Multiwaveband Observations of the TeV Blazar PKS 2155-304 with HESS, Fermi, RXTE and Swift

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LLR

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Outline

1. PKS 2155-304 , status and open questions
2. Results of the 12 days campaign in 2008
3. Correlations

- Located in the southern hemisphere (RA : 329.7,DEC : -30.2), z=0.117
- Radio source : PKS 2155-304 belong to the Parkes Catalog

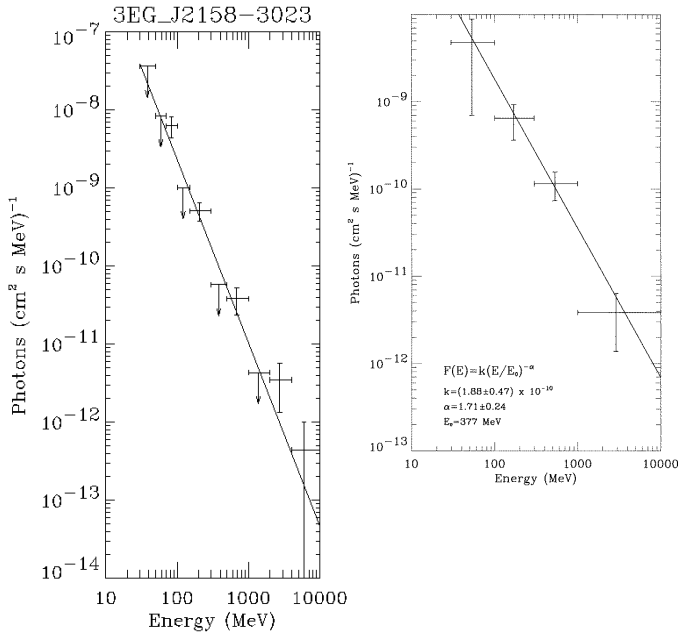
- Detected by EGRET (3EG : 5.9σ)
- First VHE emission observed in 1999 with Durham Mk VI telescopes, not seen by CANGAROO until recently
- Very bright and variable source in VHE range (E>200 GeV)

EGRET measurements :
Third catalog

- F(100MeV)=
  $4 \cdot 10^{-9} \mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{MeV}^{-1}$
- $\Gamma = 2.34 \pm 0.2$

Hard state (Vestrand et al (1995)), 2 weeks of pointing mode, 5.8 σ

- F(100MeV)=
  $1.8 \cdot 10^{-9} \mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{MeV}^{-1}$
- $\Gamma = 1.71 \pm 0.24$



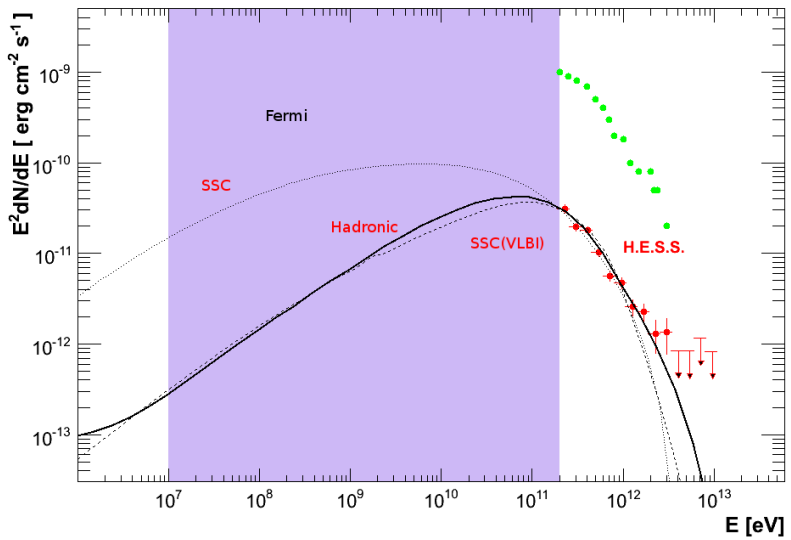
3EG catalog Hard State

LAT : detection in 1-2 day of NomSciOps observation (low state)
For the first time, variability in GeV range can be characterised with a timescale of a day.

VHE range : the HESS high state flux is 50 times higher than the low state flux
High state, photon index = 3.53 ± 0.05 (E>500GeV)
Low state, photon index = 3.37 ± 0.07

(Aharonian et al, An Exceptional VHE γ-ray flare of PKS 2155-304)

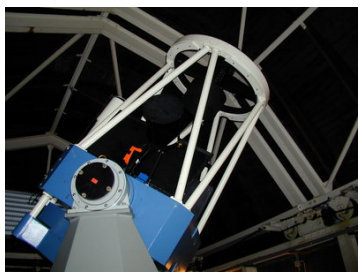
- where is the spectral break ?
- leptonic (SSC,EC), hadronic model ?
- leptonic model : origin of the seed photons



FGST should discriminate between models, independently of the flux state.

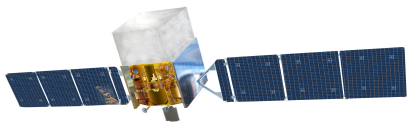
First Fermi-HESS MWL campaign

4 instruments to cover the broad band spectrum
12 days of observation

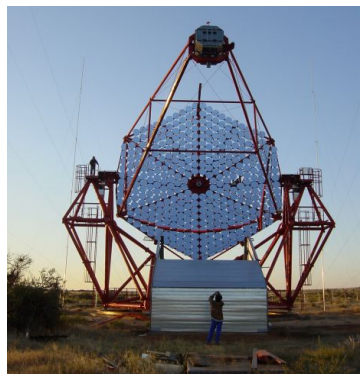


ATOM (RVB)

RXTE (+
Swift ToO)



Fermi



HESS

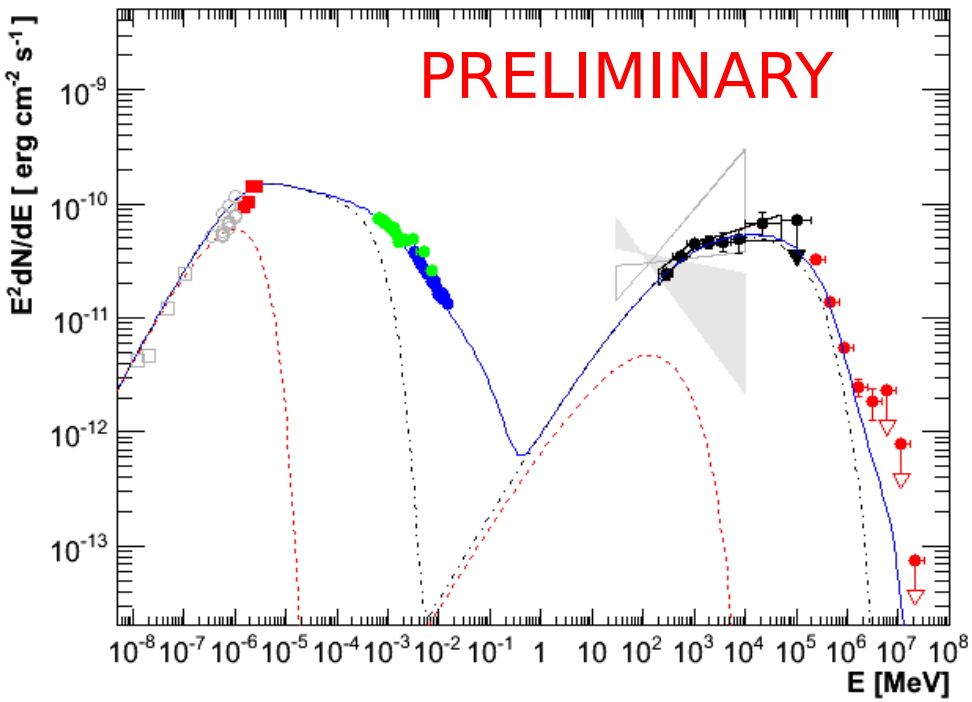
First simultaneous observation in optical, X-ray, and HE γ-ray
SED modeling with 1-zone, homogeneous SSC model, study of correlations between different wave-band.

Time average SSC model : "Straw man" model

LAT : $\Gamma_L = 1.61 \pm 0.16$, $\Gamma_H = 1.96 \pm 0.08$, $E_{br} = 1.0 \pm 0.3$

SSC parameters :

- $N_e \propto E^{-s}$, $s_0 = 1.3$, $s_1 = 3.2$, $s_2 = 4.3$
- $\gamma_1 = 1.4 \times 10^4$, $\gamma_2 = 2.3 \times 10^5$
- $R = 1.5 \times 10^17$, $\delta = 32$, $B = 0.018 G$



Electrons producing X-ray do not produce VHE photons.
HE and VHE photons are produced by electrons $\gamma_1 < \gamma < \gamma_2$

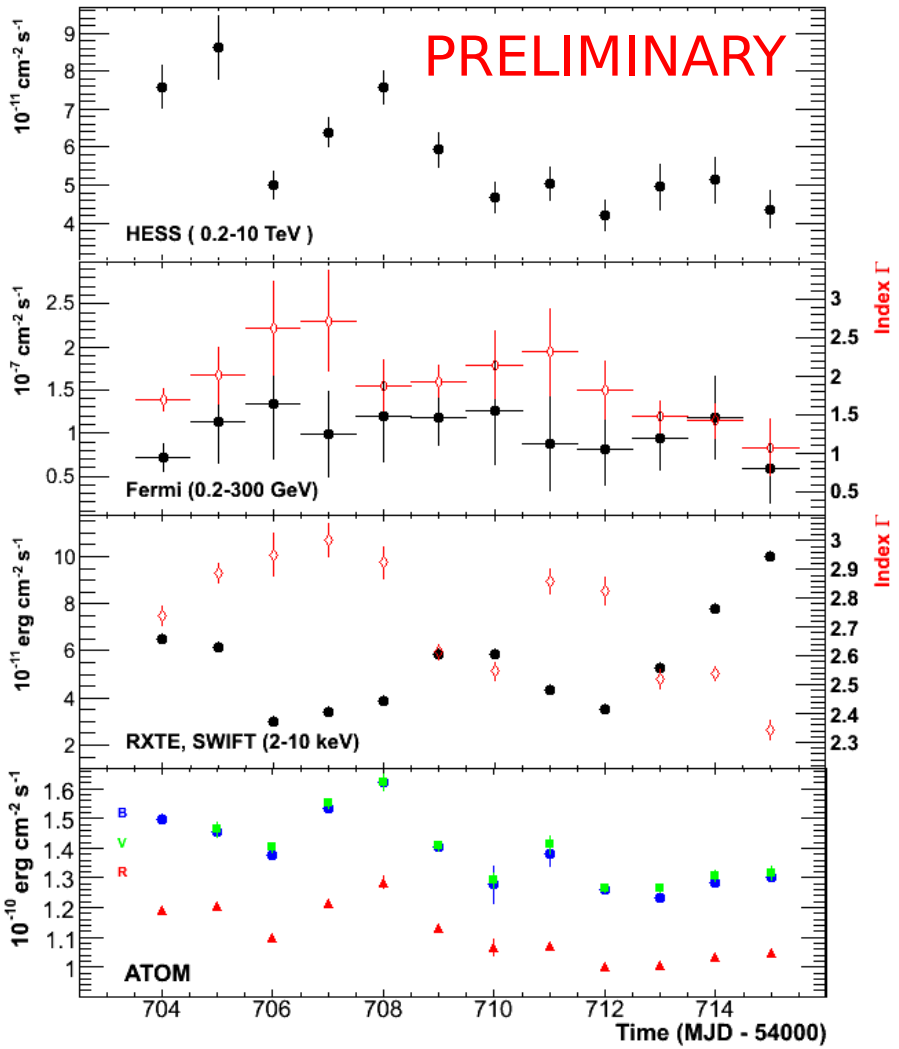
LC of 12 days

- VHE, $F_{\rm var} = 23 \pm 3\%$
- HE, $F_{\rm var} < 20\%$
- X, $F_{\rm var} = 35 \pm 0.05\%$
- Opt, $F_{\rm var} = 8 \pm 0.5\%$

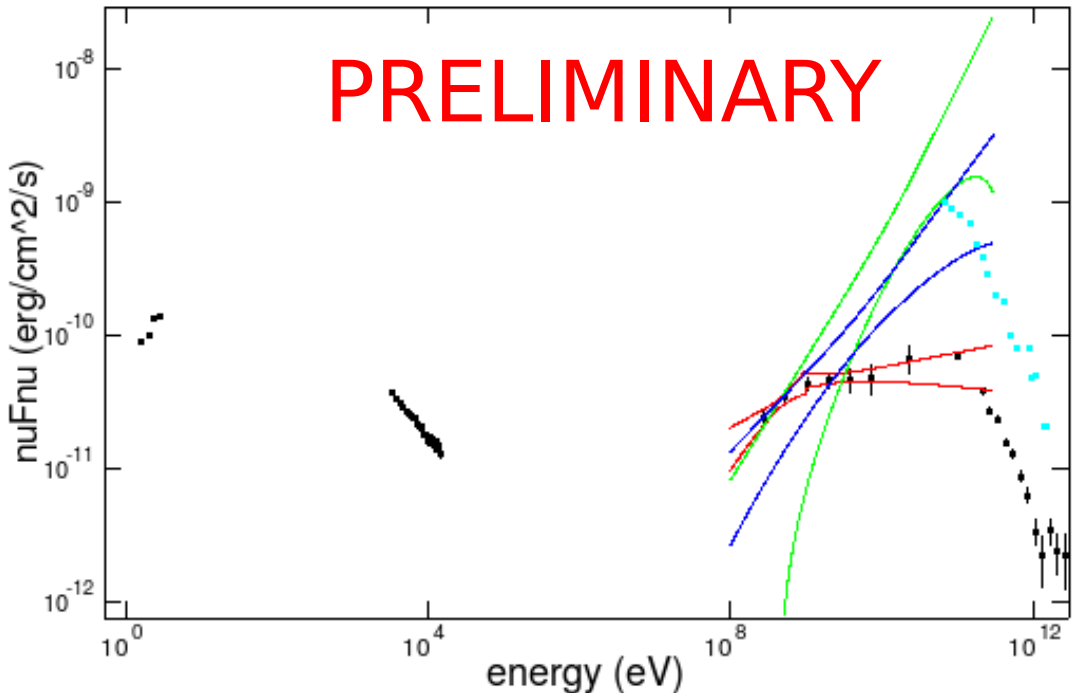
No spectral variability in VHE range ($\Delta\Gamma < 0.2$) weak cooling regime

F_{HE} : no variability but more variation of Γ_{HE} ($P_{\rm cst} = 19\%$)

X-ray : softer when lower behaviour
strong cooling regime



VHE flares



blue curves : 1 sigma contours for the 1.77 day power-law fit

green curves : 1 sigma contours for the 0.22 day fit

Time interval	Integral (100 MeV-300 GeV)	Index
0.22 day	1.90 $\pm$ 1.00 e-7	-0.97 $\pm$ 0.26
1.77 day	1.43 $\pm$ 0.52 e-7	-1.32 $\pm$ 0.16

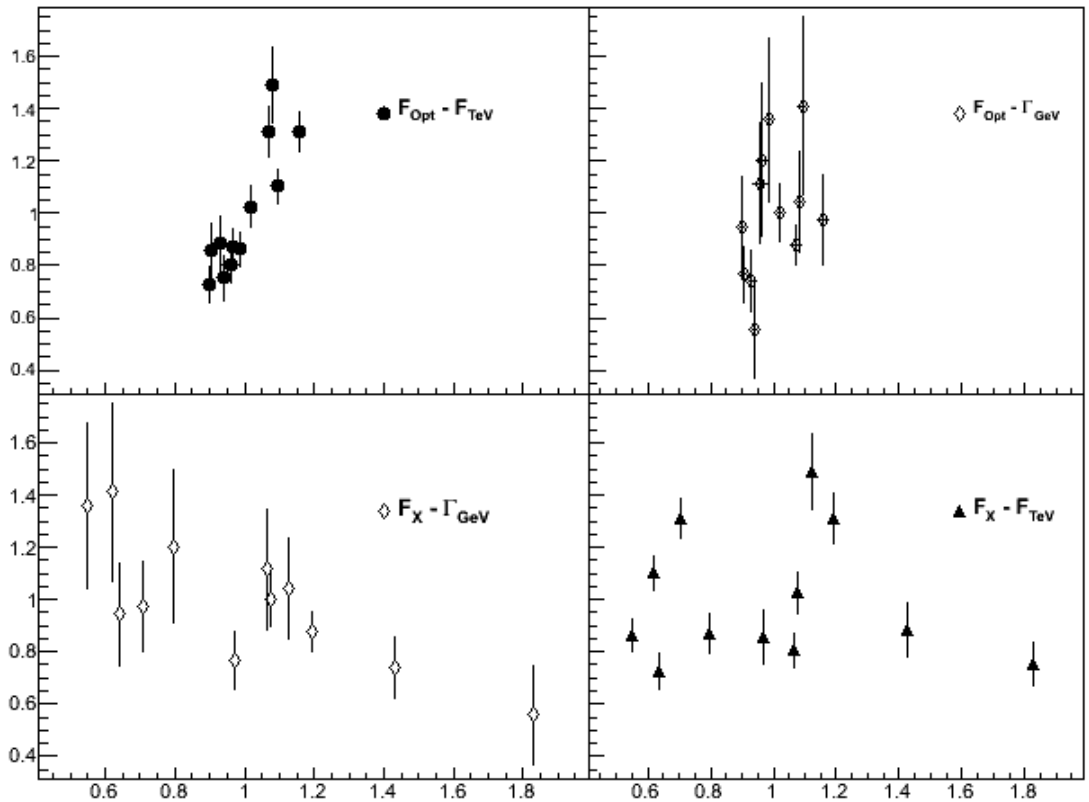
Flux alone might not indicate an ongoing TeV flare

summary of correlations

No correlation $F_X - F_{VHE}$,
$r = 0.12 \pm 0.10$

Optical and VHE fluxes are correlated $r = 0.77 - 0.86 \pm 0.09$

X-ray flux and HE index are correlated $r = -0.80 \pm 0.15$



Optical and VHE fluxes correlation : Is it real ?

Possible bias :

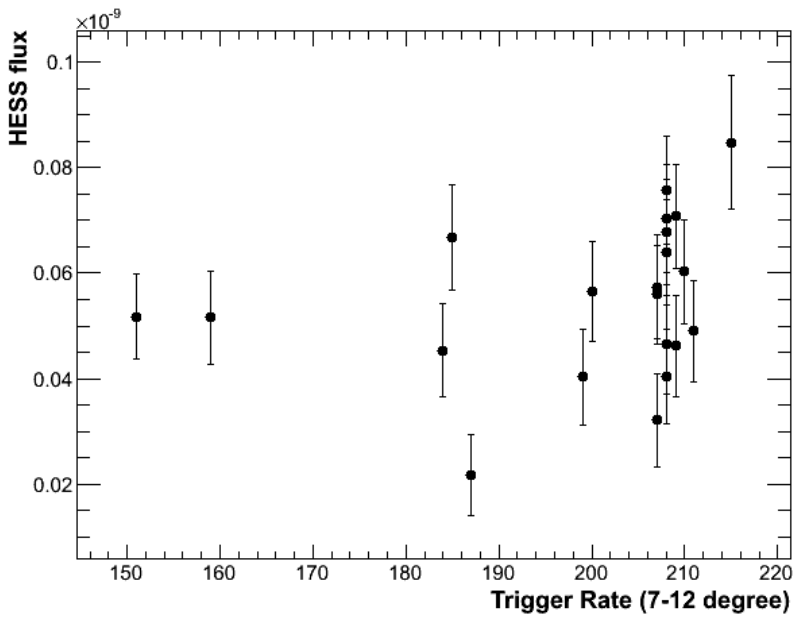
- ATOM and HESS share the same site : atmospheric effects
- Systematic errors are not taken into account

HESS trigger rate

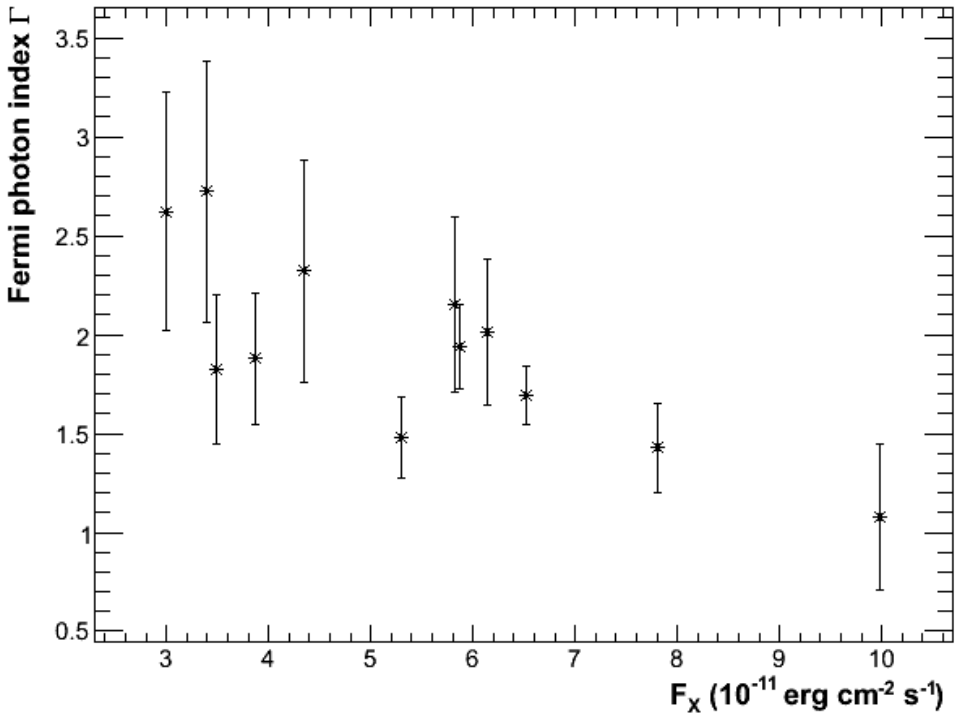
For each night, small zenith angle window (7-12 degree) : clearly no correlation

Reference stars are stable in the ATOM light curve

errors enhanced by 30% : the correlation is still here



$F_X - \Gamma_{HE}$ correlation



1-degree (p0) and 2-degree (p1) polynomial fit
p0 probability = 19%
p1 probability = 64%
F_{test} : 8.73, probability 1.4%

Conclusions

- SSC model described the time average SED.
- electrons that produce X-ray do not produce VHE (in this model) : no correlation
  not the same cooling regime

BUT :

- optical-VHE correlation, $\Delta\Gamma_{VHE}$: optical seed photons drive VHE variability
- no optical-HE correlation
- correlation $F_X - \Gamma_{HE}$

Those results challenge 1-zone SSC model : need complex multi-zone model