UNIVERSITY OF Southampton

Timing properties of blazar light curves

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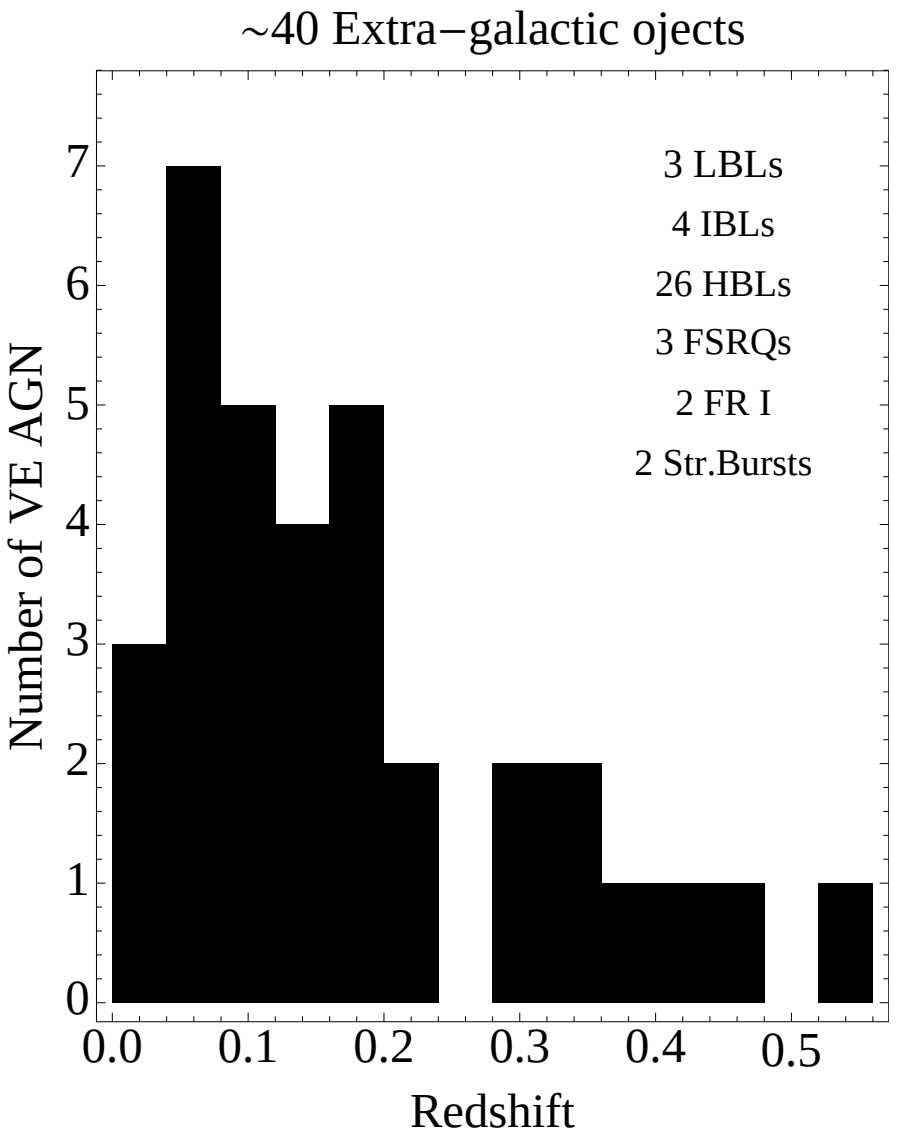
First LINK Workshop: Probing physics beyond the Standard Model with CTA, Friday 12th November 2010, Oxford UK

Overview

- VHE AGN
- Properties of blazar light-curves in VHE?
- Current results

VHE AGN

Object	Redshift
M 87	0.004
Mrk 421	0.030
Mrk 501	0.034
1ES 2344+514	0.044
Mrk 180	0.046
1ES 1959+650	0.047
BL Lac	0.069
PKS 0548-322	0.069
PKS 2005-489	0.071
RGB J0152+017	0.080
W Comae	0.102
PKS 2155-304	0.116
H 1426+428	0.129
1ES 0806+524	0.138
1ES 0229+200	0.139
H 2356-309	0.165
1ES 1218+304	0.182
1ES 1101-232	0.186
1ES 0347-121	0.188
1ES 1011+496	0.212
PG 1553+113	>0.25
3C 279	0.536



VHE AGN Variability Studies

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No evidence for variability

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Very Weak evidence for variability (Years)

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Weak evidence for variability (Months)

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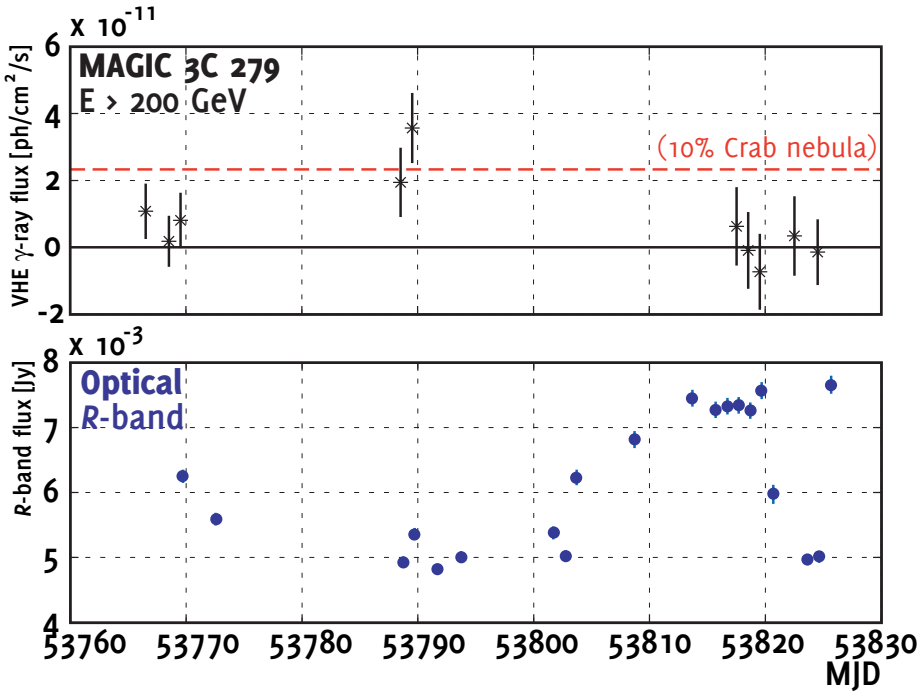
Some indications of daily variations



Teshima et al.,Proc.30th ICRC,**3**, 1045–1048 (2007)

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The classical sources!

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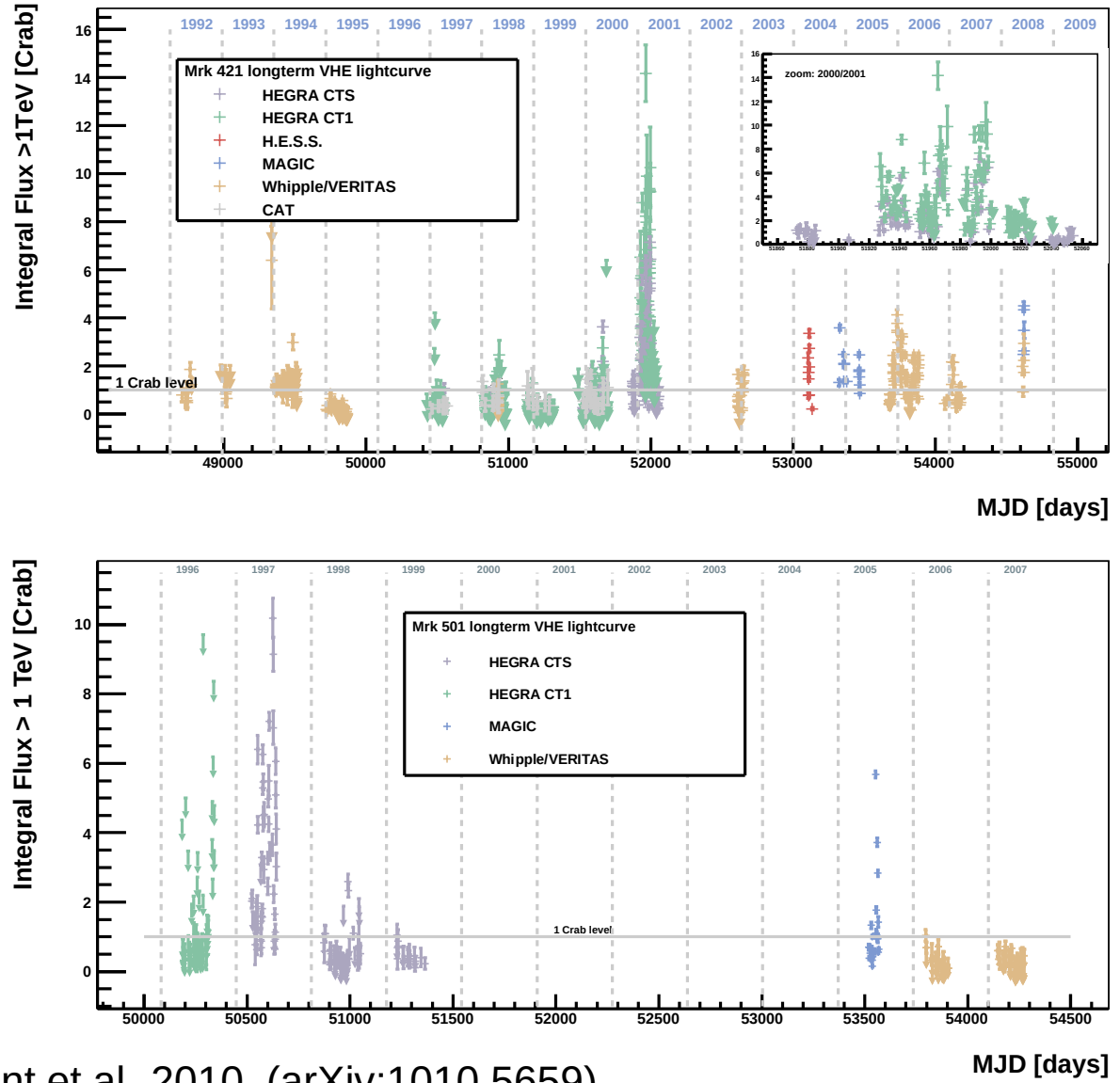
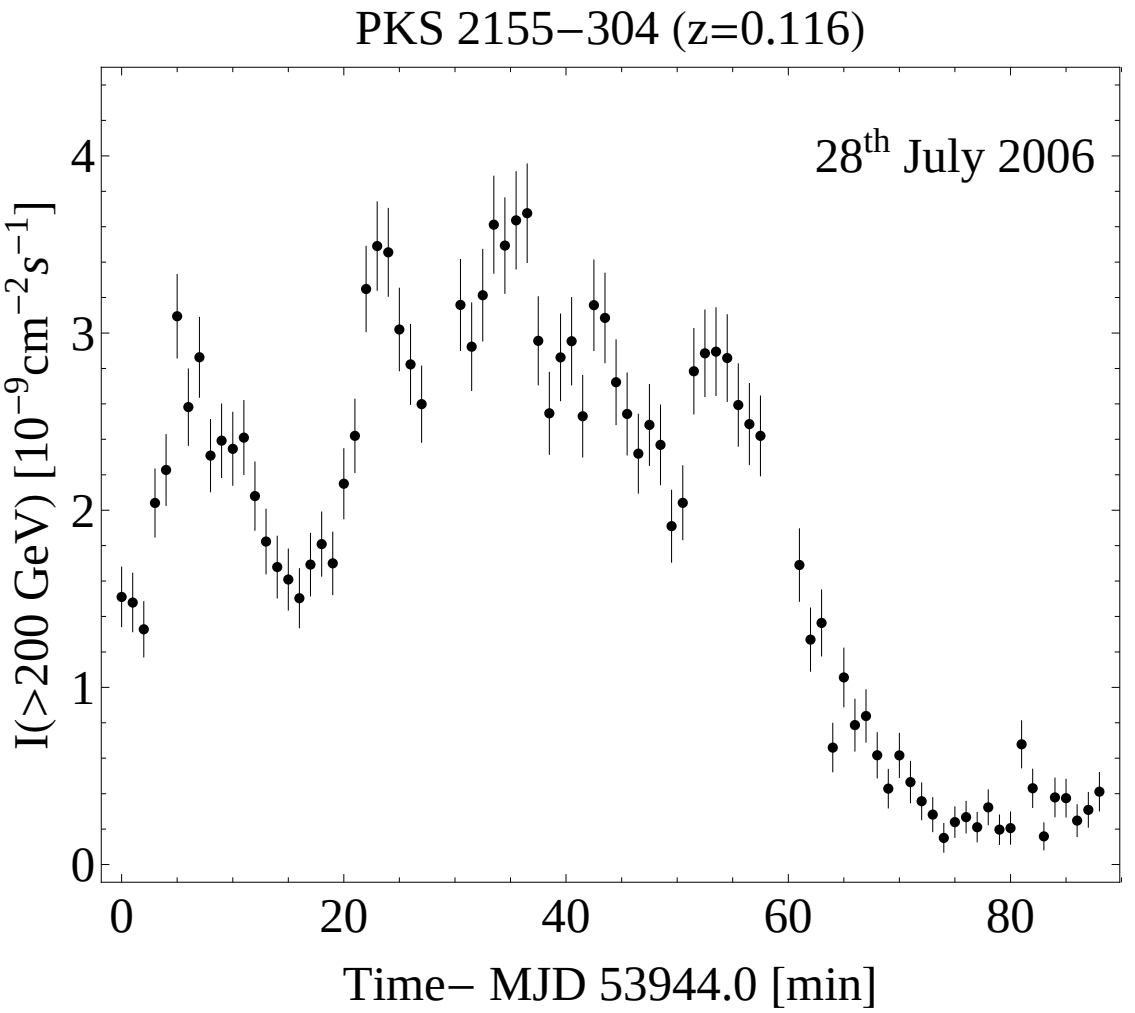
FOR QG studies!!!

Properties of blazar light-curves in VHE



Tluczykont et al. 2010, (arXiv:1010.5659)

Properties of blazar light-curves in VHE



Aharonian et al. 2007 (HESS Collaboration), Apj, **664**,L71

Properties of blazar light-curves in VHE

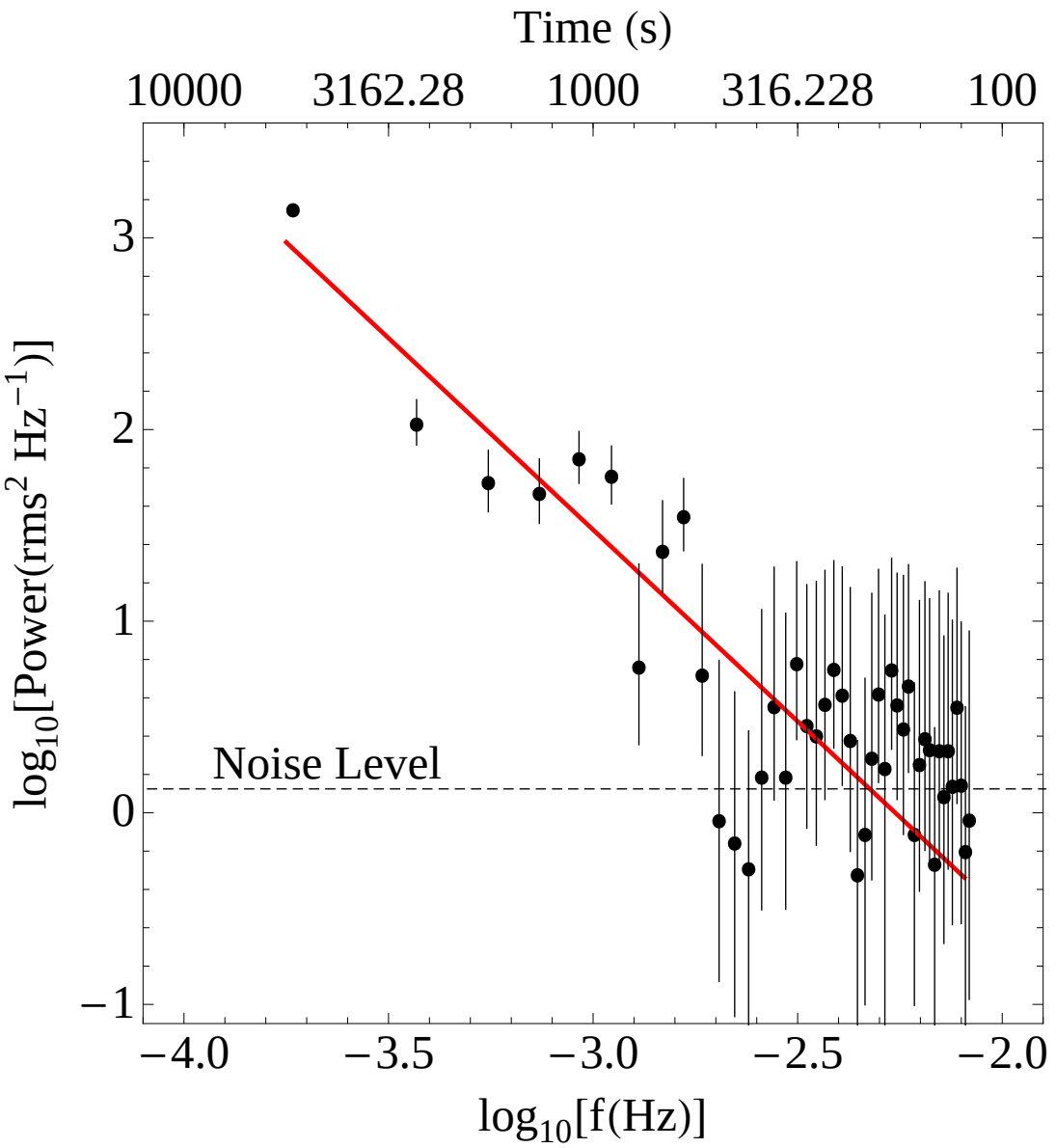
Light-curve decomposition $\Longleftrightarrow$ Power spectral density

For a set of observations x_i measured at t_i ($i = 1, \ldots, N$)

$$|DFT(f_j)| = \left| \sum_{i=1}^{N} x_i e^{2\pi i f_j t_i} \right|^2$$

where $j = \frac{j}{N\Delta t}$ and $j = 1, \ldots, N/2$

Properties of blazar light-curves in VHE



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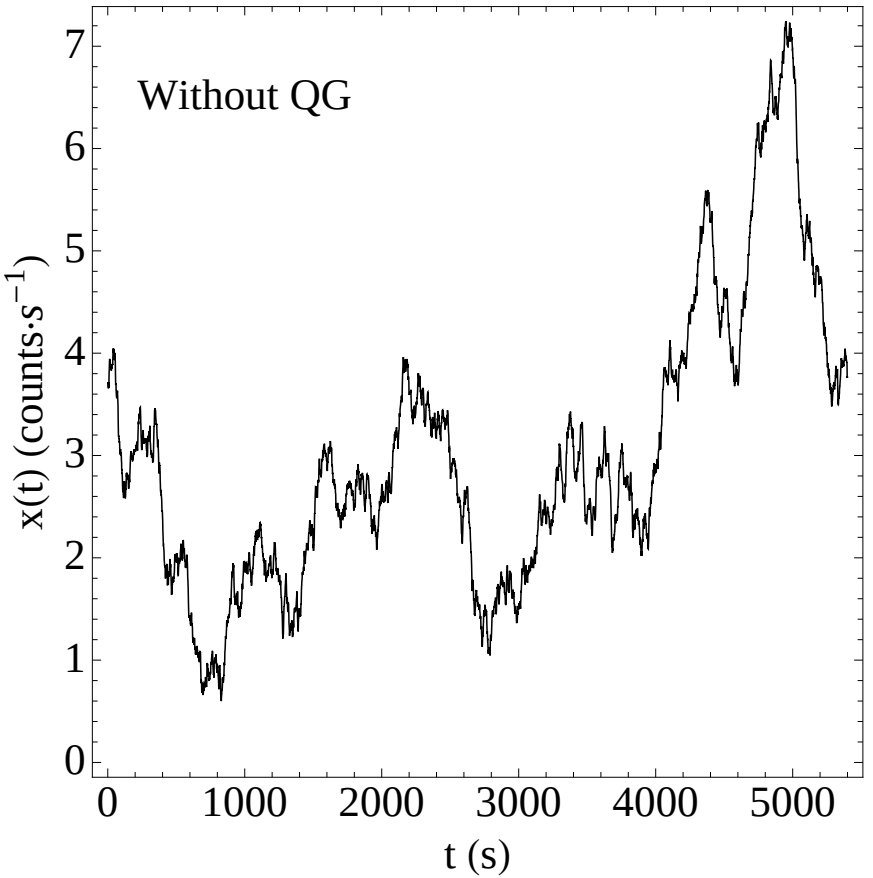
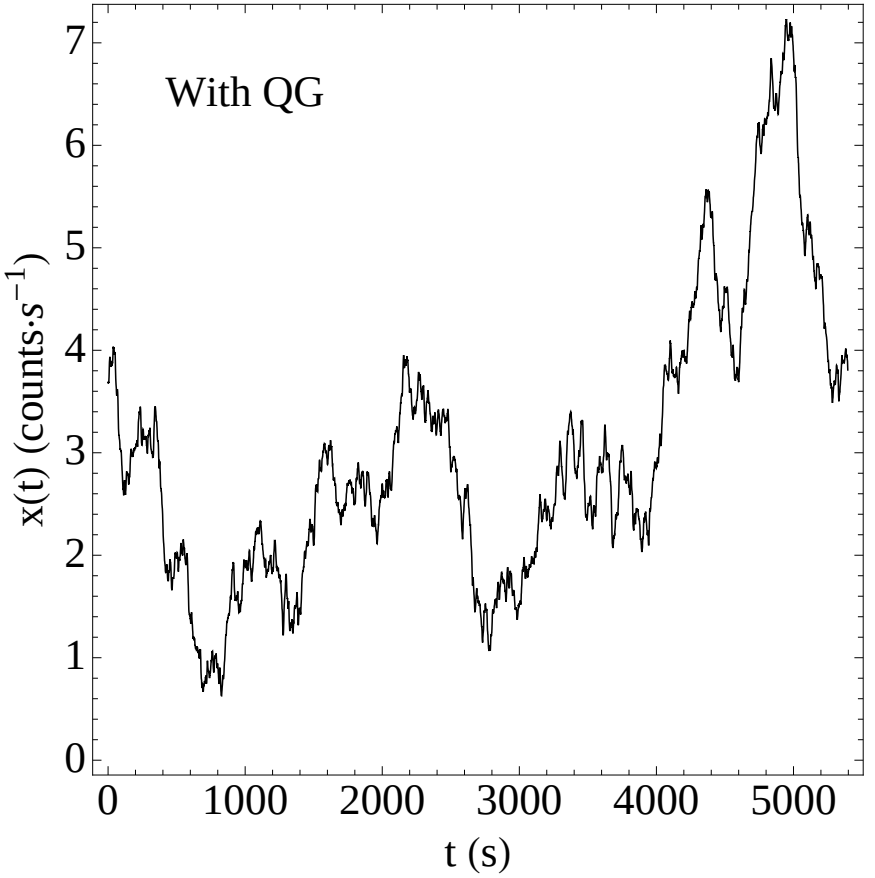
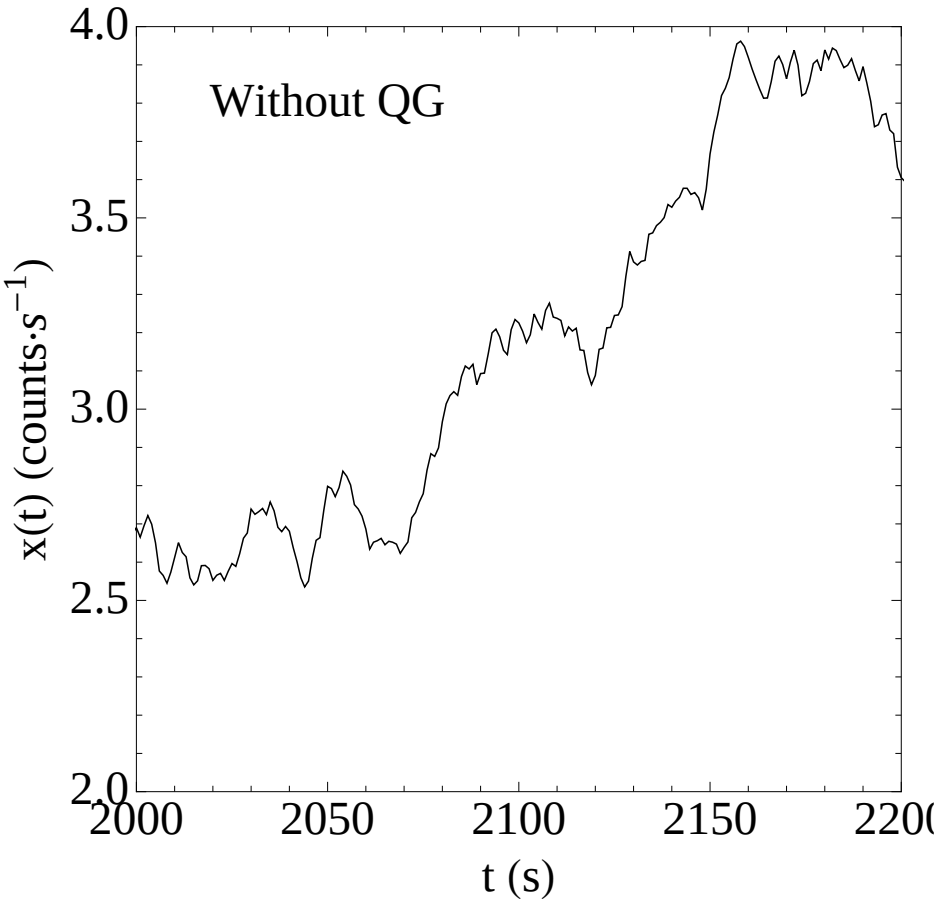
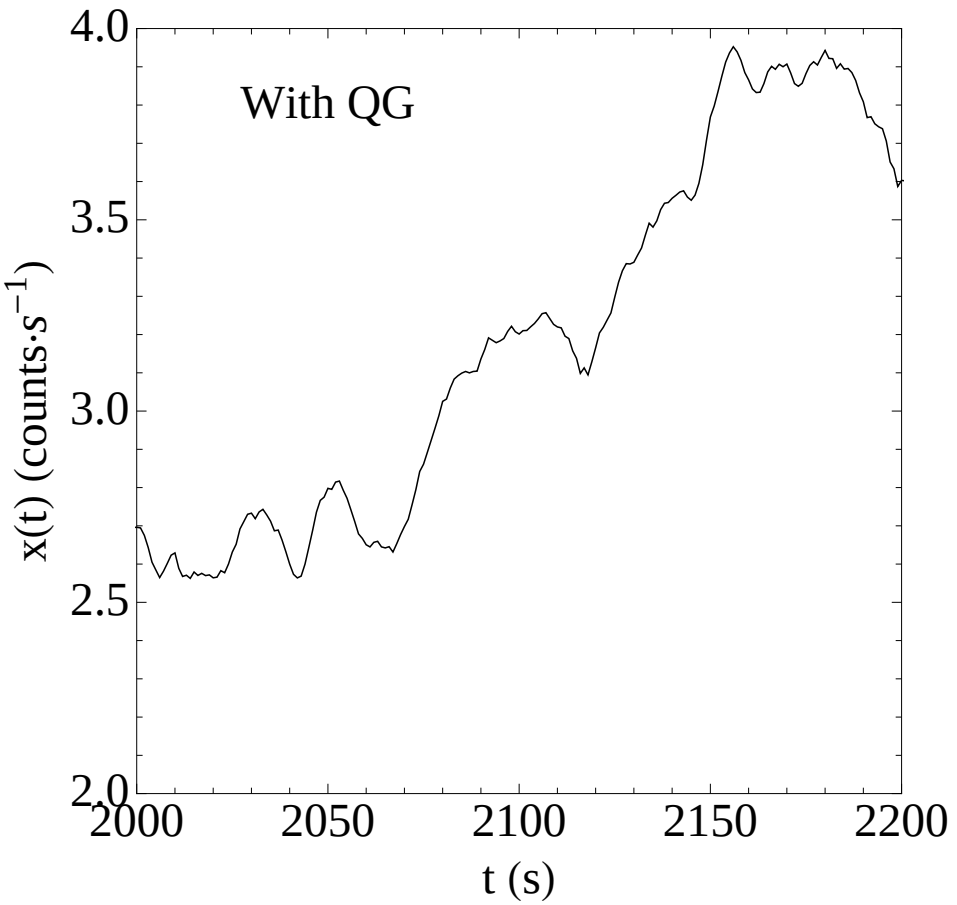




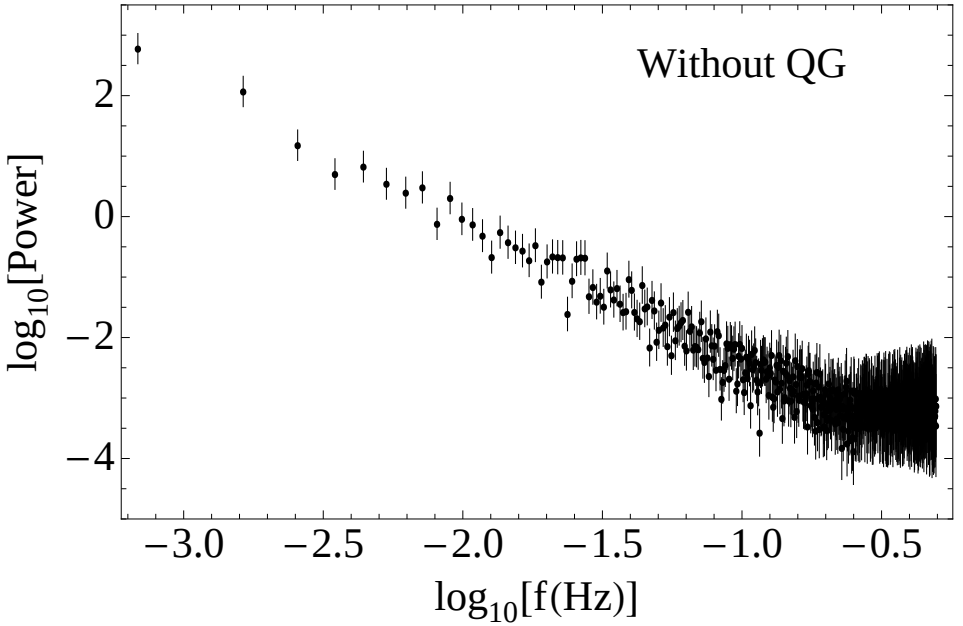
Properties of blazar light-curves in VHE

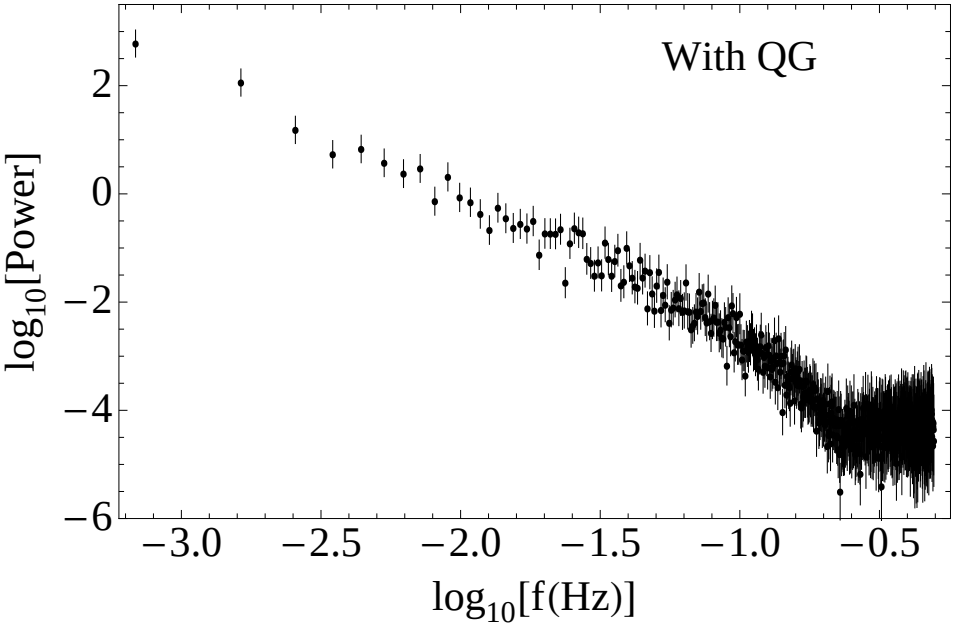




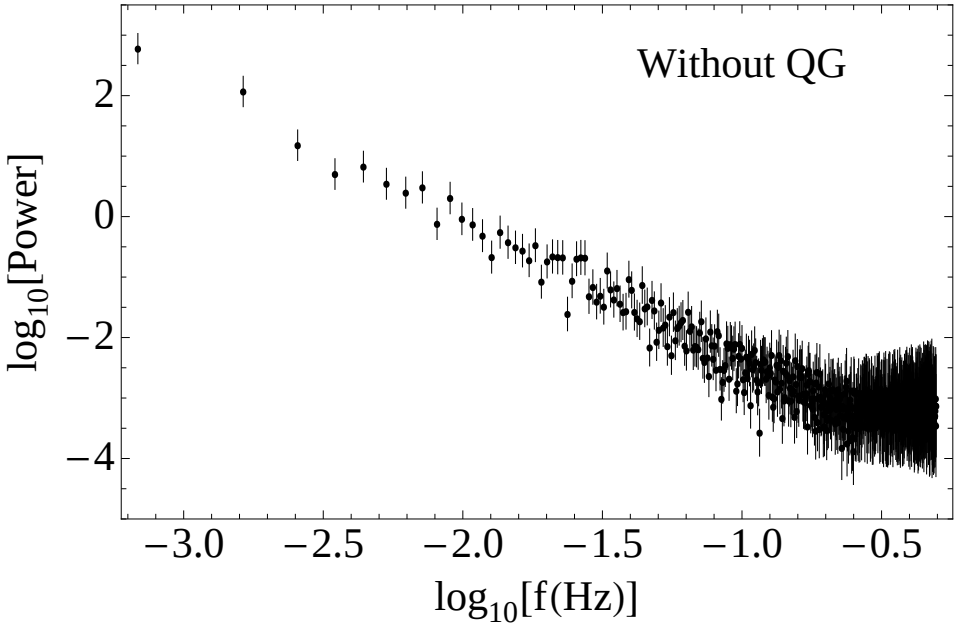
Smoothing out features $<$ 20 s

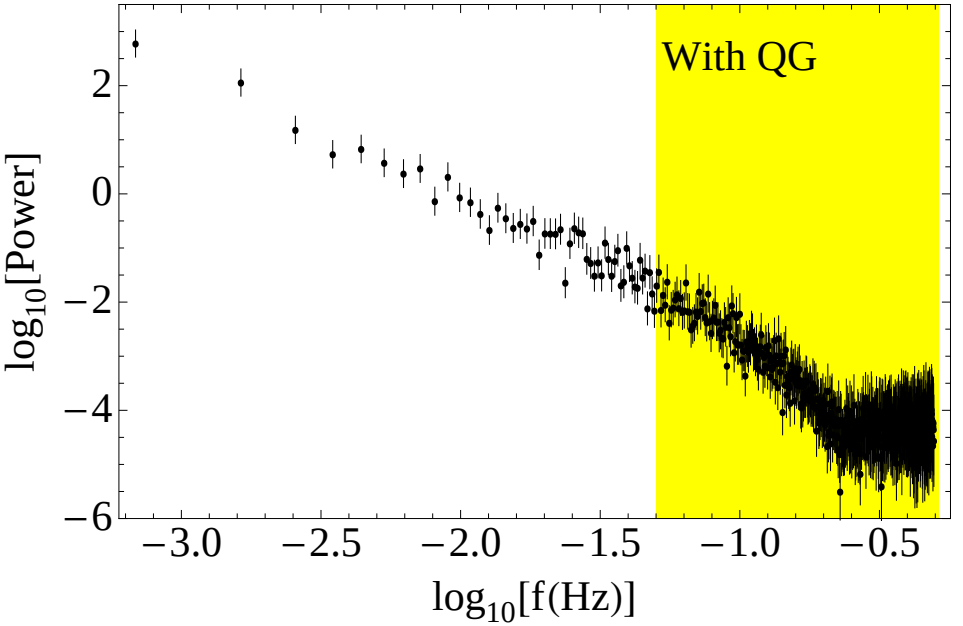
Properties of blazar light-curves in VHE





Properties of blazar light-curves in VHE





Variabity power is dropping towards small time-scales.

Properties of blazar light-curves in VHE

- No need to split the light-curve in energy bands.
- You can average periodograms over different epochs.
- You can readily pinpoint the noise level.

Properties of blazar light-curves in VHE

In the frequency domain: Lag-analysis requires knowledge of the phase.

Properties of blazar light-curves in VHE

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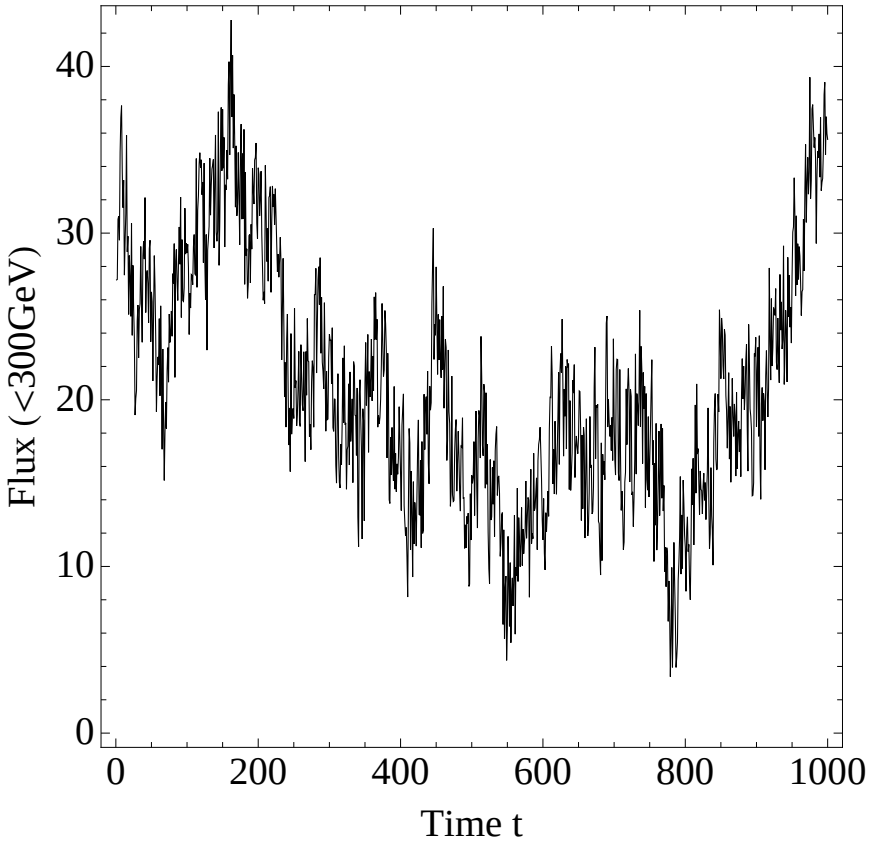

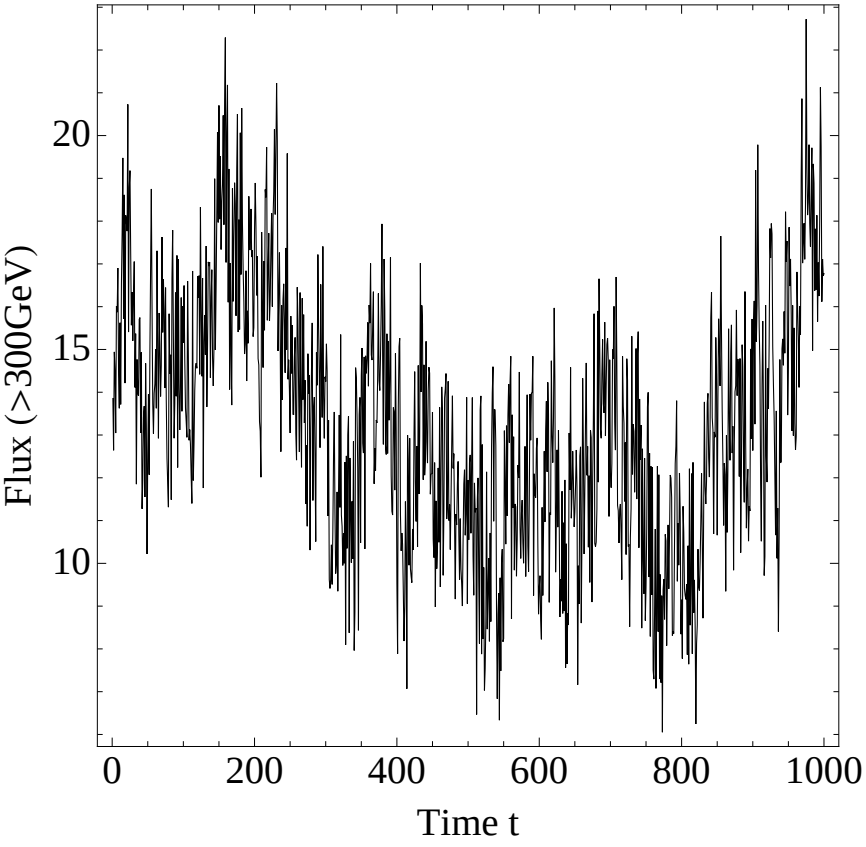

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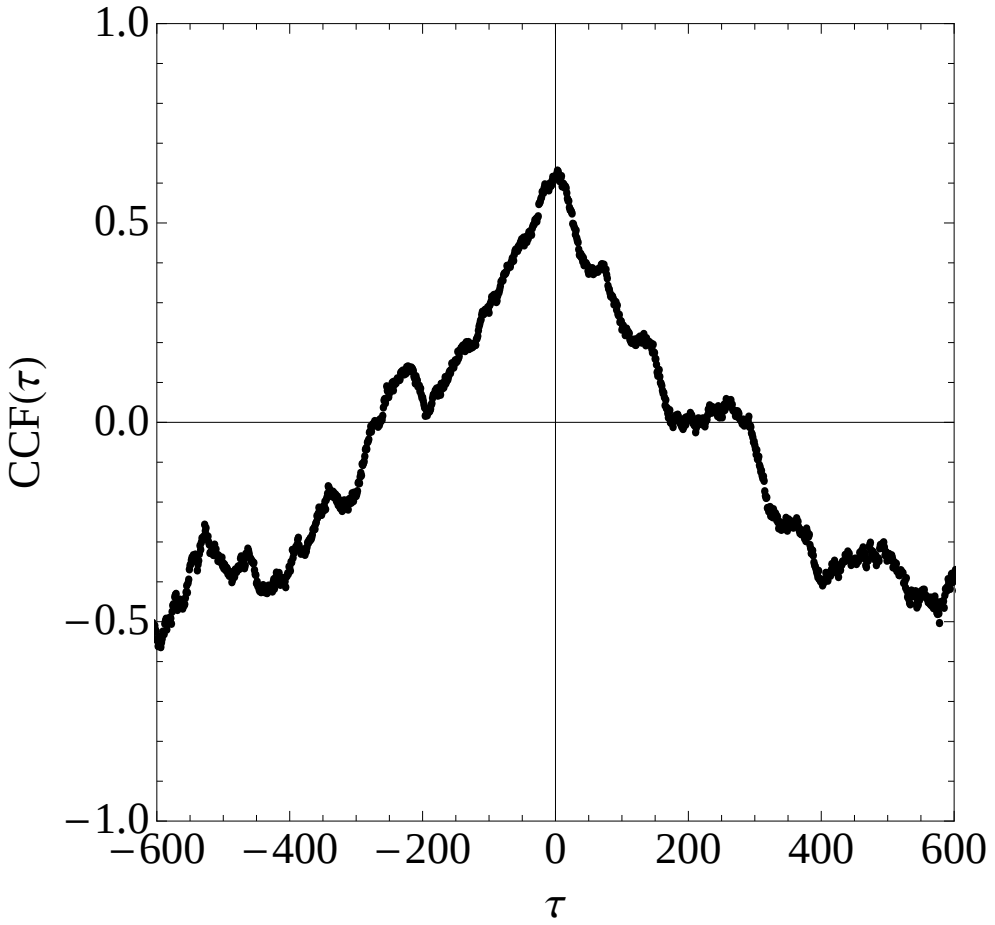

All sinusoids have random phase shifts.

Properties of blazar light-curves in VHE

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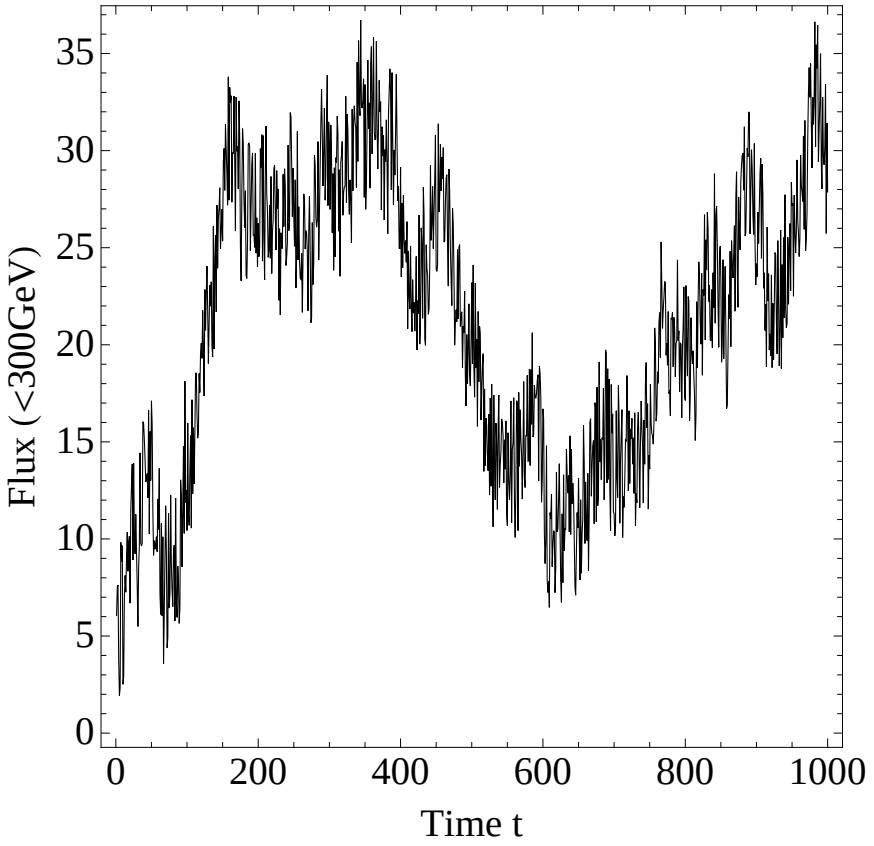

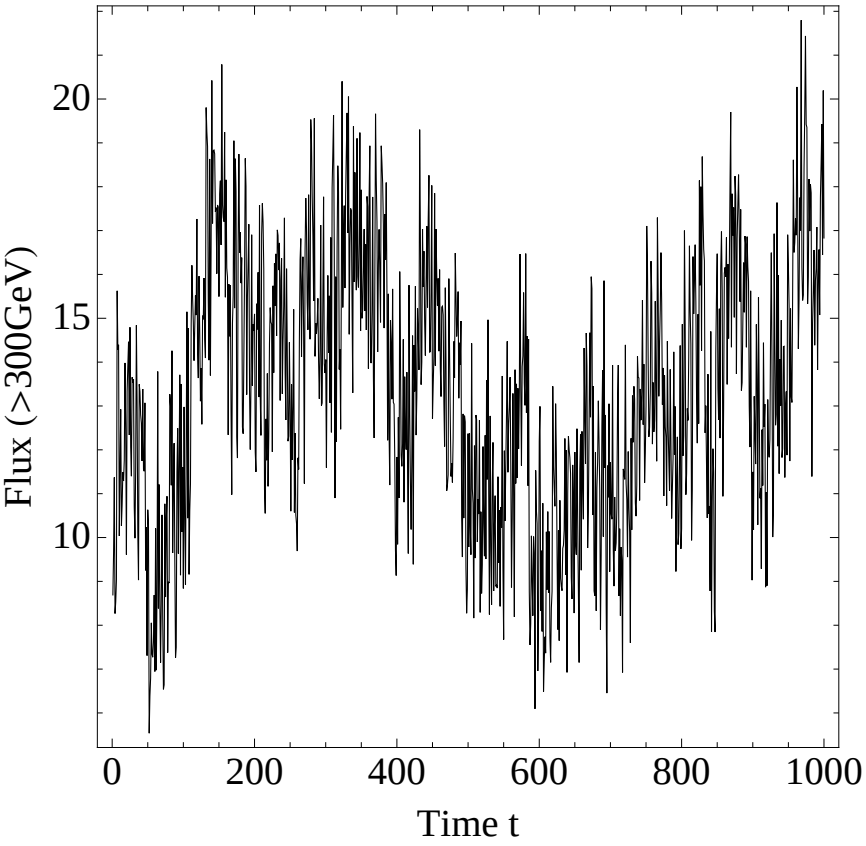

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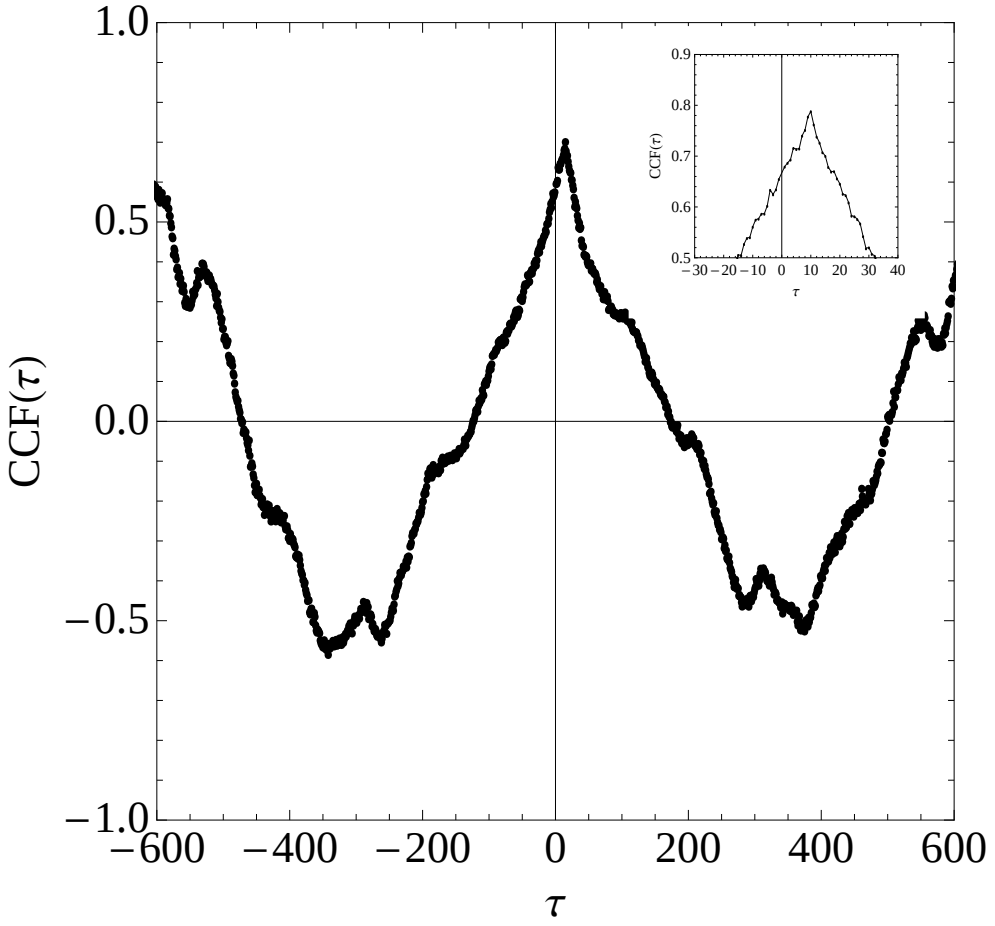


All sinusoids have the same phase-shift. This can be induced by QG effects.

Properties of blazar light-curves in VHE

In the frequency domain: Lag-analysis requires knowledge of the phase.

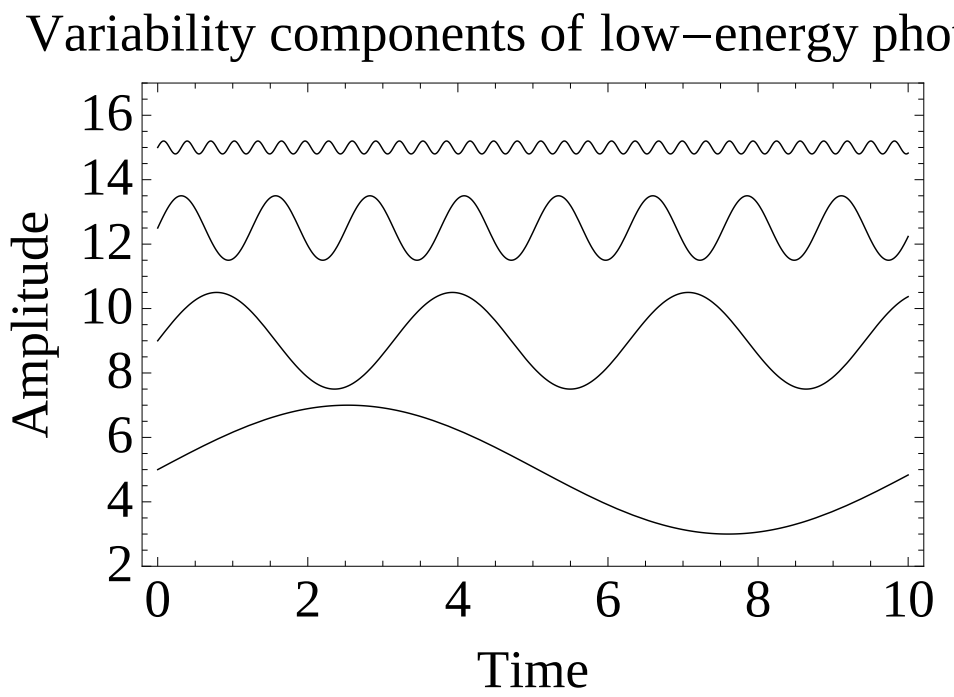
In the presence of QG effects

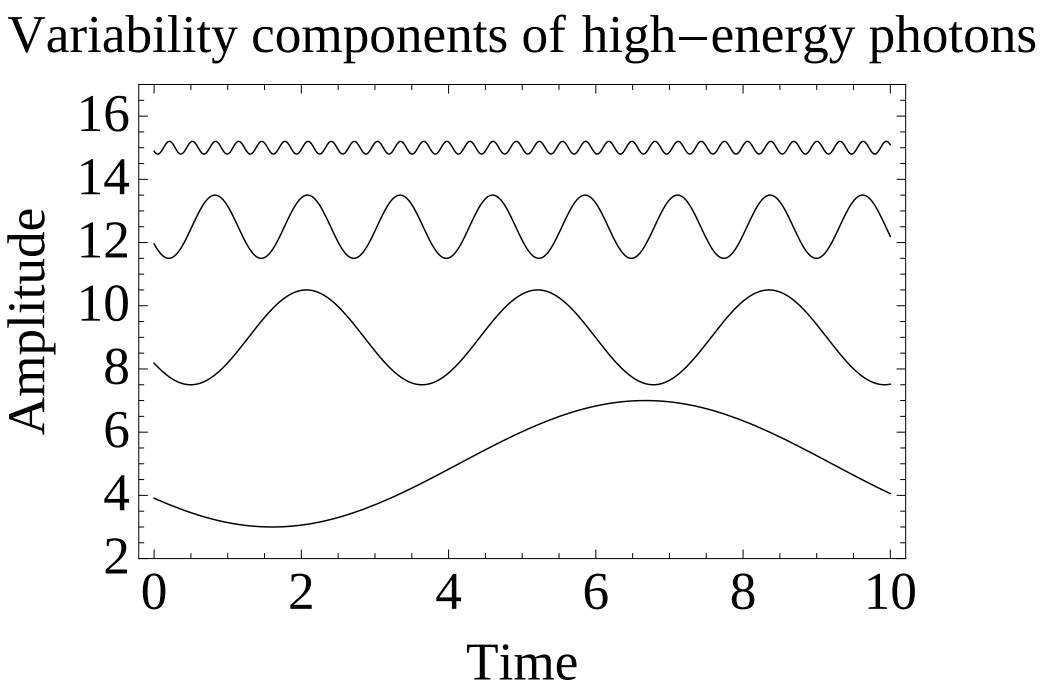
- All the time-scales experience the same time-shift!

Properties of blazar light-curves in VHE

In the frequency domain: Lag-analysis requires knowledge of the phase.

In the presence of QG effects





Properties of blazar light-curves in VHE

Cross-spectrum analysis.

$$\phi(f) = \arg\langle P_{\rm L}(f)^* P_{\rm H}(f)\rangle$$

with an error

$$\Delta\phi(f) = \frac{\sqrt{1-\gamma(f)^2}}{|\gamma(f)|\sqrt{2N_{\rm s}}}$$

$$\gamma(f)^2 = \frac{|\langle P_{\rm L}(f)^* P_{\rm H}(f)\rangle|^2}{\langle|P_{\rm L}(f)^2|\rangle\langle|P_{\rm H}(f)^2|\rangle}$$

Properties of blazar light-curves in VHE

Cross-spectrum analysis.

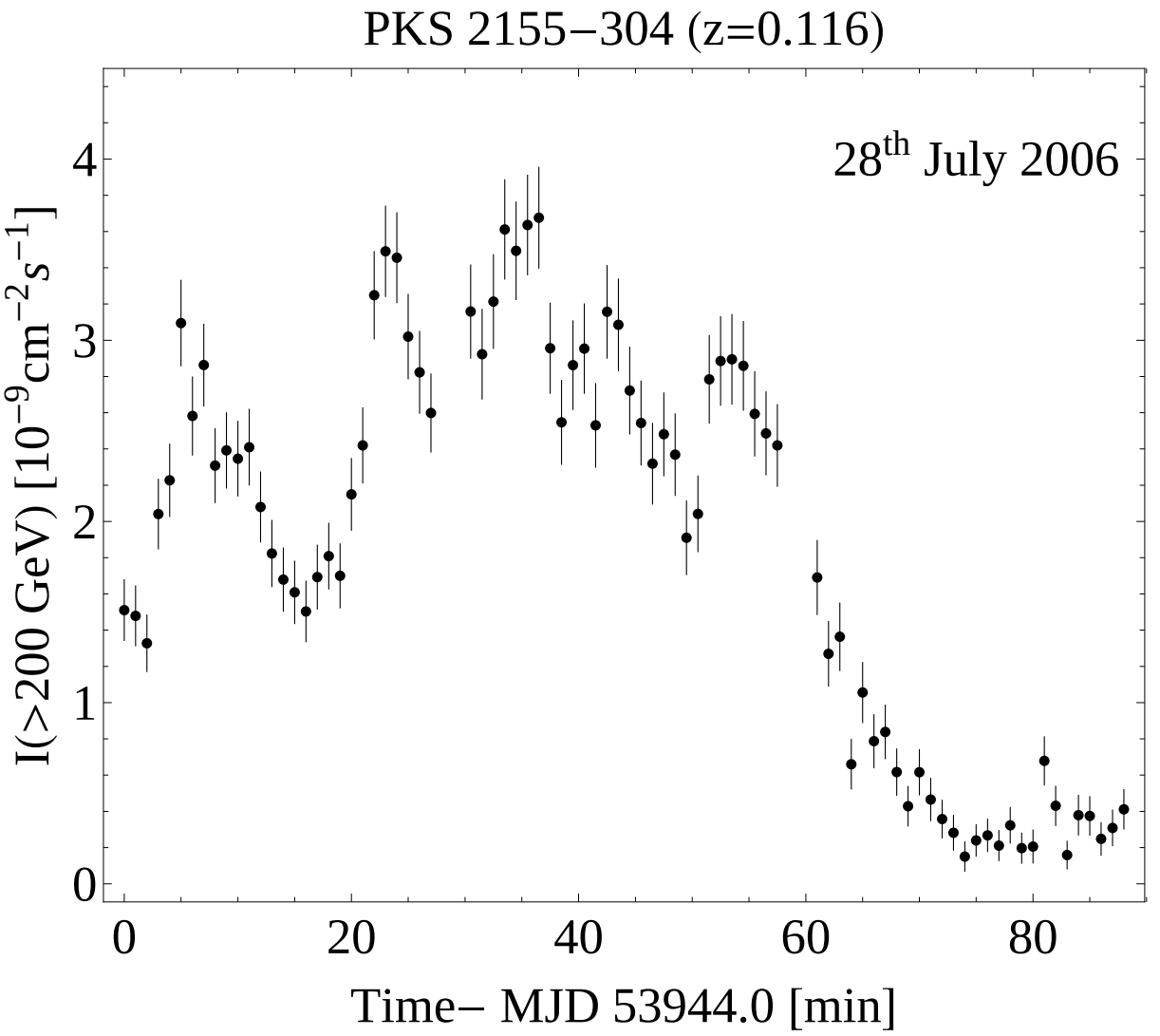
$$\phi(f) = \arg\langle P_{\mathrm{L}}(f)^* P_{\mathrm{H}}(f)\rangle$$

and the time-lag

$$\tau(f) = \frac{\phi(f)}{2\pi f}$$

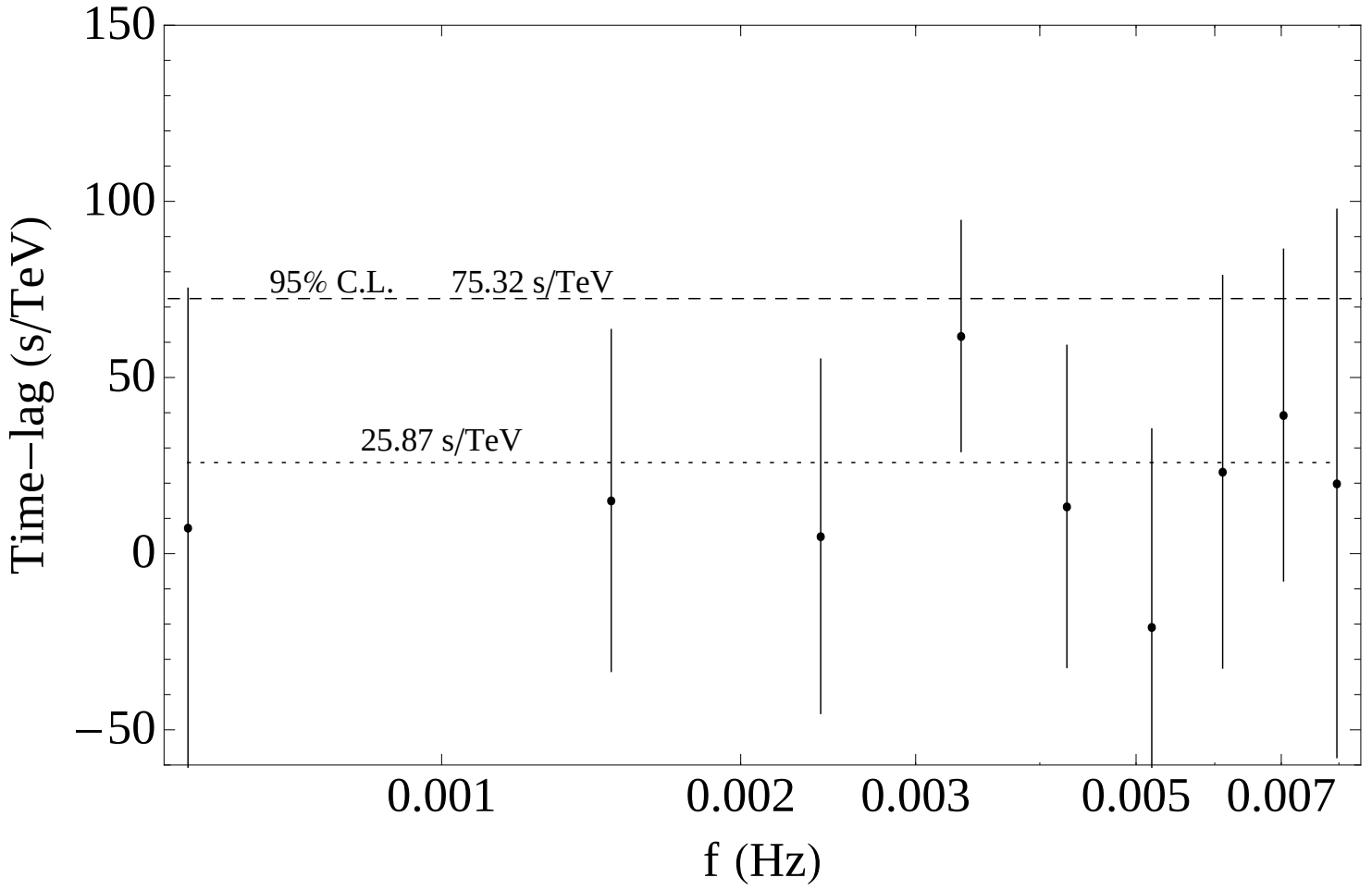
Keep in mind, for QG-effects: $\tau(f) = \mathrm{const.}$

Properties of blazar light-curves in VHE

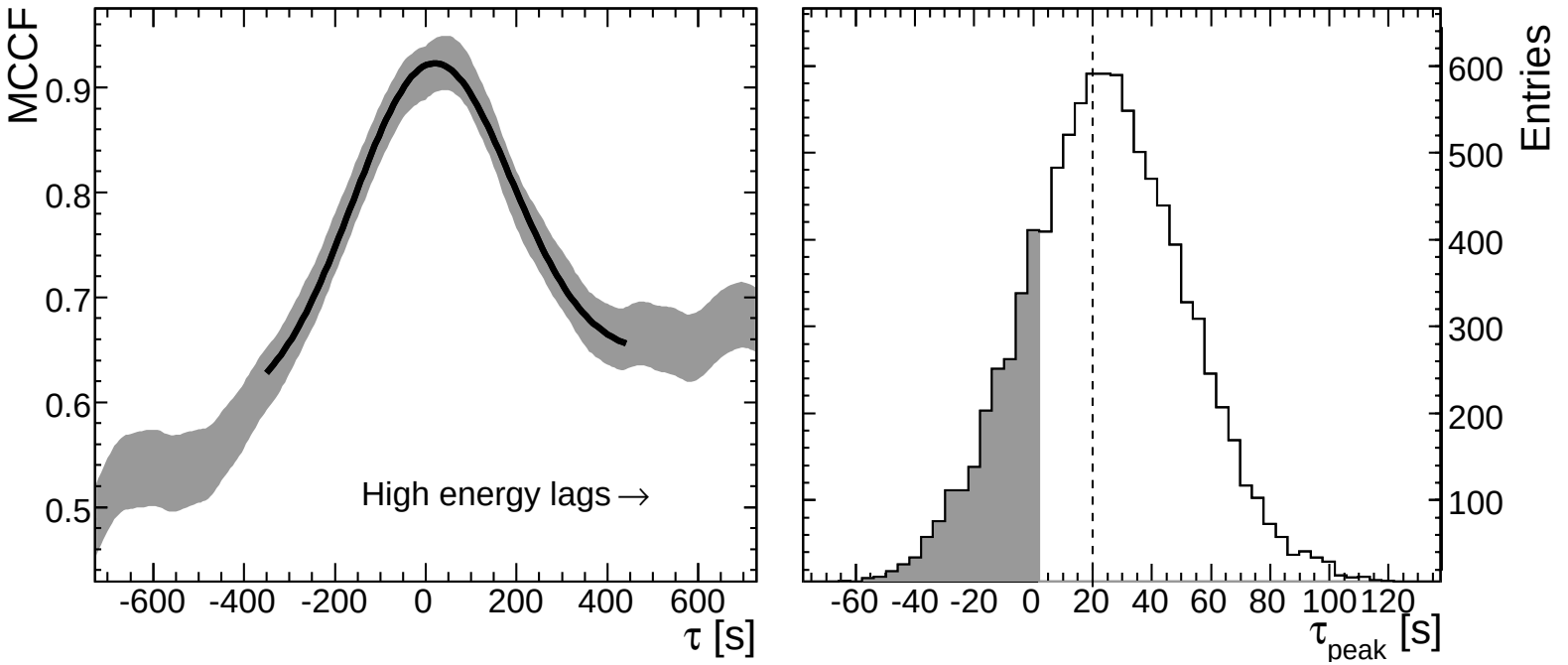


Properties of blazar light-curves in VHE

Cross-power-spectrum between 0.2–0.8 TeV and > 0.8 TeV



Current results



$$t_{\rm peak} = (20 \pm 28)\text{sec} \overset{\Delta t \approx \xi \frac{\Delta E}{E_{\rm P}} \frac{L}{c}}{\longrightarrow} \xi < 17$$

Aharonian, F. et al. 2008, (HESS Collaboration), PRL, **101**, 170402 (2008)

Current results

- $\xi < 200$ from Mrk 421 (z=0.030)

  Biller, S. D. et al. 1999, (WHIPPLE Collaboration), PRL, **83**, 2108

- $\xi < 30$ from Mrk 501 (z=0.034)

  Albert, J. et al. 2008, (MAGIC Collaboration), Phys. Lett. B, **668**, 253–257

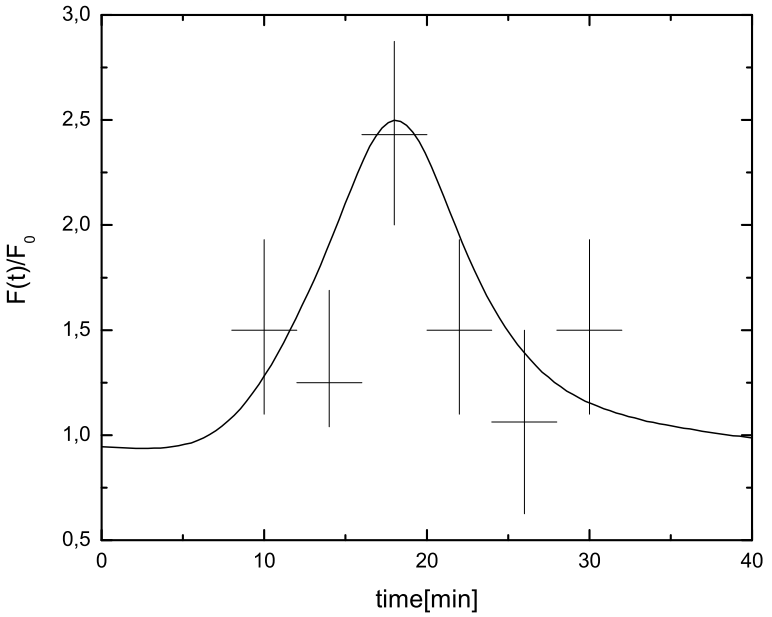
- $\xi < 17$ from PKS 2155-304 (z=0.117)

  Aharonian, F. et al. 2009, (HESS Collaboration), PRL, **101**, 170402

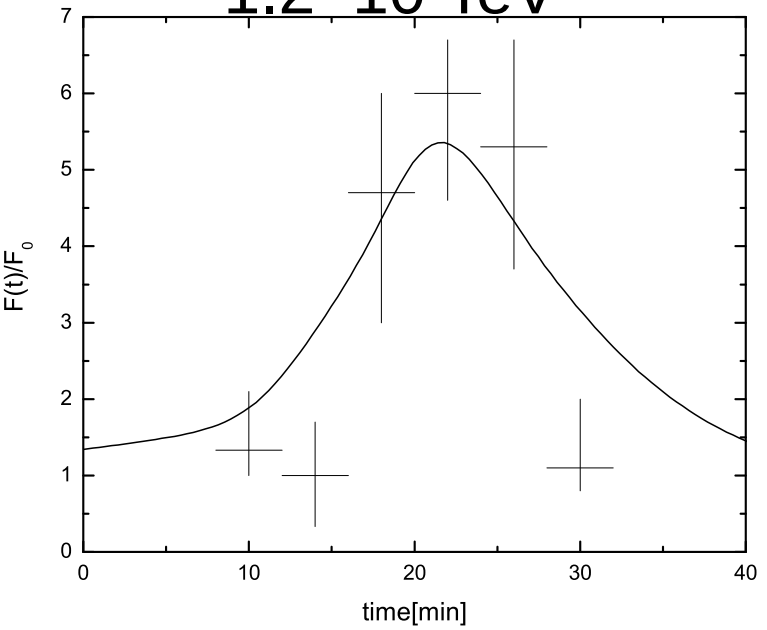
Current results

BUT...

0.15–0.25 TeV

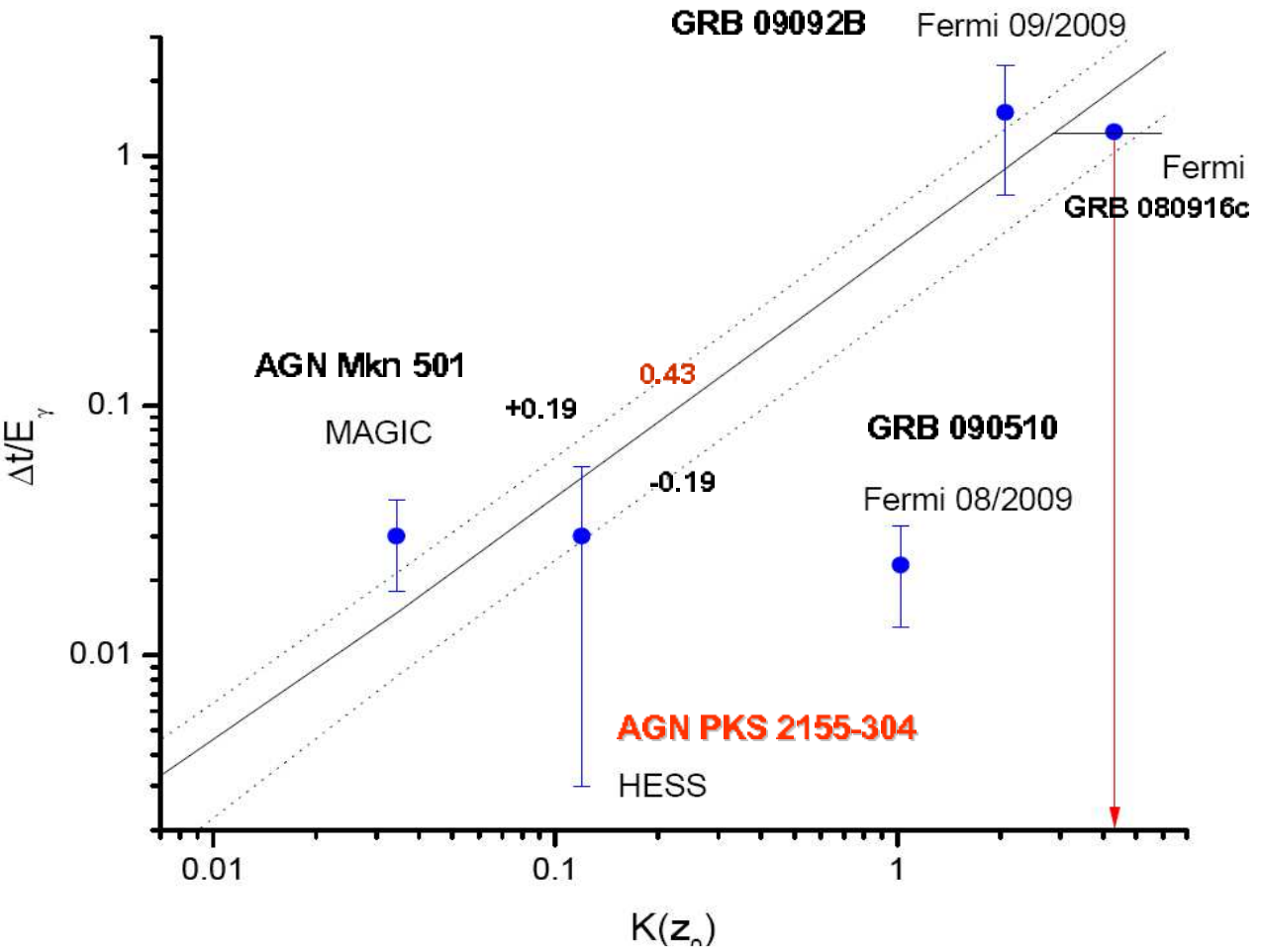


1.2–10 TeV



Mastichiadis, A. et al., A&A, **491**, 2, L37–L40, (2008)

Current results



Mavormatos N.E. 2010, (arXiv:1010.5399)

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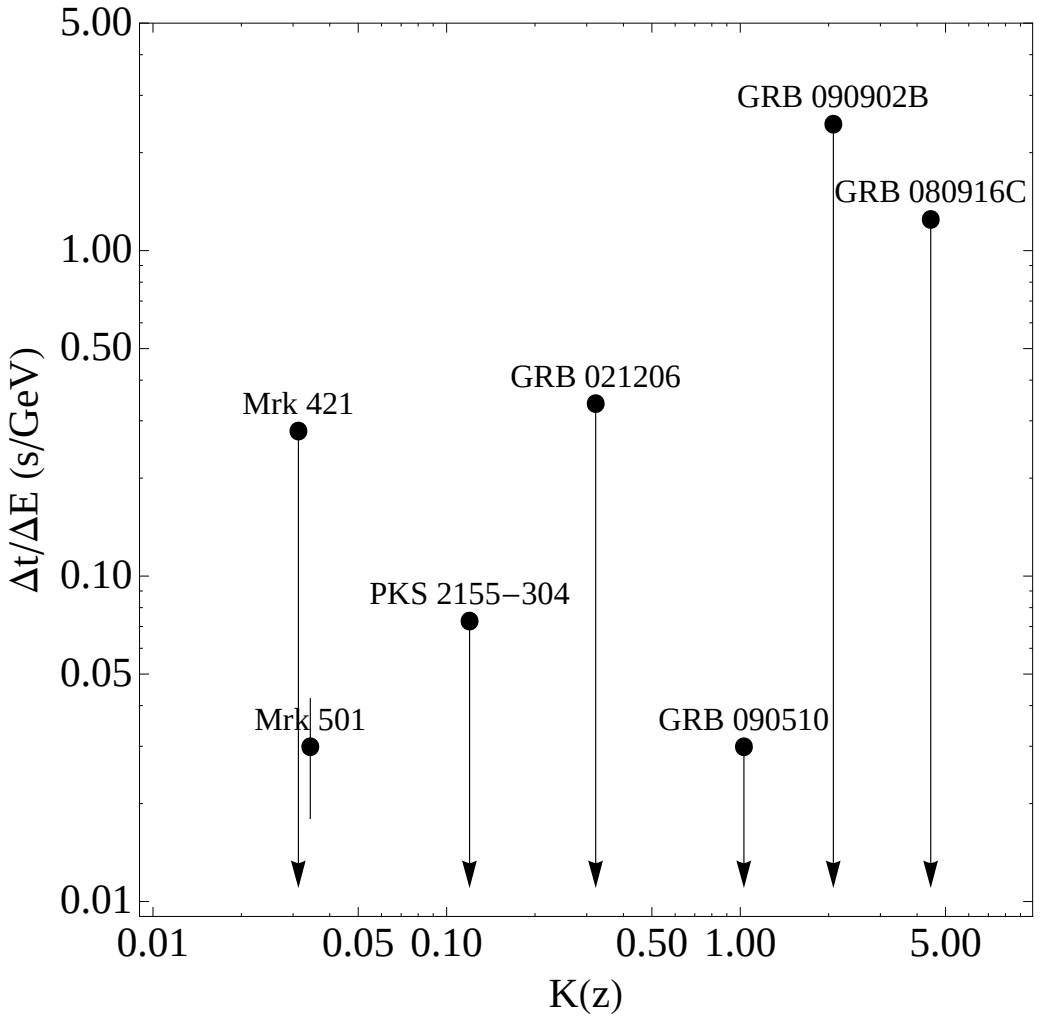

Conclusions

- Population studies are necessary!!!

  CTA is the next step.