Spectral characteristics of Mrk 501 during the 2012 and 2014 flaring states

Gabriele Cologna for the H.E.S.S. collaboration

H.E.S.S.

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SLW

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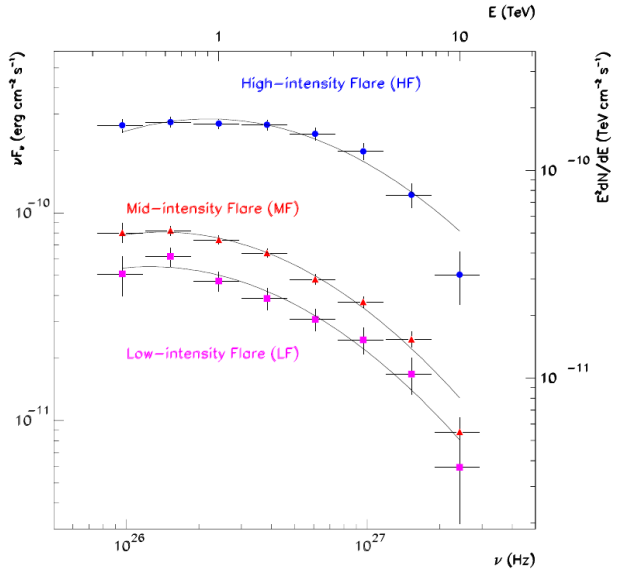
Mrk 501 at Very High Energies

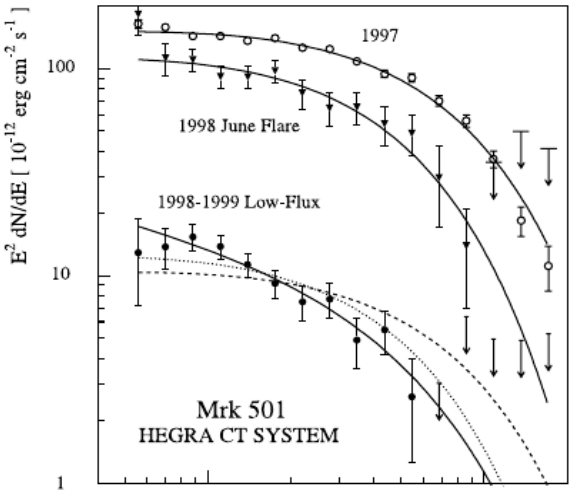
Mrk 501:

- HBL at z ~ 0.034
- very luminous
- second extragalactic object discovered at VHE in 1995



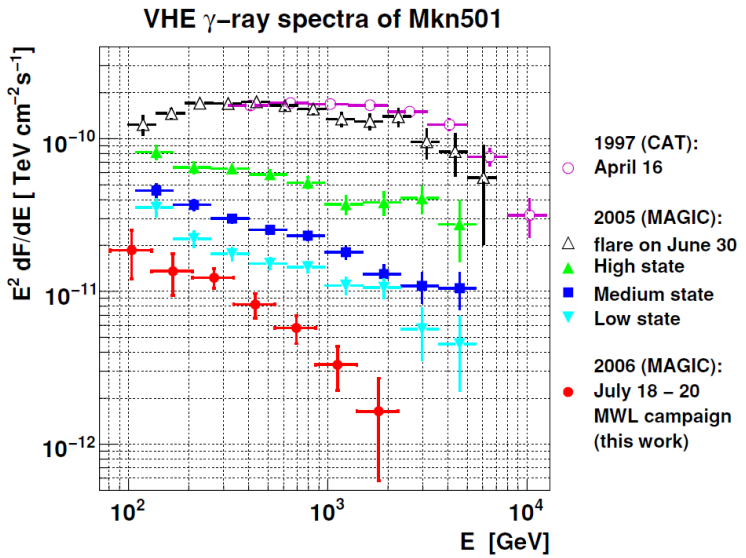
CAT - Djannati-Atai et al. 1999

HEGRA – Aharonian et al. 2001



- strongly variable at all energies
- object of several MWL campaigns
- historically highest VHE flux on April 16, 1997
- similar fluxes in 2005, 2012 and 2014

- SED peaks migrate to higher energies during flares
- harder when brighter behavior



MAGIC – Anderhub et al. 2009

Mrk 501 at Very High Energies – H.E.S.S. observations

H.E.S.S. observed in four periods:

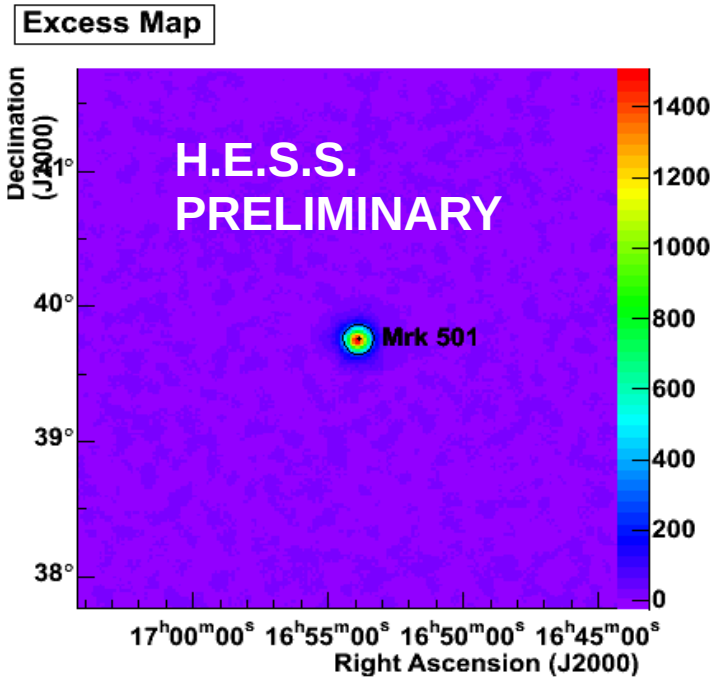
- 2004 and 2006 for MWL campaigns upper limits were published
- 2012 and 2014 as a ToO

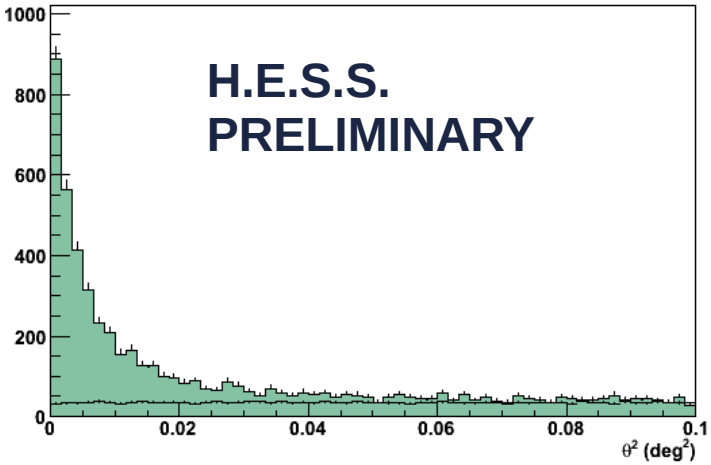
- 2004-2012 with H.E.S.S. I
  ~ 6 hours
- 2014 with H.E.S.S. II
  ~ 8 hours

- Observations have mean ϑ_{zenith} = 63.7°

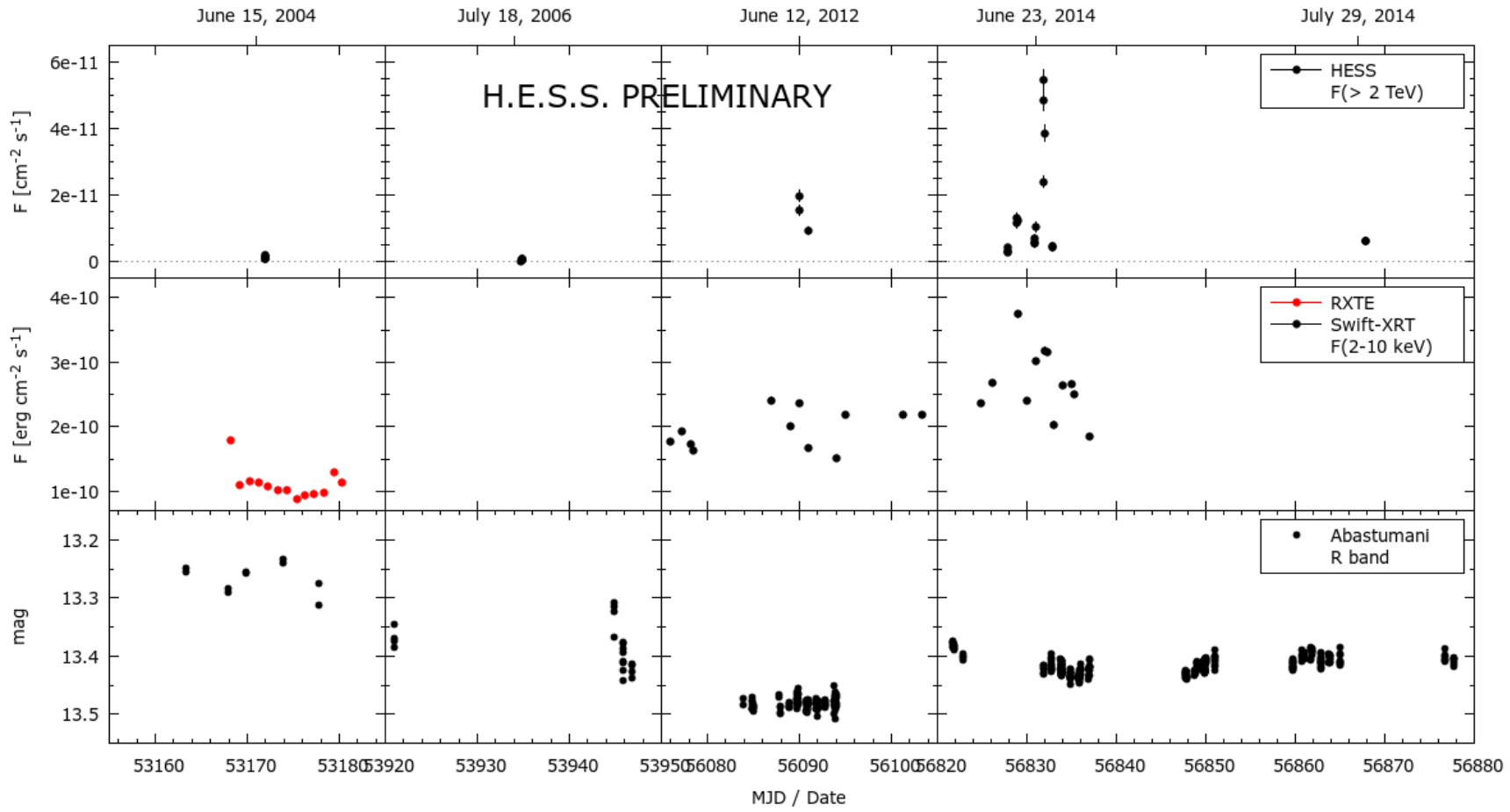
Reanalysis of whole dataset:

- only H.E.S.S. I style analysis
- source detected with high significance
- high energy threshold ~2 TeV



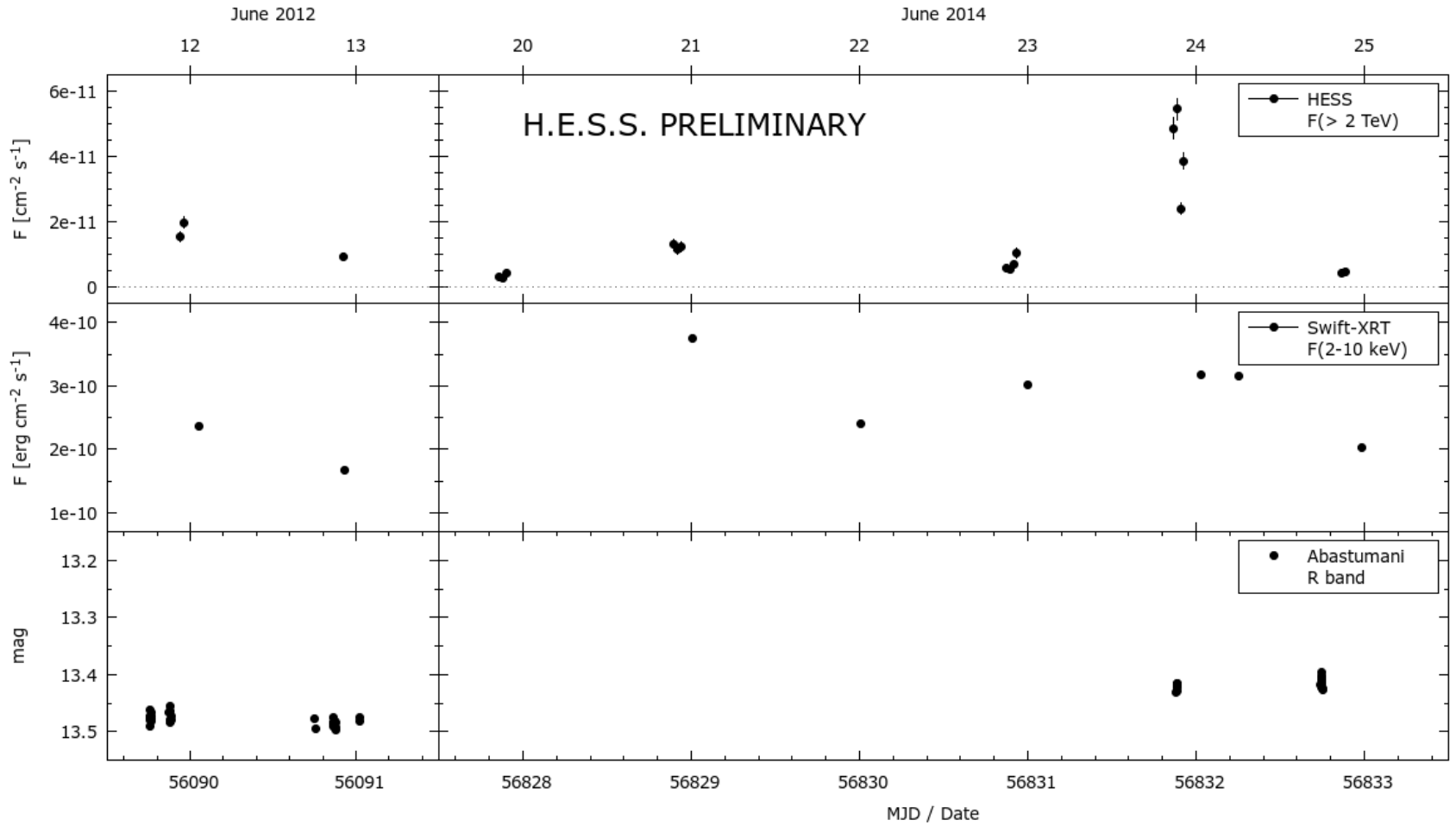


Lightcurves



- No obvious correlation of the variability in different bands → two or more zones/mechanisms needed
- No correlation of optical and X-rays

Lightcurves



- Flux doubling time scale < 10 minutes
- X-rays observations follow VHE ones by ~ 90 min
- 4 x TeV flux in 90 min

(Assuming SSC model, quadratic correlation expected)

Further studies on variability in poster contribution ID 1187, Chakraborty et al.
“Rapid variability at very high energies in Mrk 501”

Spectra

- Spectra clearly curved
- EBL absorption, $\tau \geq 1$ expected above ~ 8 TeV (Franceschini et al 2008)
- PL+EBL fit:

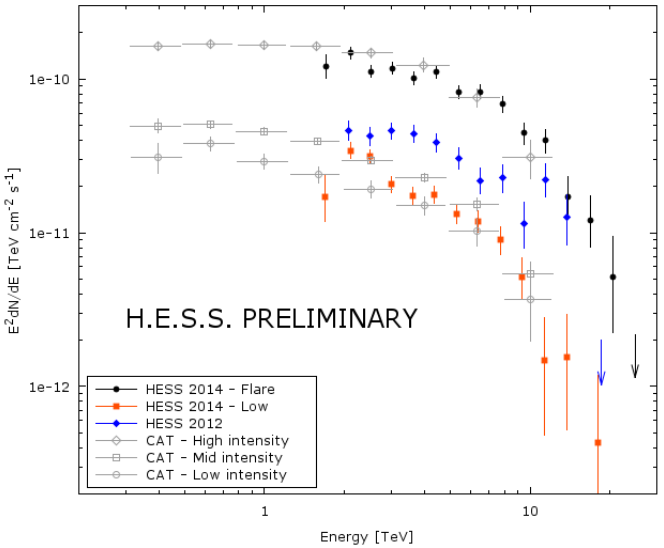
  2014 flare $\Gamma = 2.15 \pm 0.06_{stat} \pm 0.2_{sys}$

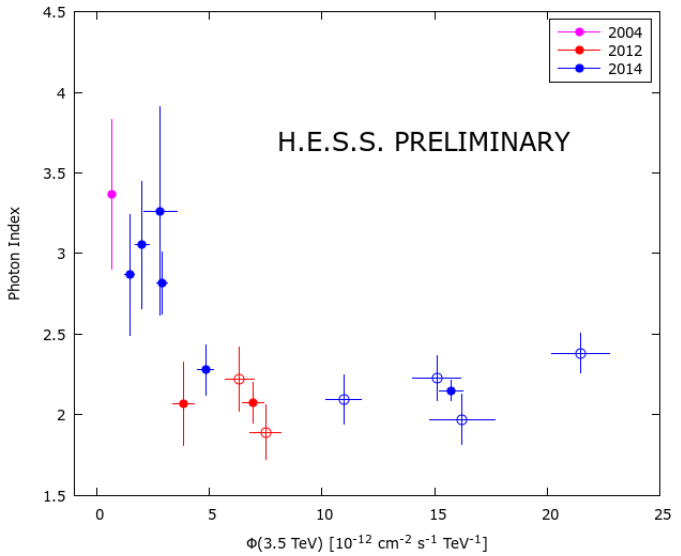
  2012 $\Gamma = 2.2 \pm 0.1_{stat} \pm 0.2_{sys}$

  2014 low $\Gamma = 2.7 \pm 0.1_{stat} \pm 0.2_{sys}$
- Spectra are clearly hard at high fluxes

  at pure TeV energies!
- CPL/ECPL+EBL do not improve the fit

  → No signs of Klein-Nishina suppression

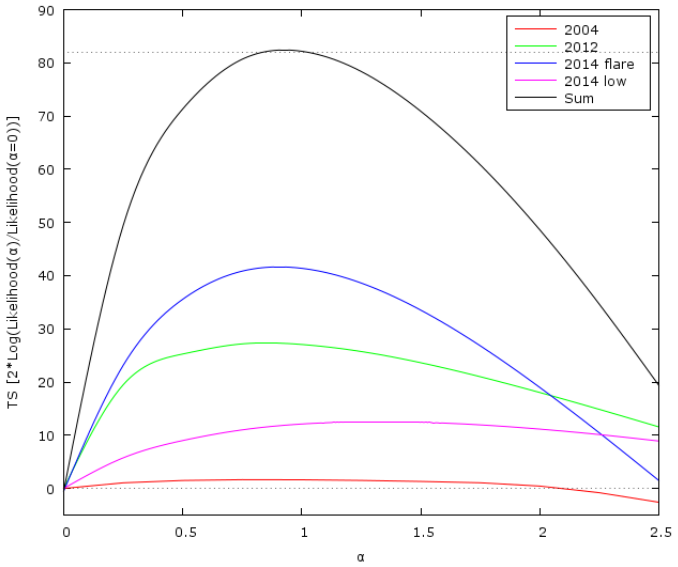




Full circles: nights
Open circles: runs

EBL determination

- test the EBL model of Franceschini et al. 2008 as in HESS Collaboration et al. 2013
- ~ 2-25 TeV ↔ 2.5-30 μm
- EBL > 0 @ 9 σ level



This work	
2004 - 2014	$0.93^{+0.15}_{-0.14}$
2012+2014 flares	$0.89^{+0.16}_{-0.14}$

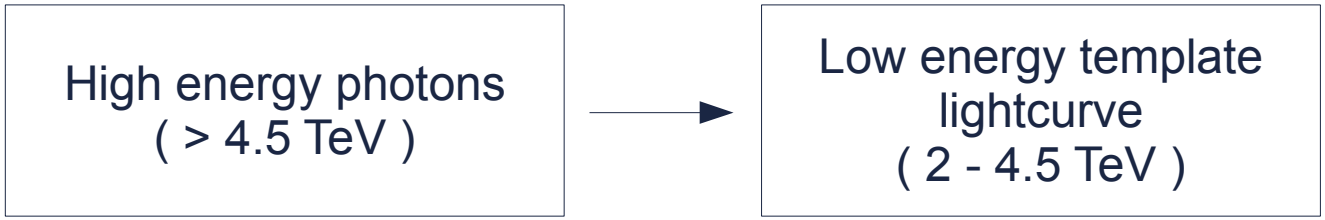
Compatible with FR08

HESS Collaboration et al. 2013		
all datasets	$1.27^{+0.18}_{-0.15}$	Dominated by PKS 2155-304
low redshift dataset	$1.6^{+0.5}_{-1.1}$	
high energy dataset	$1.05^{+0.32}_{-0.28}$	Compatible

Further studies on EBL characterization in the oral contribution GA18 EGAL, Lorentz et al.
"Update on the determination of the extragalactic background light spectral energy distribution with H.E.S.S. "

Lorentz invariance violation (LIV) studies

- Hard energy spectrum → promising for LIV studies
- Likelihood method following HESS Collaboration et al. 2011



95% CL Quantum Gravity limits		
	Linear term	Quadratic term
Sub-luminal	8.5×10^{17} GeV	1.15×10^{11} GeV
Supra-luminal	6.4×10^{17} GeV	1.0×10^{11} GeV
PKS 2155-304 (sub.)	2.1×10^{18} GeV	6.4×10^{10} GeV
GRB 090510 (sub. / sup.)	$(1.8 \times 10^{19} / 3.2 \times 10^{19})$ GeV	$(4.0 \times 10^{10} / 3.0 \times 10^{10})$ GeV
Mrk 501 (MAGIC 2005)	2.1×10^{17} GeV	2.6×10^{10} GeV

Best limits on the quadratic term!

Conclusions

- H.E.S.S. observations of Mrk 501 between 2004 and 2014 have been reported in a MWL context
- The 2014 flare spectrum is comparable in flux and shape with the 1997 historical high state reported by CAT and HEGRA
- 20 TeV are measured in a single night of observation (~2 h) for the first time
- Spectra are hard during periods of high flux, soft otherwise
- Intrinsic hard PL extending to about 20 TeV during the 2014 flare peak indicates the absence of Klein-Nishina suppression at these high energies
- Rapid variability in the 2-20 TeV energy range during flares
- No direct relation with the emission at lower energies has been found
  - single zone models cannot explain the optical emission
- The EBL normalization factors derived are consistent with the model of FR08 up to 30 μm
- Quadratic limits on the QM scale are the best ones derived up to now

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