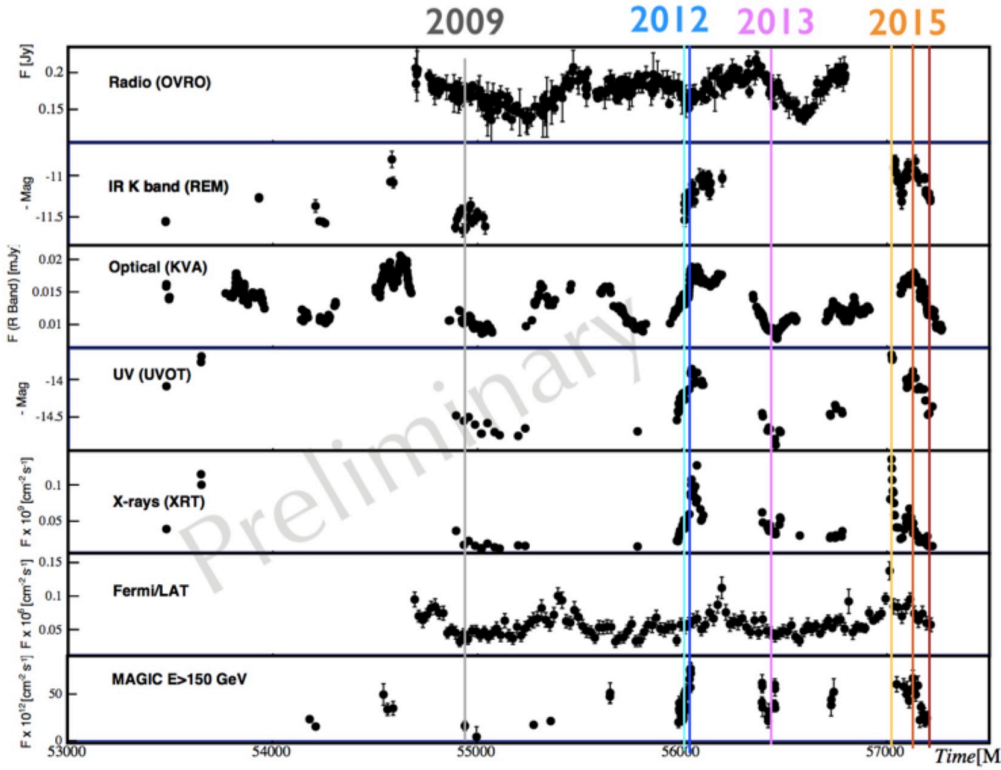
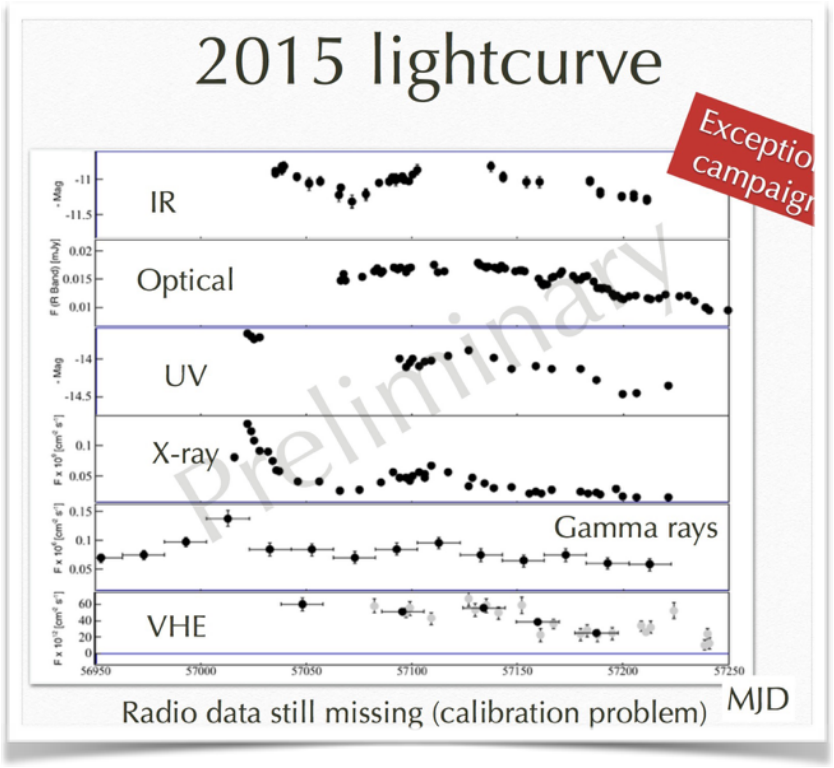
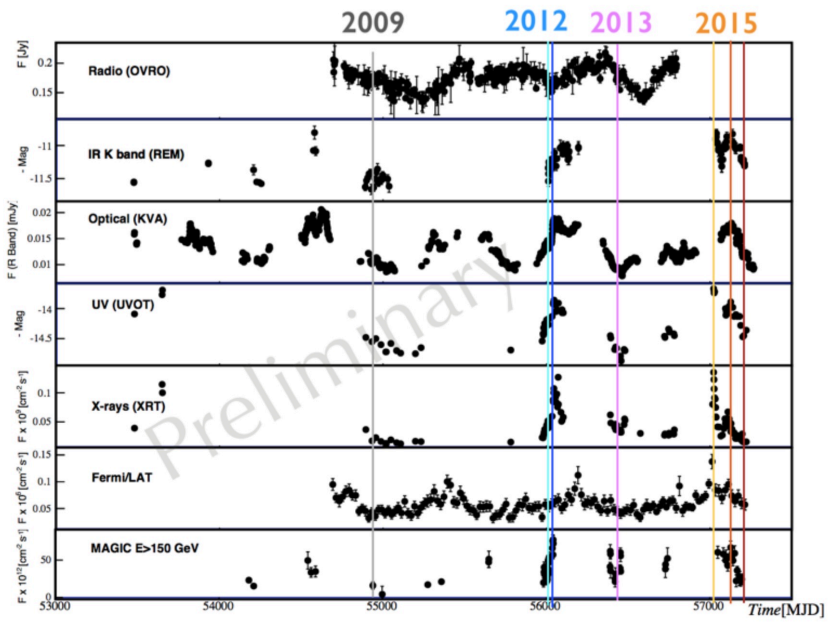




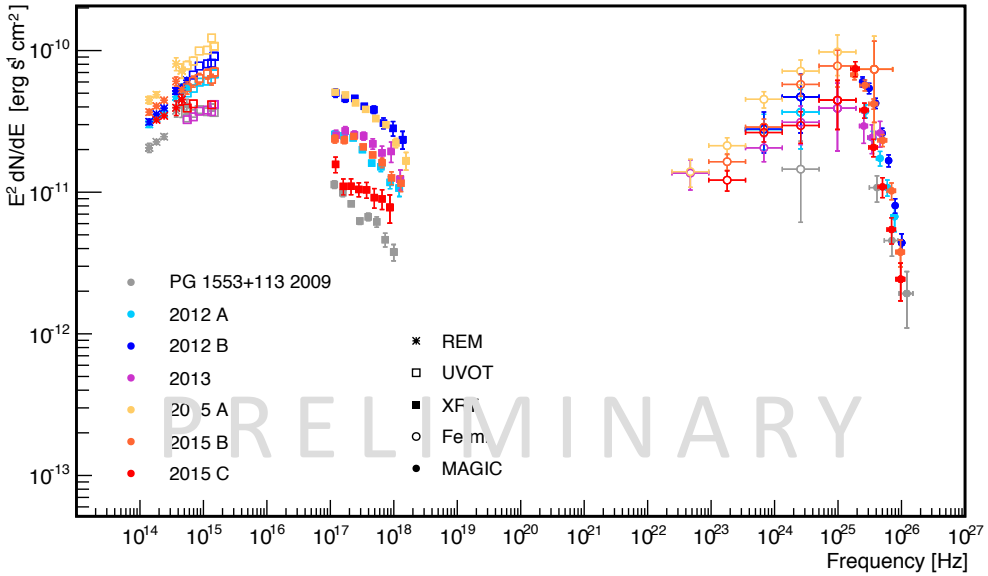
The baseline: a old MAGIC friend with a young touch on periodicity

MAGIC coll. + MWL partners, in prep.

- **Long-term observations with MAGIC since 2005**
- **MAGIC regular monitoring since 2014**
- **correlation studies, time lags, SED,… in progress**

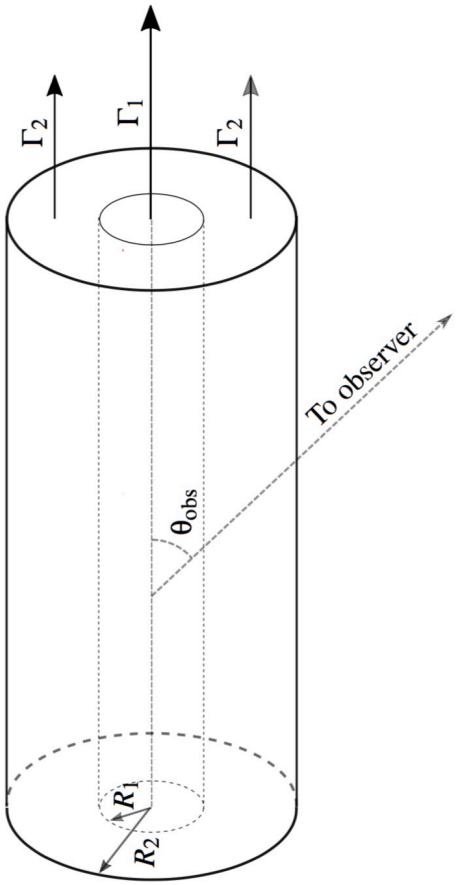


PG 1553+113 in seven different flux states (2009-2015)



A geometrical model

E. Sobacchi, M. Sormani, AS (subm.)



- **Structured jet (spine+sheath)**

$$F_{\rm tot} = \frac{\pi L R_2^2}{D^2}\left(\int_{-\infty}^{+\infty} j_0(y)\,{\rm d}y\right)\left[\lambda\delta_1^3 + (1-\lambda)\delta_2^3\right]$$

emissivity *geometrical factor*

λ: relative contribution sheath/spine
δ: Doppler factor

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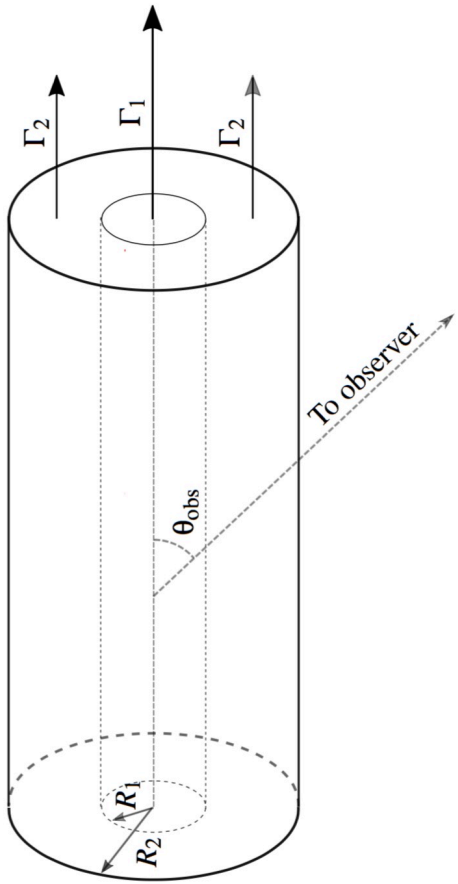

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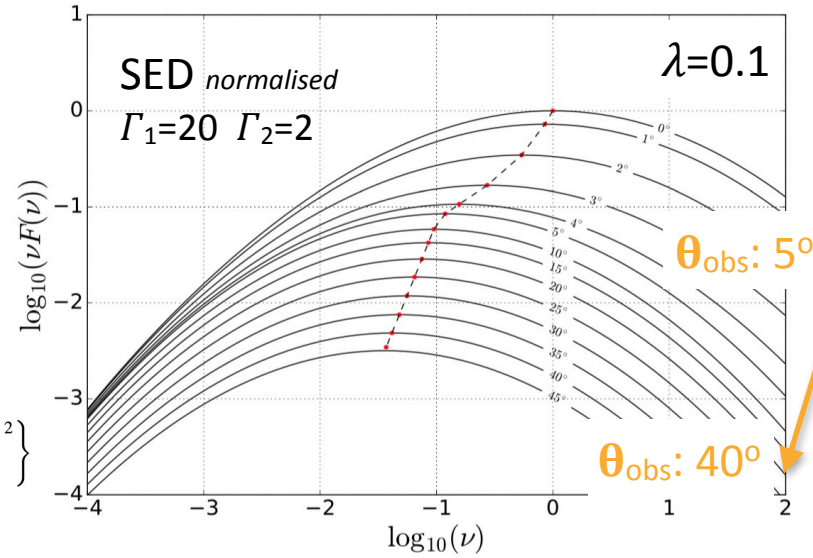

Logpar SED

$$\frac{\nu F(\nu,\hat{\mathbf{n}})}{\nu_{\rm P} F(\nu_{\rm P})} = \lambda\delta_1^3 \exp\left\{-b\left[\log\left(\frac{\nu}{\delta_1\nu_{\rm P}}\right)\right]^2\right\} + (1-\lambda)\,\delta_2^3 \exp\left\{-b\left[\log\left(\frac{\nu}{\delta_2\nu_{\rm P}}\right)\right]^2\right\}$$

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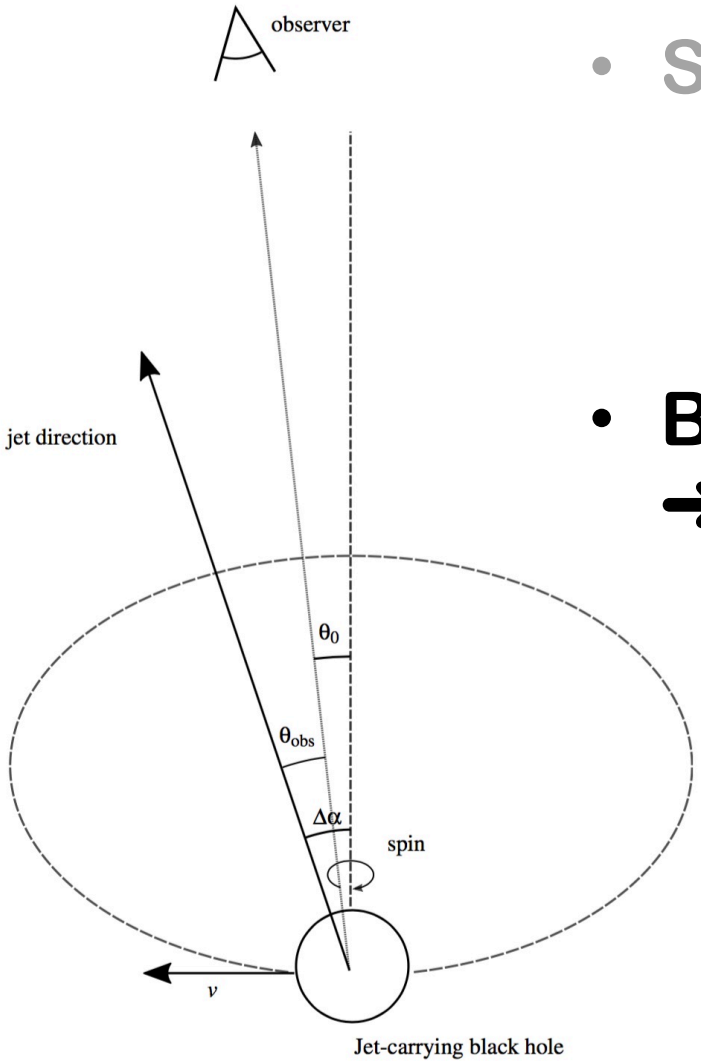

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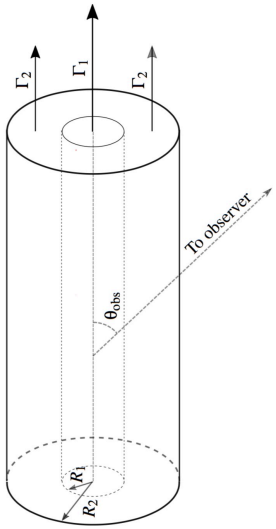
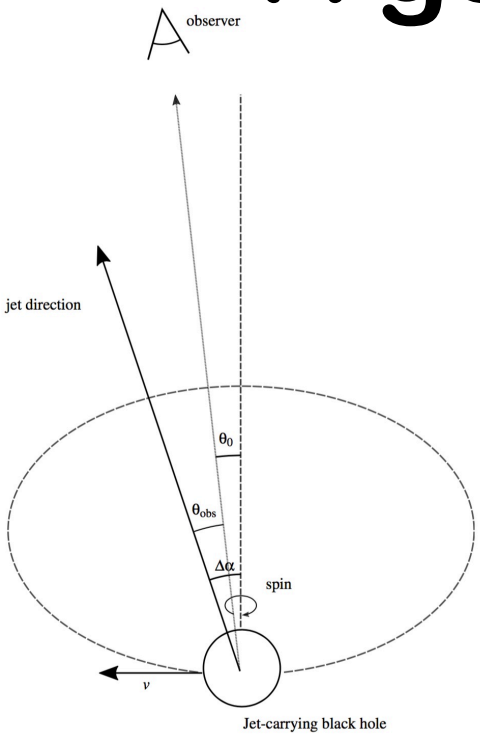


- **Binary system**
  ➜ orbital velocity + beam

A geometrical model



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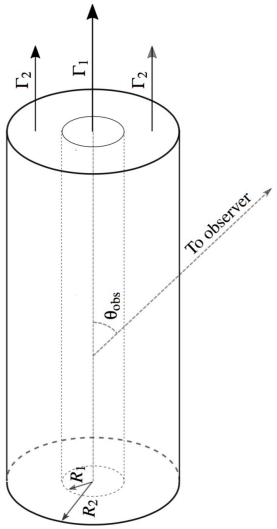
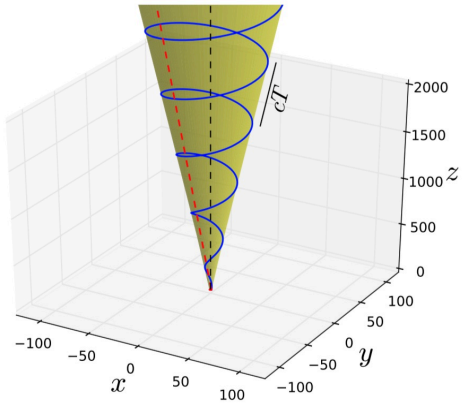


- **Structured jet** (spine+sheath)

- **Binary system**
  ➜ **orbital velocity + beam**
- **Preceding ballistic jet**
  ➜ **variation of emission angle**
  ➜ **helical structure in space**
  ➜ **Doppler factor variation**



A geometrical model: PG 1553+113

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- **QPO Light curve**

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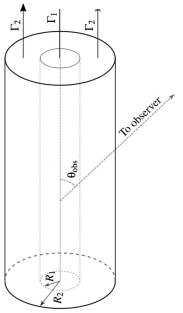
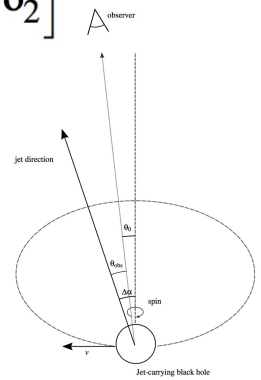


jet-param. *binary-syst*

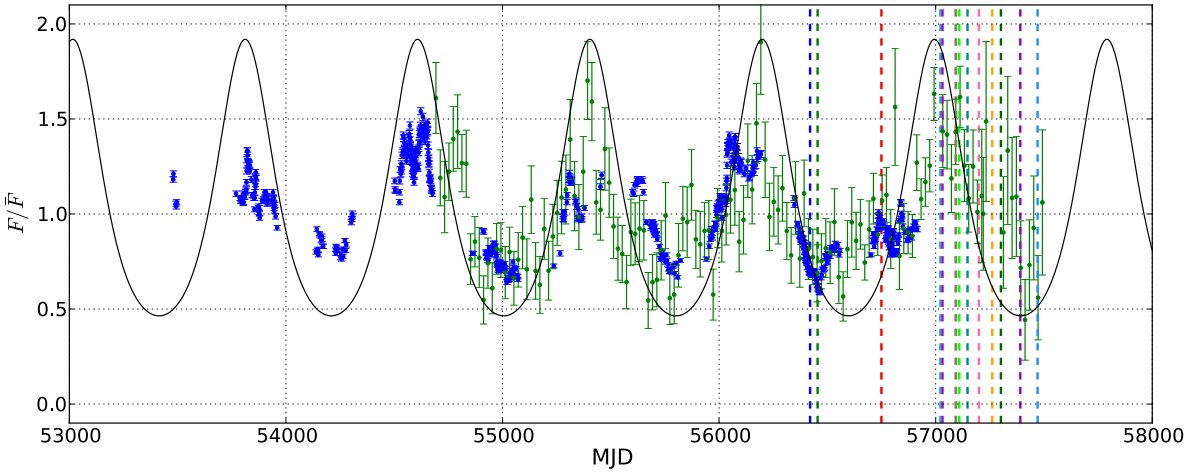
Γ_1	Γ_2	λ	θ_0	$\Delta\alpha$	$\Omega_{\rm obs}$
7.0	1.1	0.1	4°	3°	$2.88\,{\rm yr}^{-1}$



$1^o < \theta_{obs} < 7^o$

Fermi/LAT

Optical



A geometrical model: PG 1553+113

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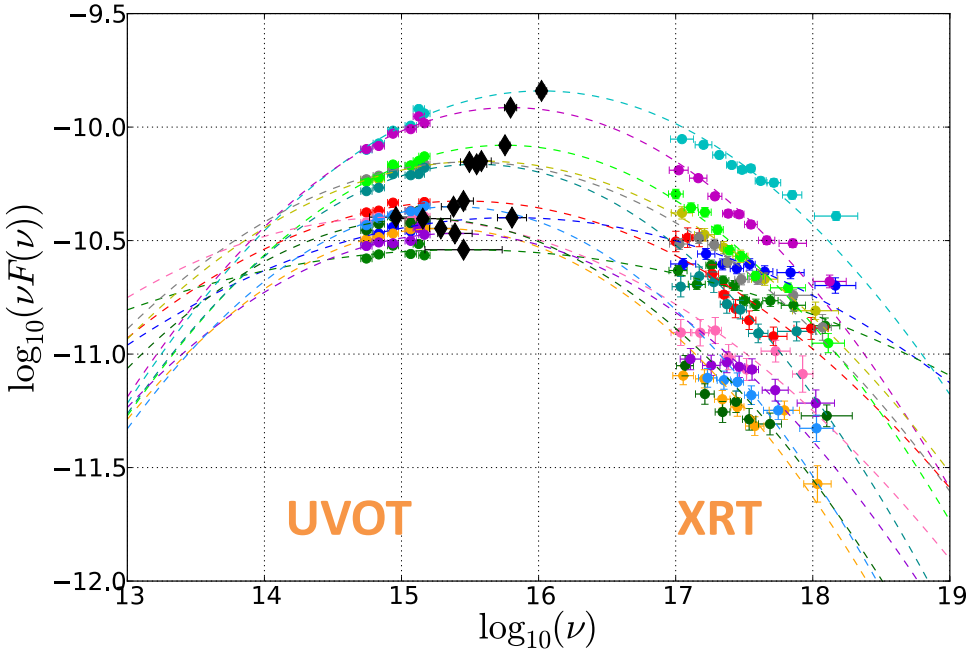
- **Synchrotron SED**
  - **Swift UVOT and XRT**
  - **Logpar fit to get peak**



♦ synch-Peaks

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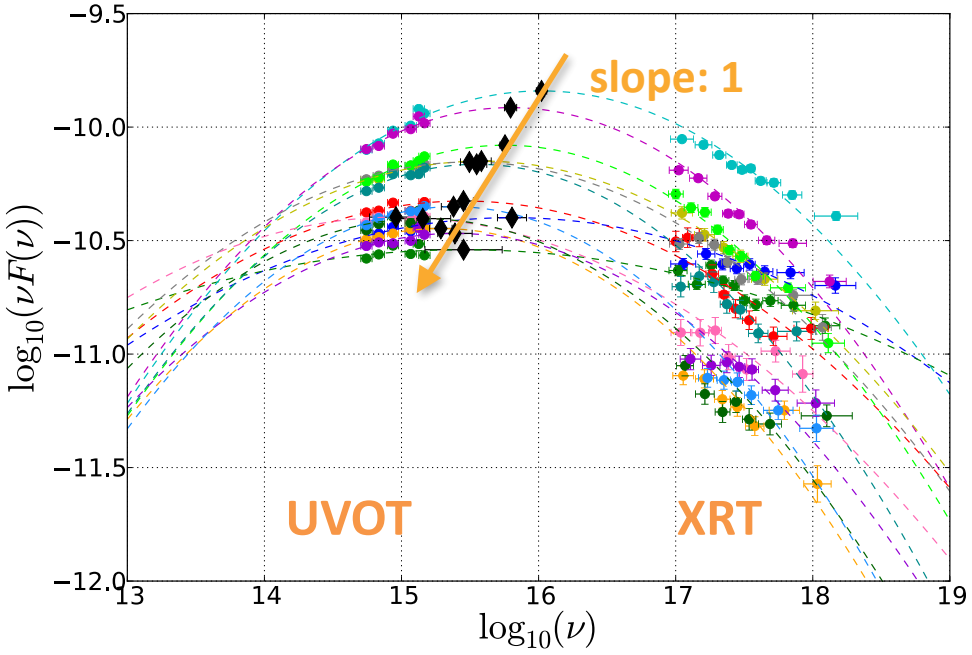

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- **Synchrotron SED**

Good agreement of BOTH SED and light curve!

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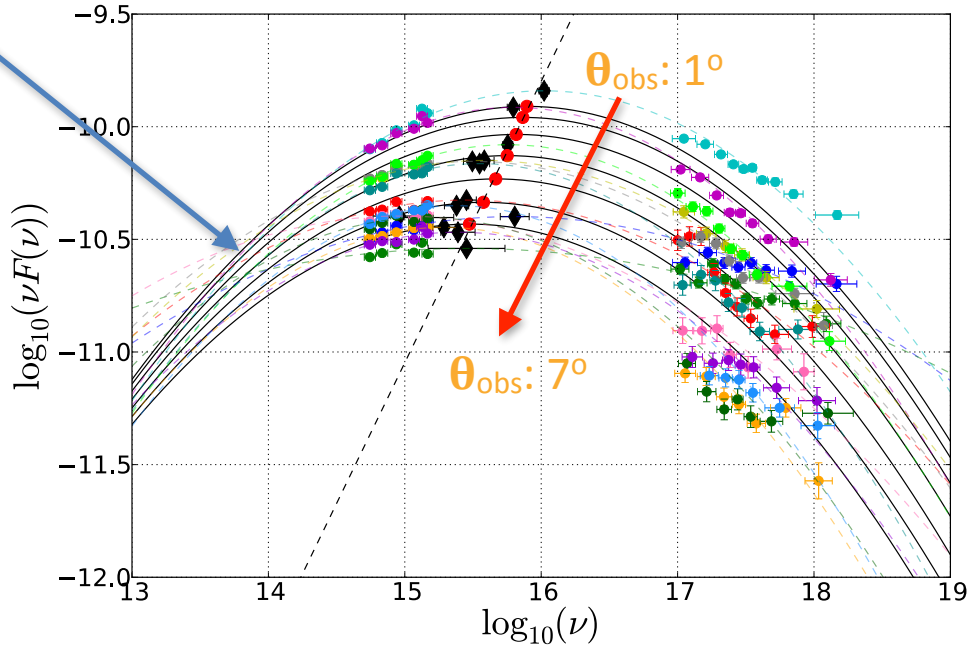

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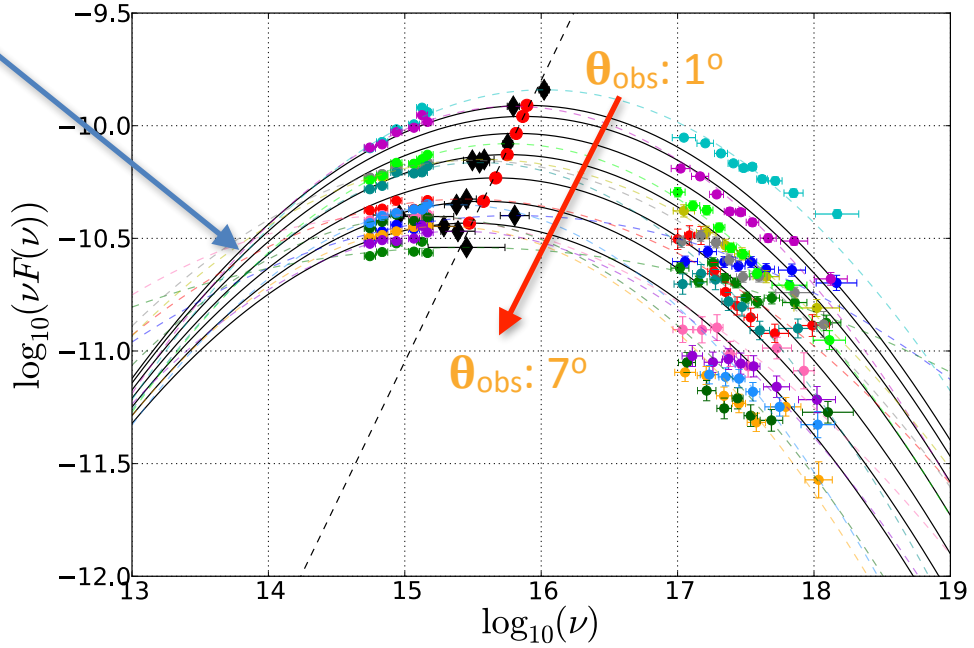

♦ synch-Peaks

Estimated parameters of the binary system

$$R = 1.1\times10^{16}\left(\frac{1+q}{q}\right)\ \mathrm{cm}$$

$$M = 2.1\times10^{8}\left(\frac{1+q}{q}\right)^3 M_\odot$$

$q \sim 1$

Summary

- PG 1553+113 first AGN with evidence of multi-frequency periodic emission.
- Interpretation still open
  - Possible milli-pc SMBH binary system
  - QPO from helical paths or flow instabilities
- Dedicated geometrical model explains light-curve and behaviour of SED variability
- Regular MWL observations led by MAGIC
  - Disentangle flaring episodes from long-term modulation
  - MAGIC TeV observations and MWL campaign

✦ **Next maximum expected from January 2017**

Credits:
NASA's Goddard Space Flight Center/CI Lab