HESS Studies of Galactic and Extragalactic Jet Sources

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HESS Studies of Galactic and Extragalactic Jet Sources

Outlook

HESS

Galactic Jets:
- PWN
- GRBs

Extragalactic Jets:
- Sample
- EBL absorption
- Mrk 421, PKS 2155-304, M87
- GRBs

Stefan Wagner and HESS Collaboration : Challenges of relativistic jets, Cracow, 25.06.06

The H.E.S.S. experiment

MPI Kernphysik, Heidelberg
Humboldt Univ. Berlin
Ruhr-Univ. Bochum
Univ. Hamburg
Landessternwarte Heidelberg
Univ. Tübingen
Univ. Kiel
Univ. Erlangen-Nürnberg
Ecole Polytechnique, Palaiseau
College de France, Paris
Univ. Paris VI-VII
CEA Saclay
CESR Toulouse
Univ. Montpellier
LAOG Grenoble
Paris Observatory
Durham Univ.
Dublin Inst. for Adv. Studies
Charles Univ., Prague
Yerewan Physics Inst.
Univ. Potchefstroom
Univ. of Namibia, Windhoek

4 Telescopes operational since December 2003

100 m² mirror area each

in Namibia (-23 latitude, 1800m altitude)

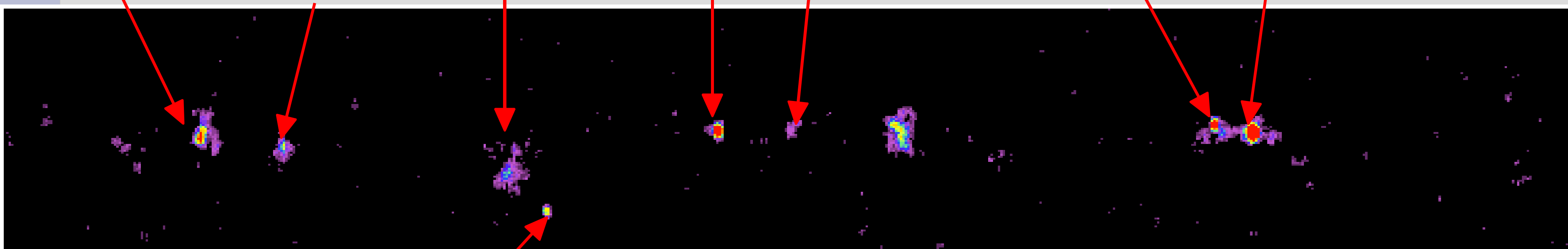
Energy threshold: 100 GeV

Single shower resolution: 0.1° , FoV: 5°

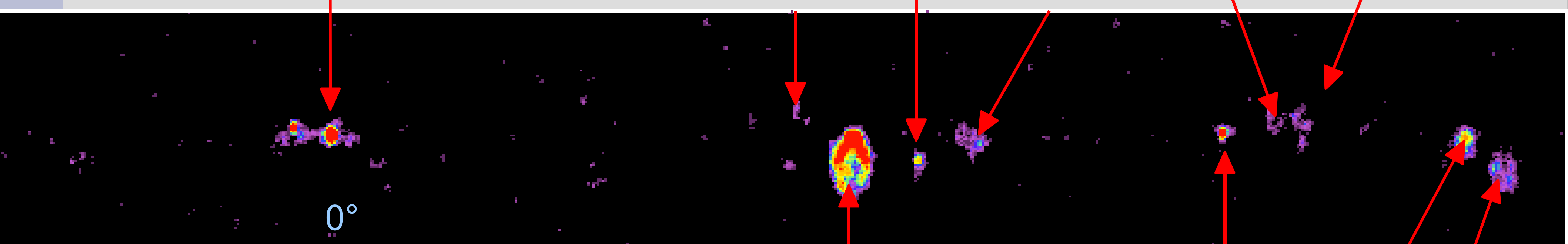
3 “sister“ experiments:

CANGAROO (2000+), similar latitude
MAGIC (2005+), similar longitude
VERITAS (2006+), similar technology

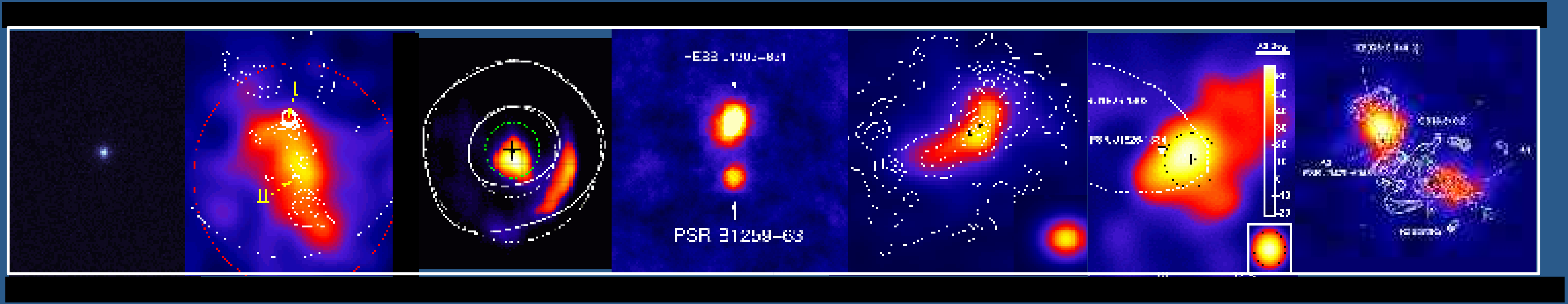
The High-Energy Galaxy



18 significant sources, 16 newly discovered (Aharonian et al., HESS collaboration, 2006)



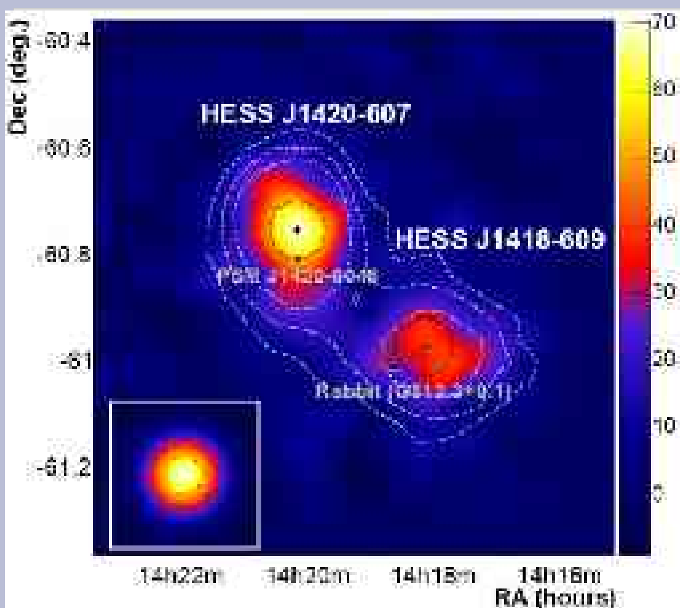
Pulsar Wind Nebulae

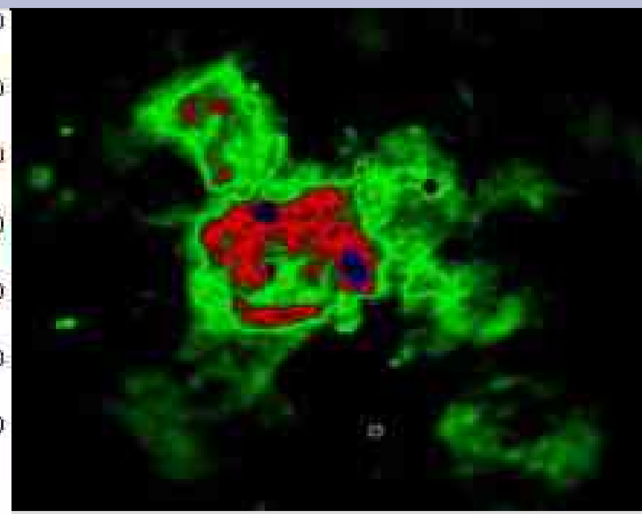


Eight known TeV PWNe: Whipple (1989): Crab;

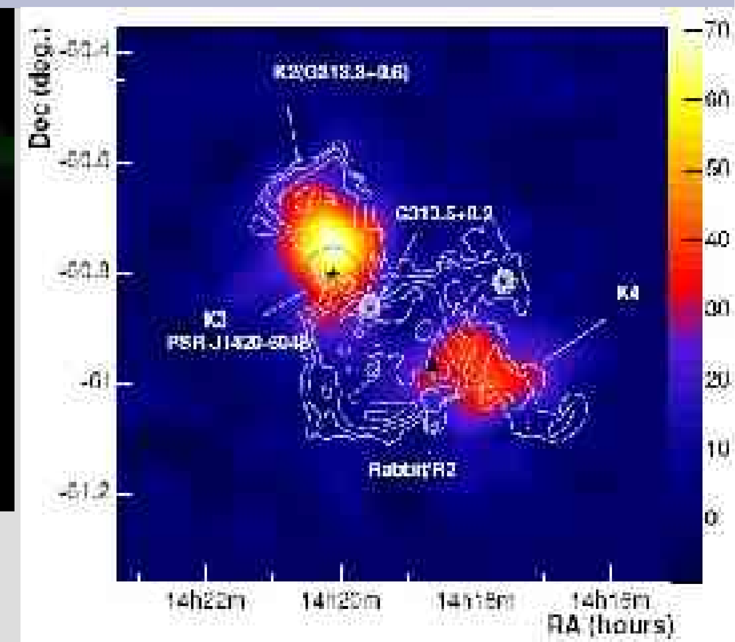
HESS ('04,'05): Vela X, G09+01, PSRB 1259-63, MSH 15-52, PSR B1823-13,PSR J1420-6048, The Rabbit, HESSJ1825-137

The most recent addition(s)





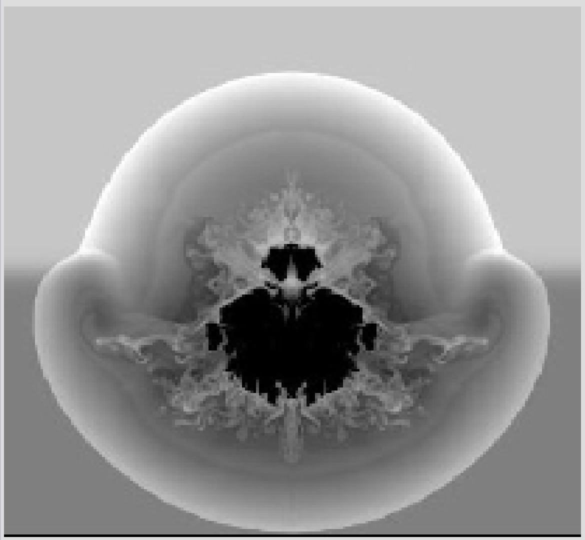
20 cm (Roberts et al., 1999)



Two nonthermal wings of the “Kookaburra“ complex.
Most likely association with two PWNe:
K3/PSR J1420-6048 (68.2ms, log E/erg/s = 37.0), 6pc offset
K4/ 'The Rabbit' (G313+0.1) with R2 (108ms, log E/erg/s = 37.1)
Aharonian et al. (HESS collaboration) astro-ph/0606311

Pulsar Wind Nebulae

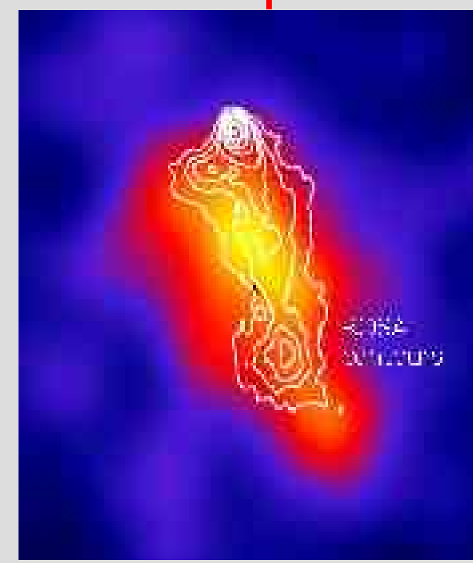
The first population of Galactic VHE sources.
TeV emission from nebulae of energetic young pulsars is ubiquitous



Blondin et al., 2001

A large fraction is asymmetric

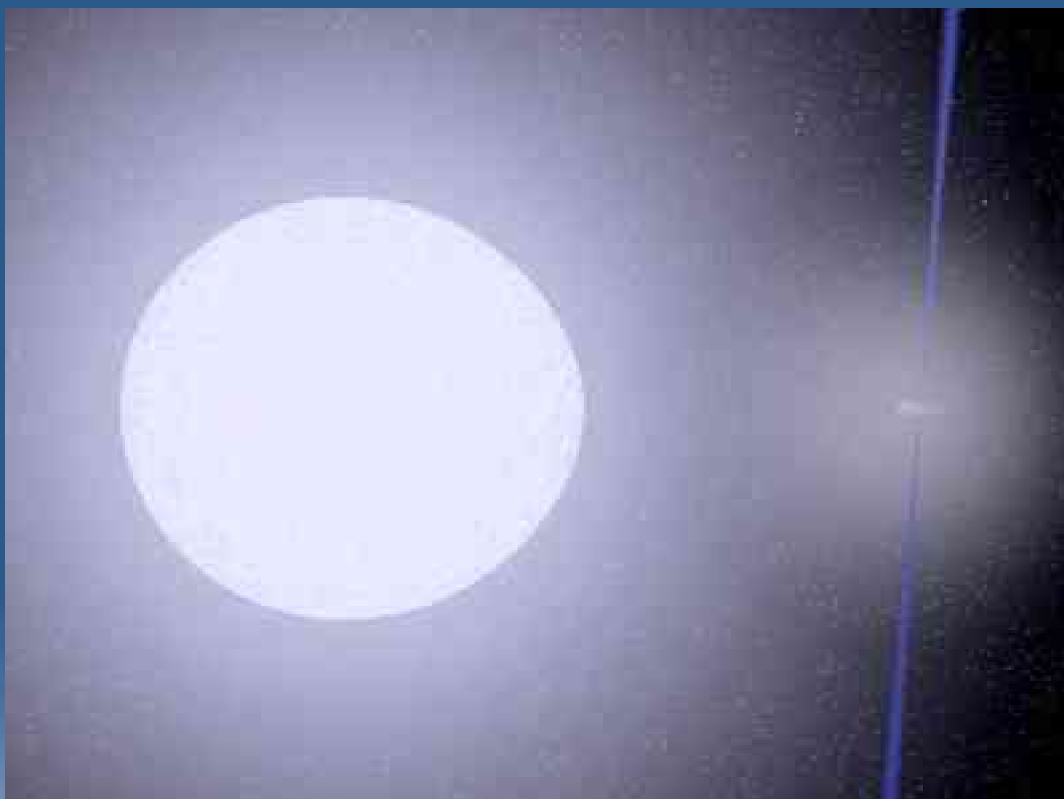
Energy-dependent morphology



e.g. HESS J 1825-137 (astro-ph 0510394): IC/synch. cooling

All X-ray / VHE sources: IC scenario favoured
Combination gives spatial and spectral distribution of e and B

Gamma-Ray Binaries (GBs)

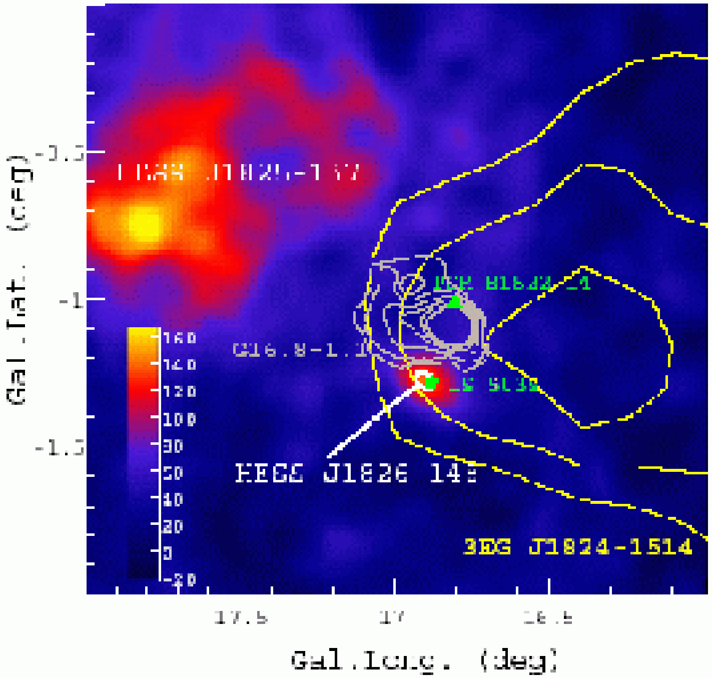


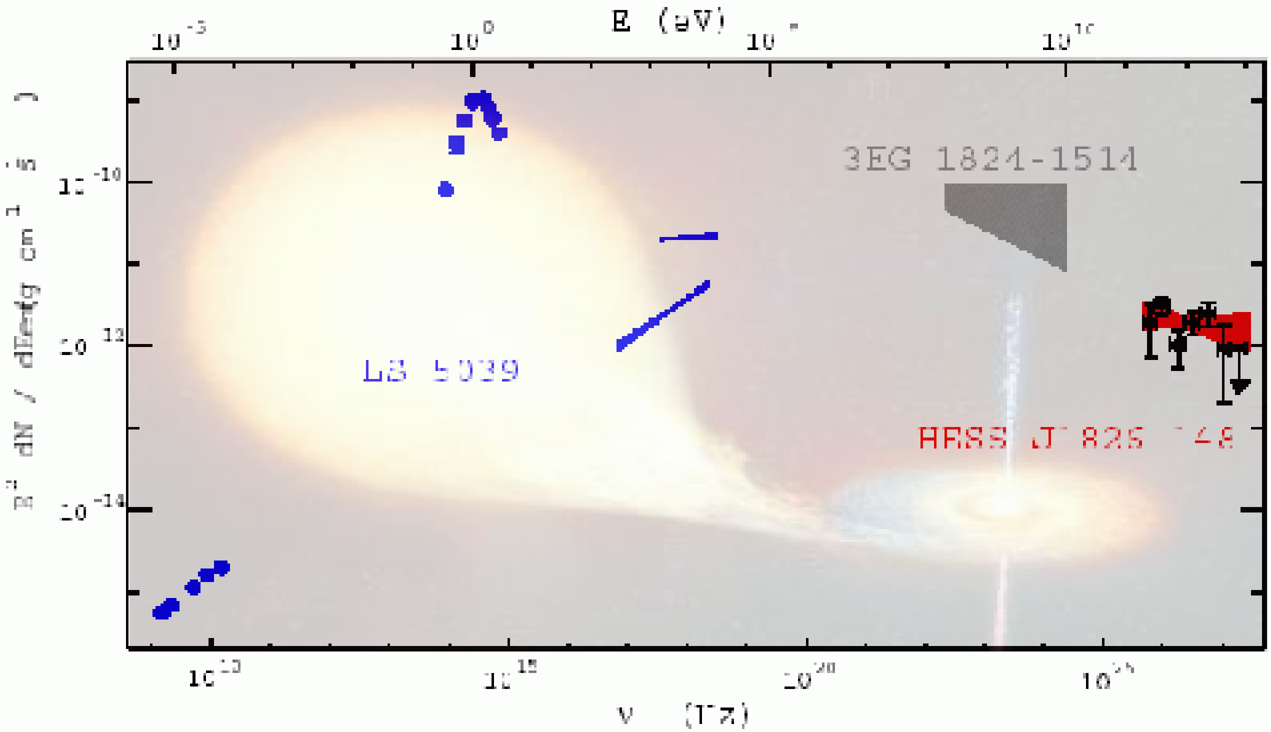
PSR B 1259-63
HESS (2004)

LS5039
HESS (2005)

LS I 61+303
MAGIC (2006)

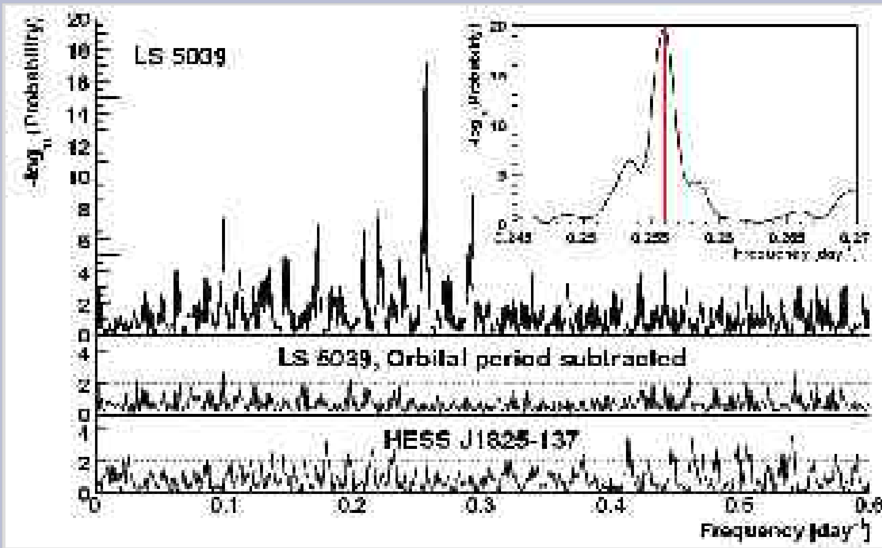
Microquasars/Binaries





LS 5039: compact object and massive companion
milli-arcsec radio jets, high U_{rad}, cascading VHE emission
Acceleration mechanisms: Shocks in wind ? Jet?, Accretion?,
Radiation mechanisms: pp or IC?

Orbital modulation in LS 5039



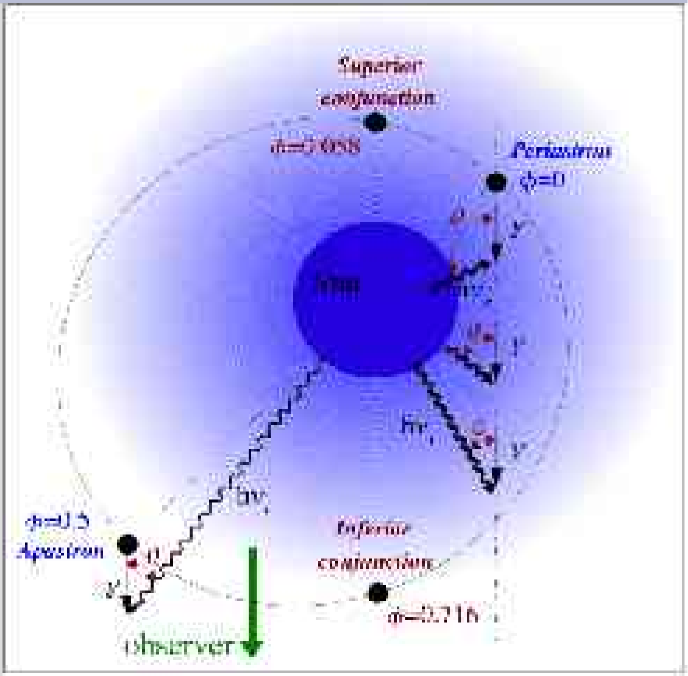
Lomb-Scargle periodogram

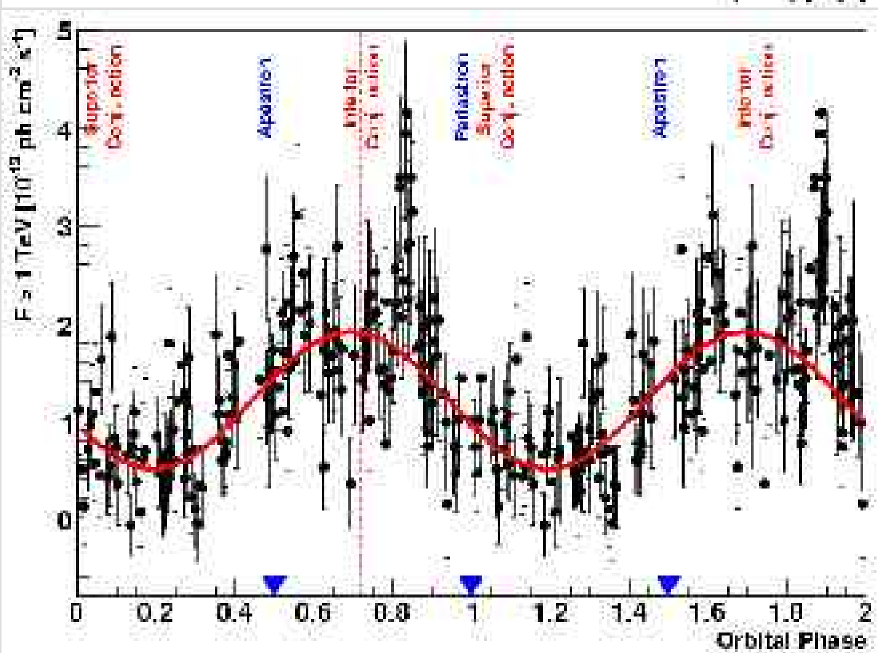
max: P~10^-20

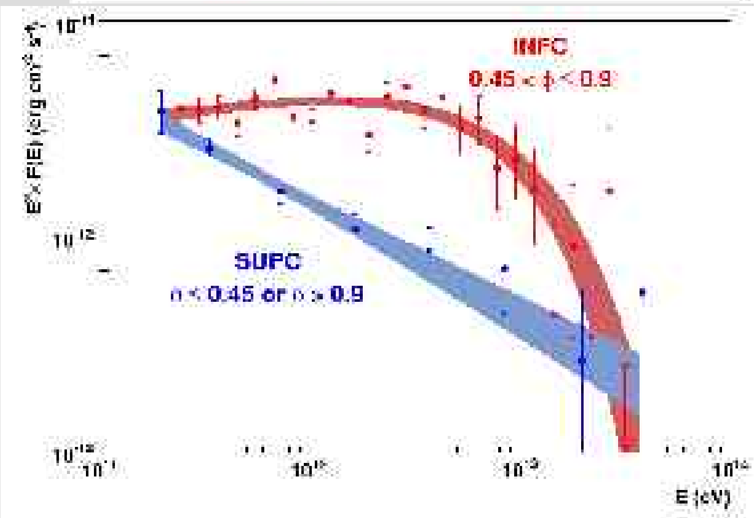
P=3.907d vs.

P_{RV}=3.9060d

Aharonian et al.
(HESS collaboration)
astro-ph/0607286

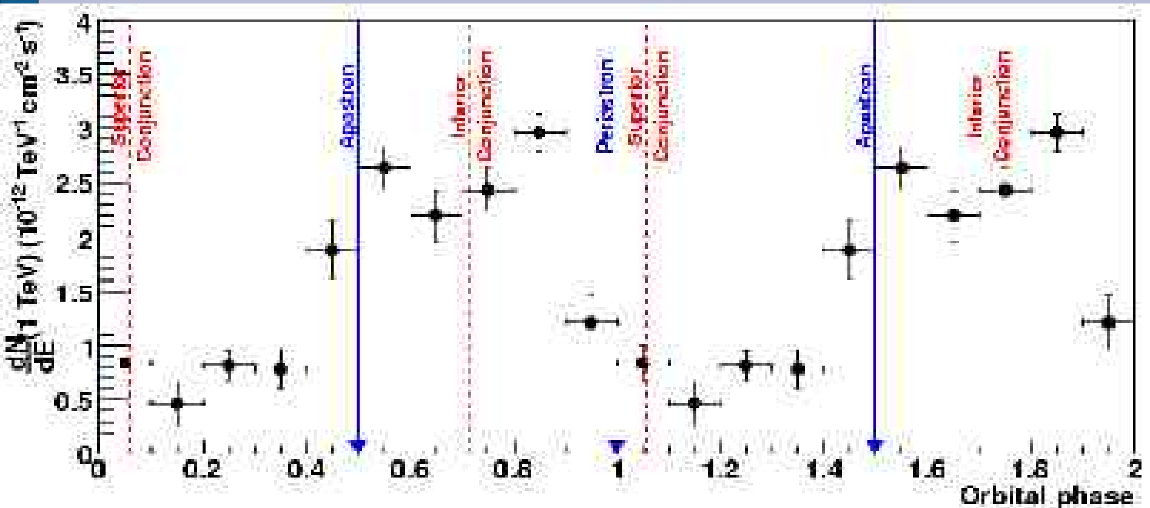






Lightcurves

LS 5039 | LS I 61+303

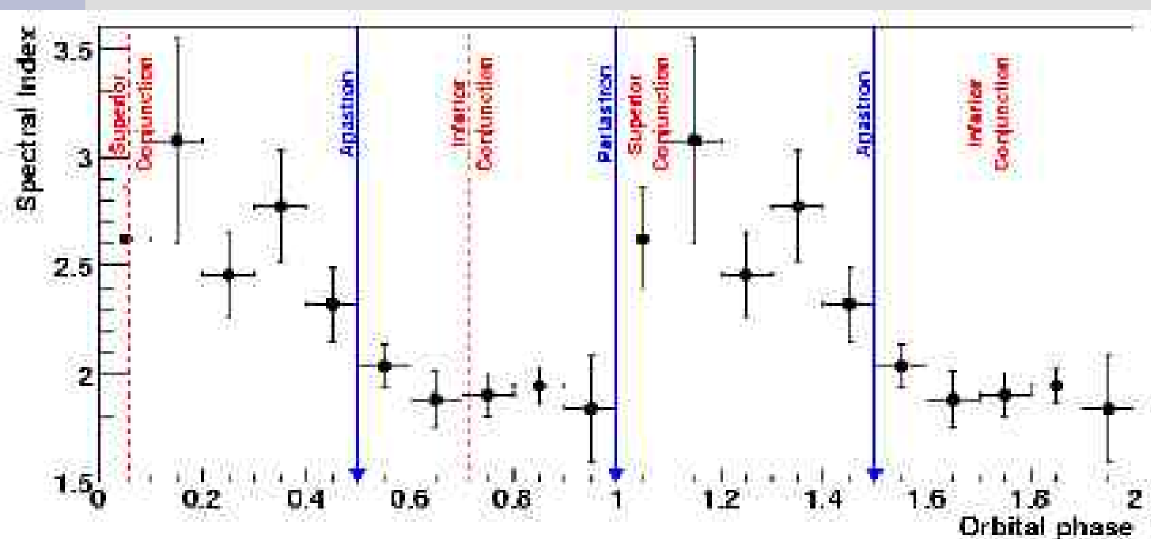


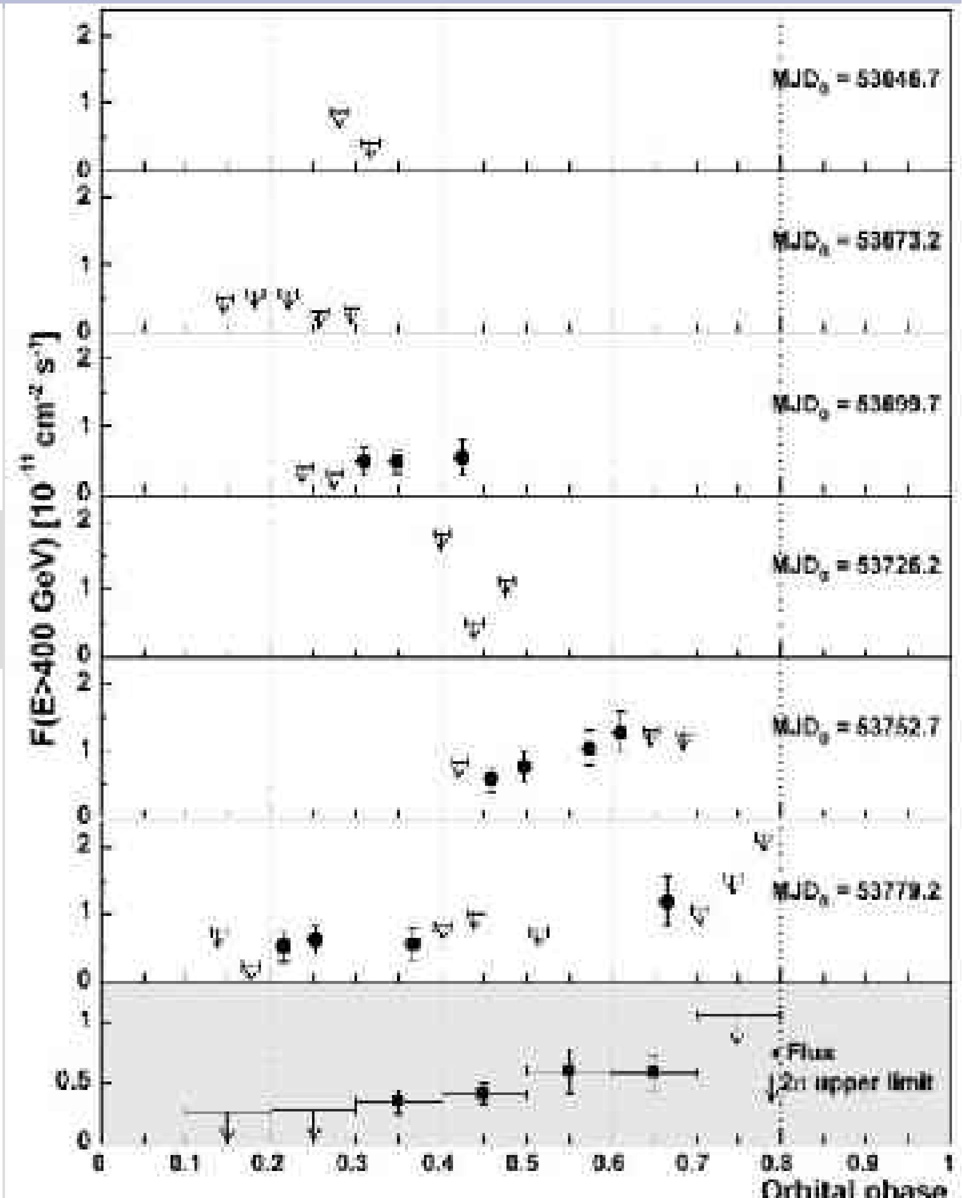
Aharonian et al. (H.E.S.S. collaboration)

astro-ph/0607192

Albert et al.

astro-ph/0605548





Blazars – the sample

Source	z		
Mrk 421	0.031	-2.1	variable
Mrk 501	0.033	-1.9	variable
2344+514	0.041	-2.0	
1959+650	0.047	-2.6	
1426+428	0.129	-2.2	
2005-489	0.071	-4.0	
2155-304	0.116	-3.3	variable
2356-309	0.165	-3.1	
1101-232	0.186	-2.8	
1553+113	?	-4.0	
1218+304	0.182	-3.0	

EBL: a problem or a promise?

-radiation is absorbed by NIR photons

Opacity within sources is low, but see e.g. Stawarz et al., astro-ph/0605721 for observable effects.

Correction requires knowledge on EBL (, z) and cosmology.

Conversely, both can be determined if intrinsic TeV spectra are predictable.

Measuring EBL in situ with VHE

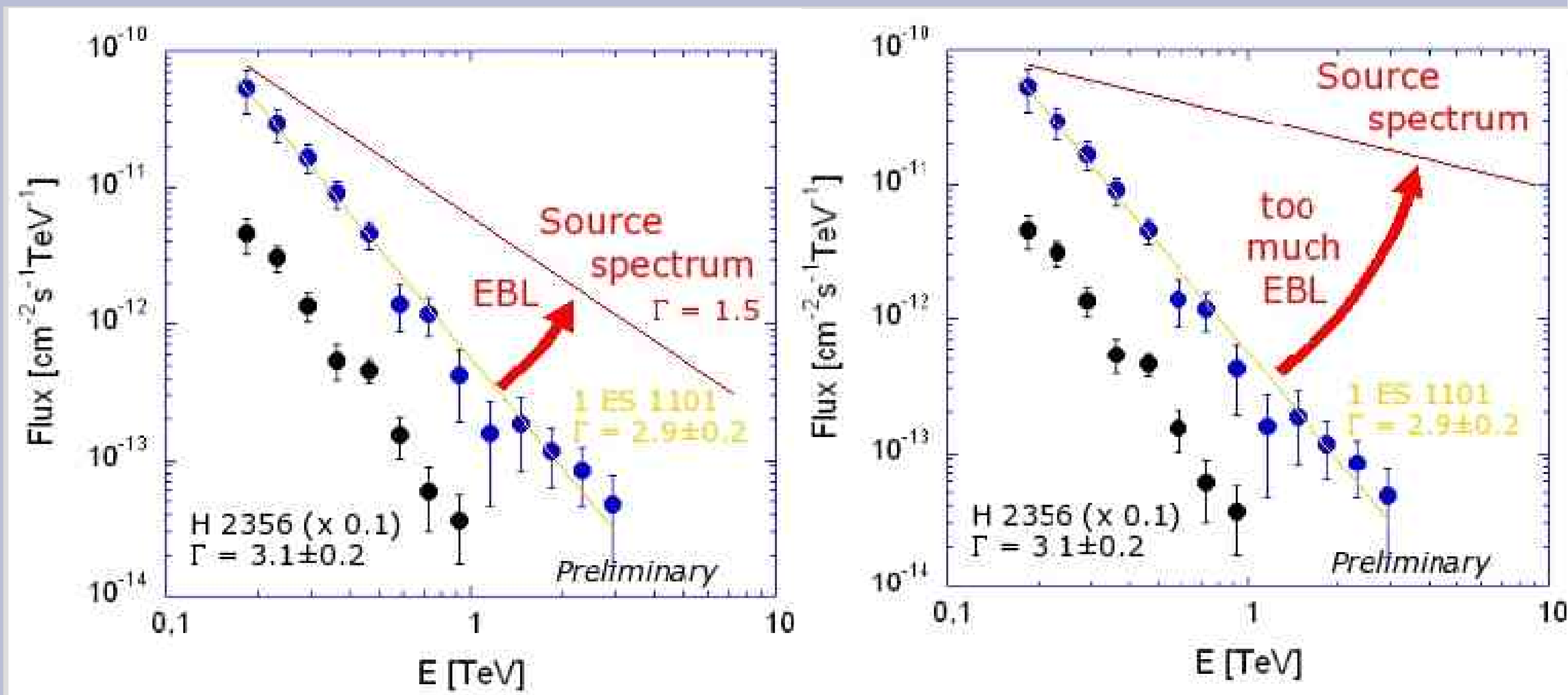
Procedure: Predict intrinsic spectrum (using SED), measure observed spectrum, derive , compute n .

Predictions involve $_{min}$, $_{max}$, B, ⦸, $\mathcal{D}$

Problems: Spectral coverage, variability of sources, complex sources, emission mechanisms

Conservative approach:
Assume EBL shape, derive upper limit from spectral model
Diffusive Acceleration, $p<1.5$ ($\log n \sim p \log E$)

Constraints on diffuse EBL



shock acceleration: s=1.5 Protons: =1.5

IC: > 1.5 unless no radiative cooling and IC fully in Thomson limit [= (s+1)/2 =1.25]

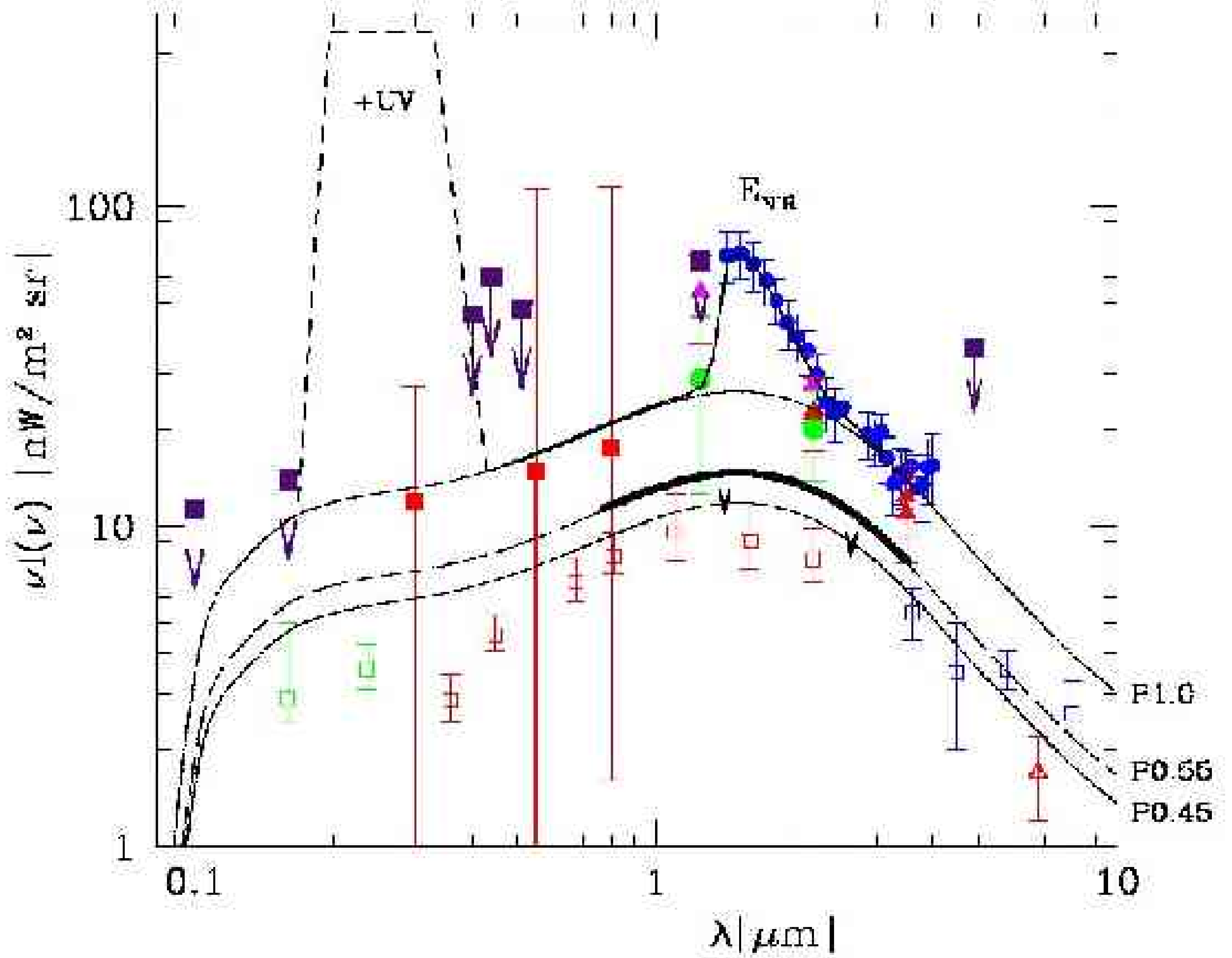
A model of the diffuse EBL

Data and upper limits compiled by Hauser

Lower limits (counts) from HST, Spitzer, ISO

P1.0 SAM by Primack
P0.55 and P0.45 are multiplicative versions thereof.

Absorption of 1101-232

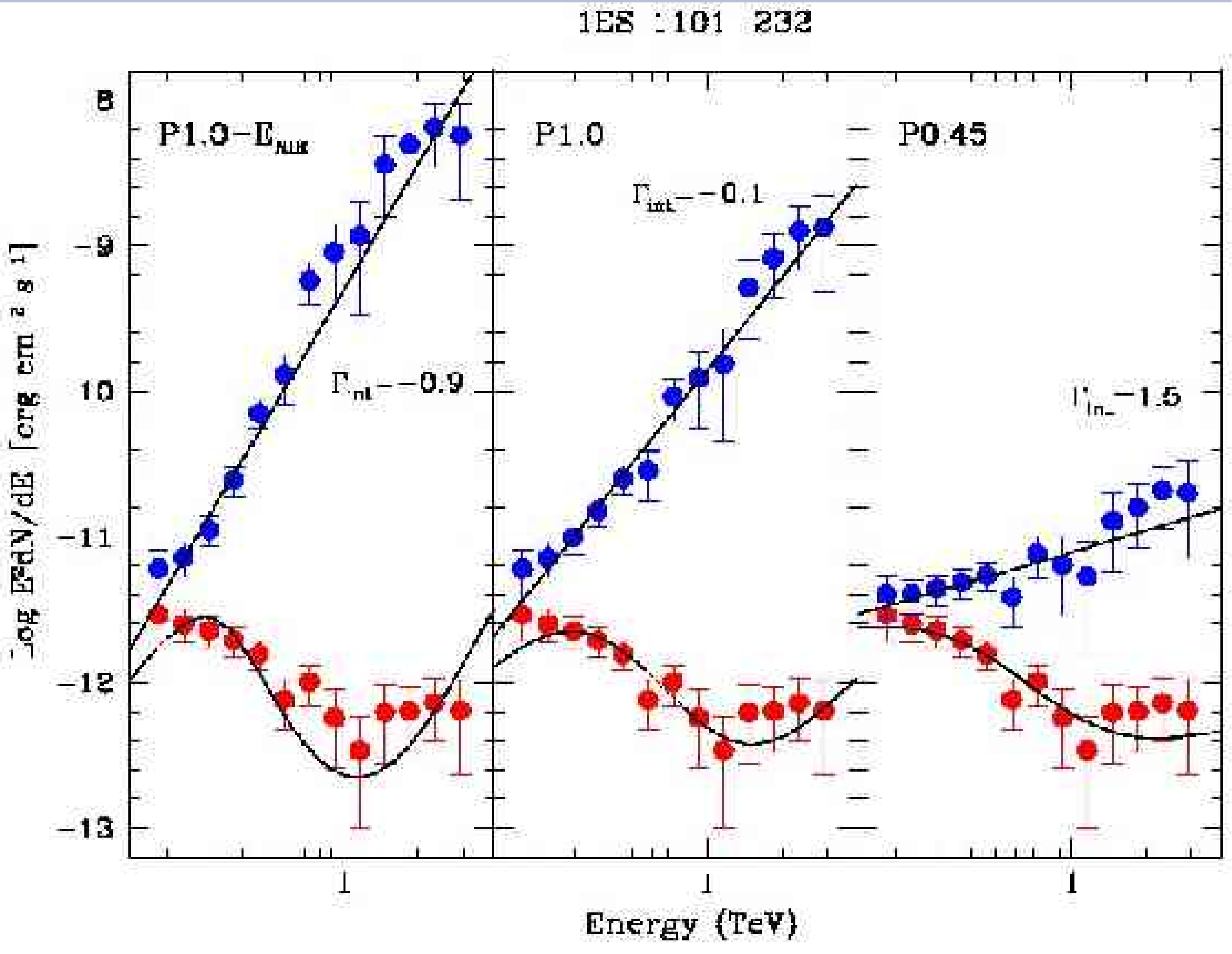


Constraints on intrinsic spectra

Measured and **computed intrinsic** spectra of 1101-232

Only an EBL level of 0.45 P1.0 = “P0.45“ is compatible with spectral constraints

Aharonian et al.
(HESS collaboration),
Nature, 2006



Why TeV?

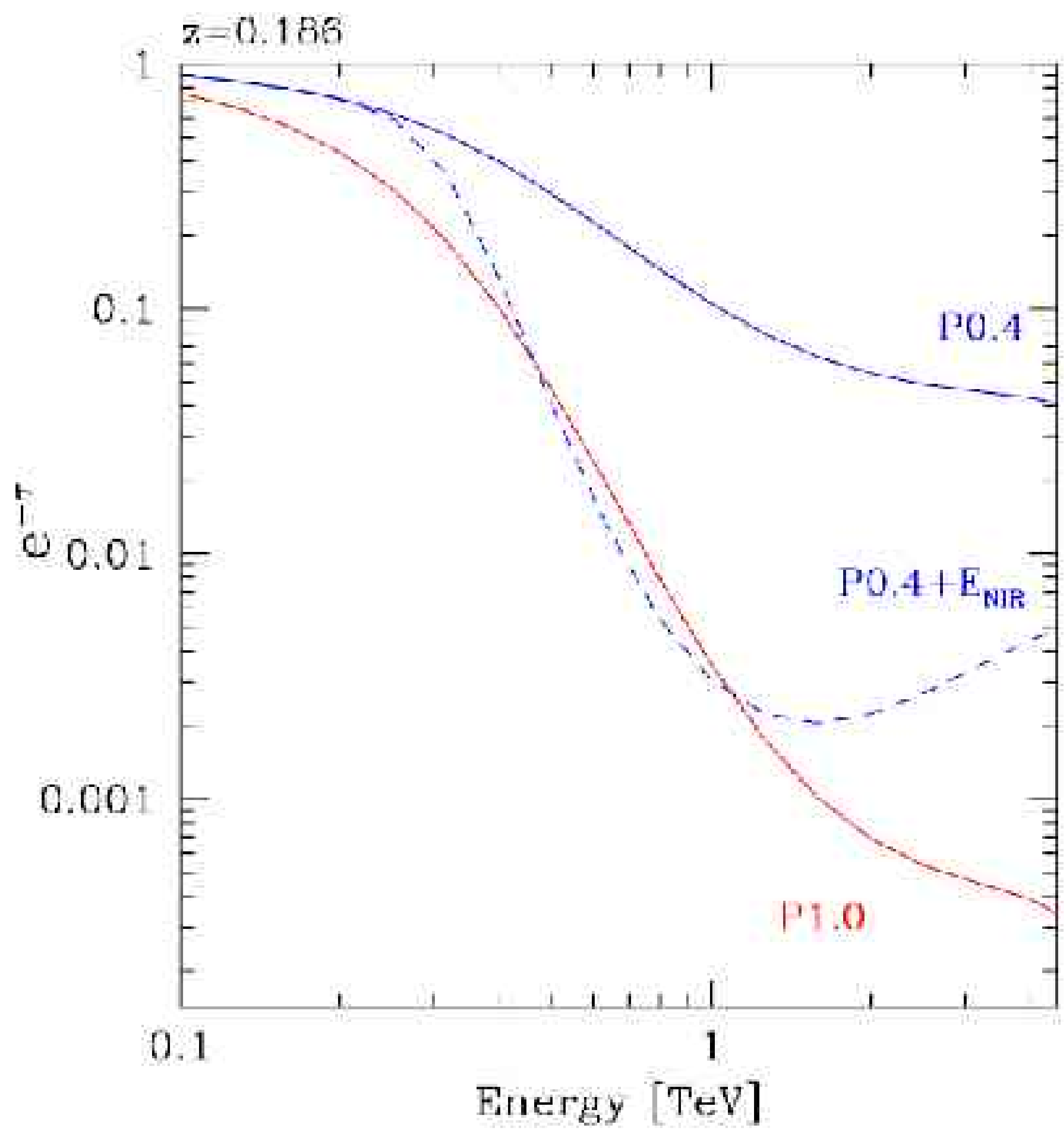
Absorption is very sensitive:

60% changes cannot be probed otherwise.

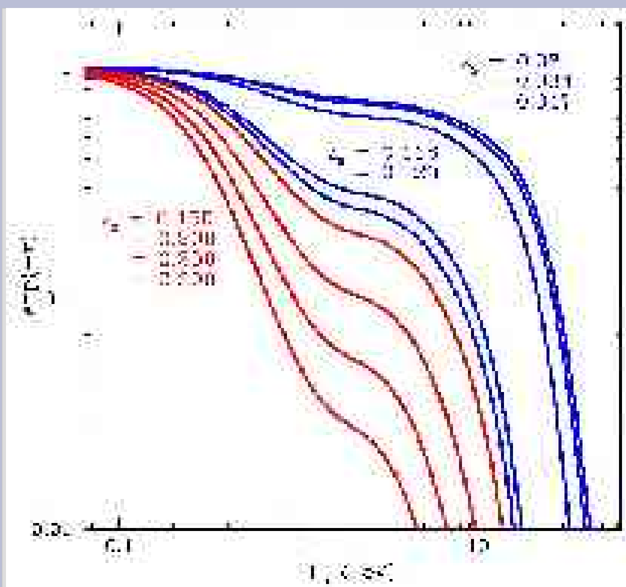
No problems with cosmic variance

in-situ capabilities allow studies of EBL evolution.

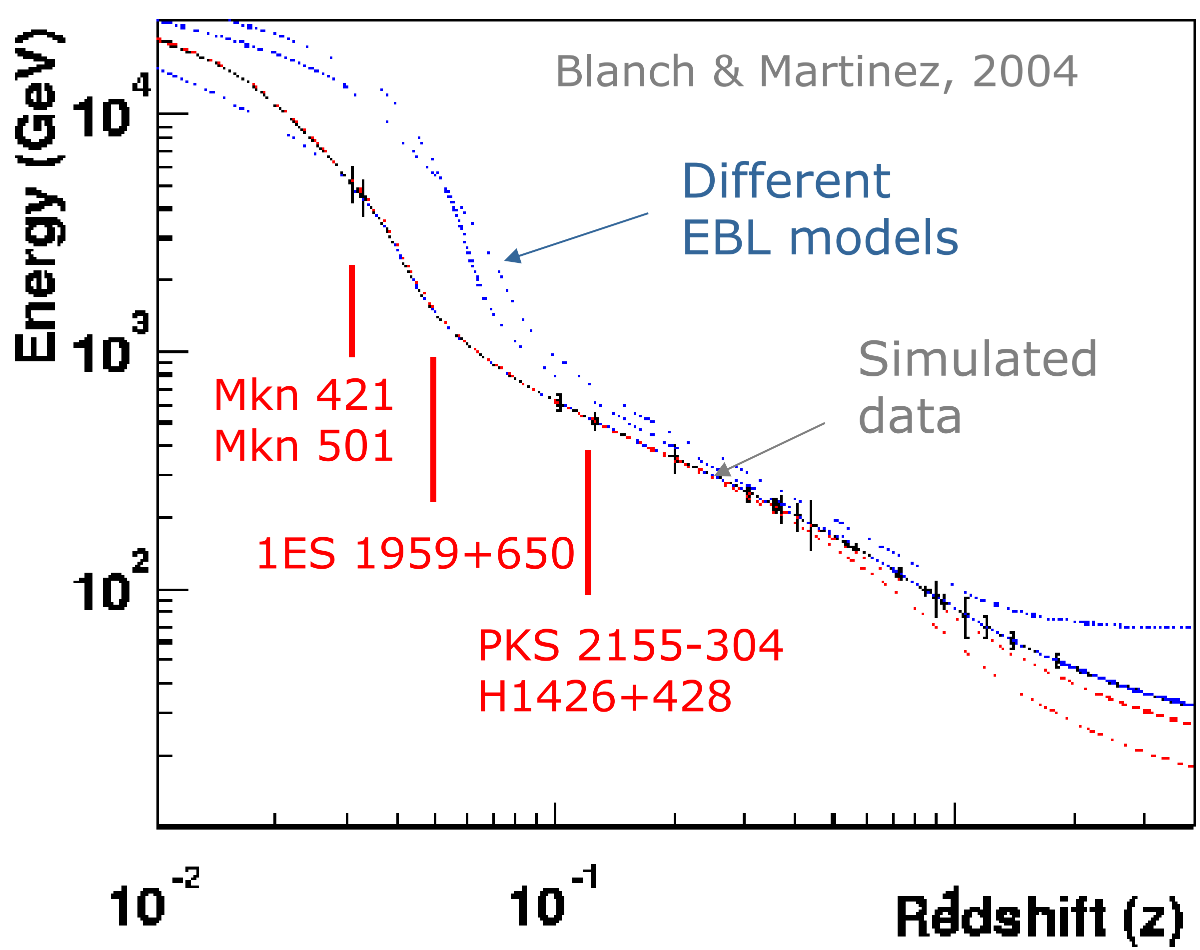
Aharonian et al.
(HESS collaboration),
Nature, 2006



Application I Cosmology



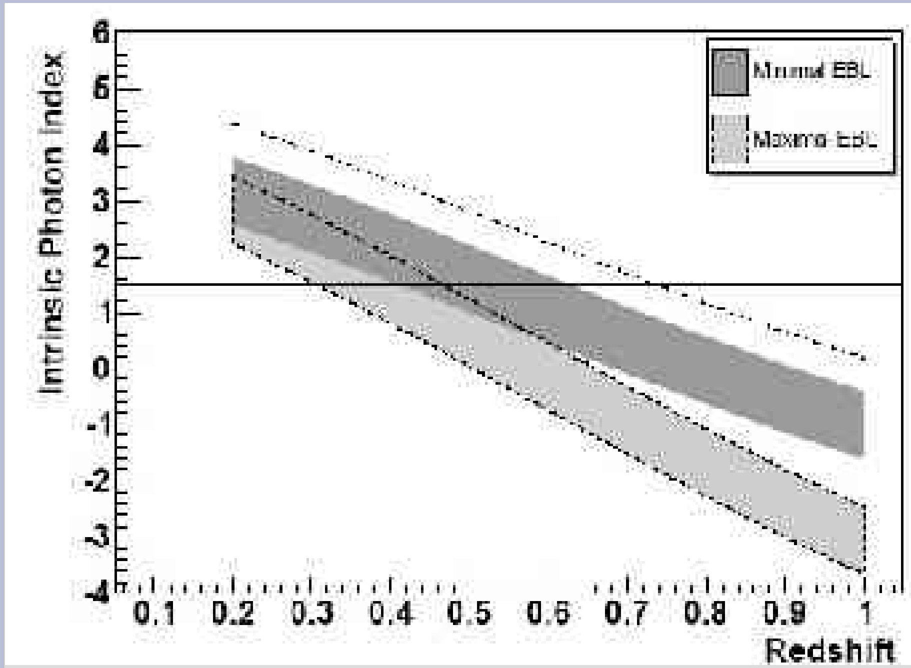
We used to assume an EBL level ~p1.0



Now we will be able to determine the EBL in situ out to z~2(?)

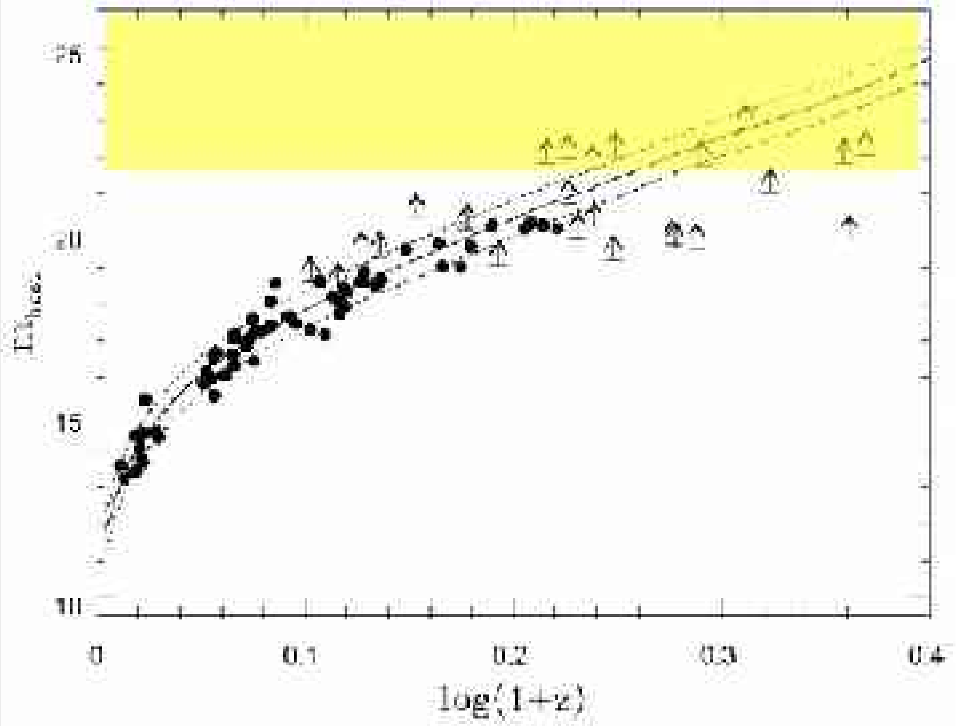
TeV Cosmology, SF history

Application II: Redshift (1553+113)



PG 1553+113 has no measured redshift despite many hours on 8m class telescopes. The spectral slope (-4 HESS, -4.2 MAGIC) can be used to infer a red-shift z<0.74; HESS (<0.78; MAGIC)

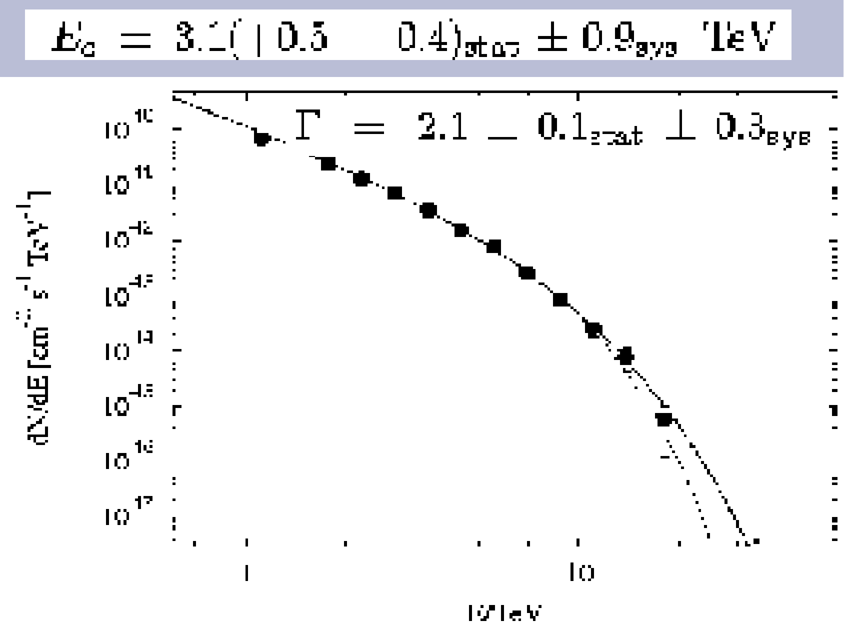
The only other constraint on the redshift of this source is due to the absence of a host galaxy (z>0.78; Sbarufati et al., 2005)

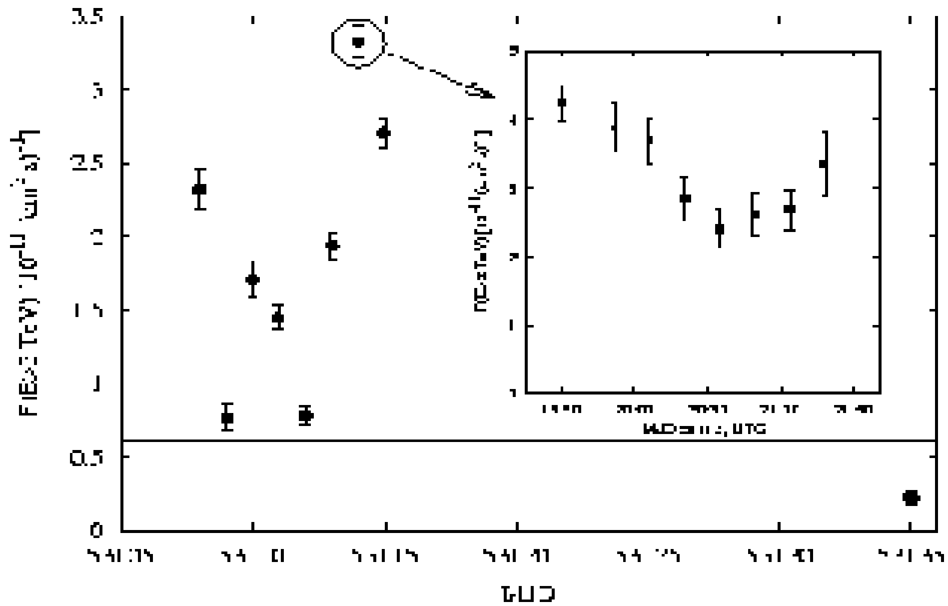


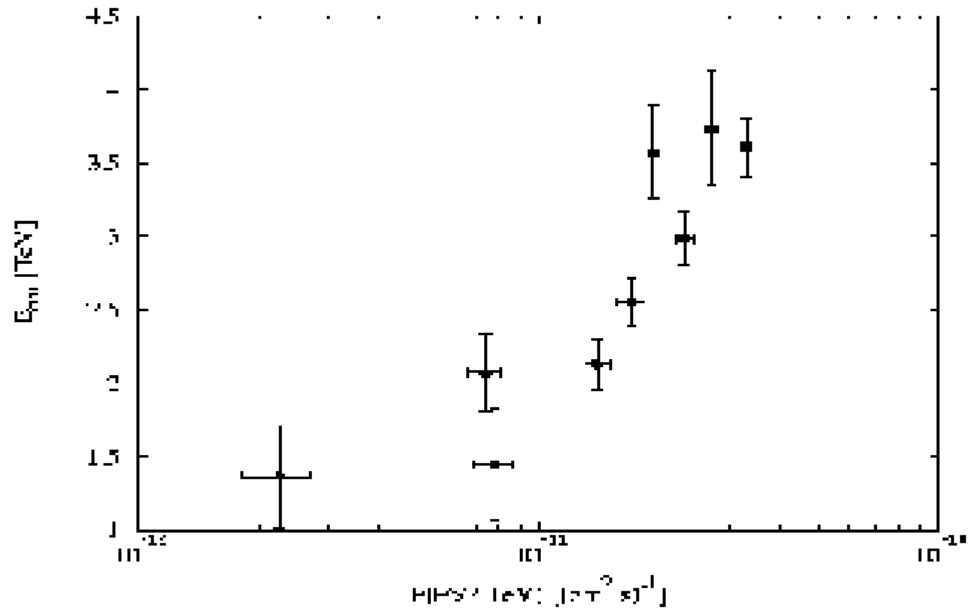
Application III: local AGN (Mkn 421)

Cut-off not due to absorption

Variability on all time-scales.
Power-law index and cut-off correlated in nightly averages
Flux correlates with cut-off energy





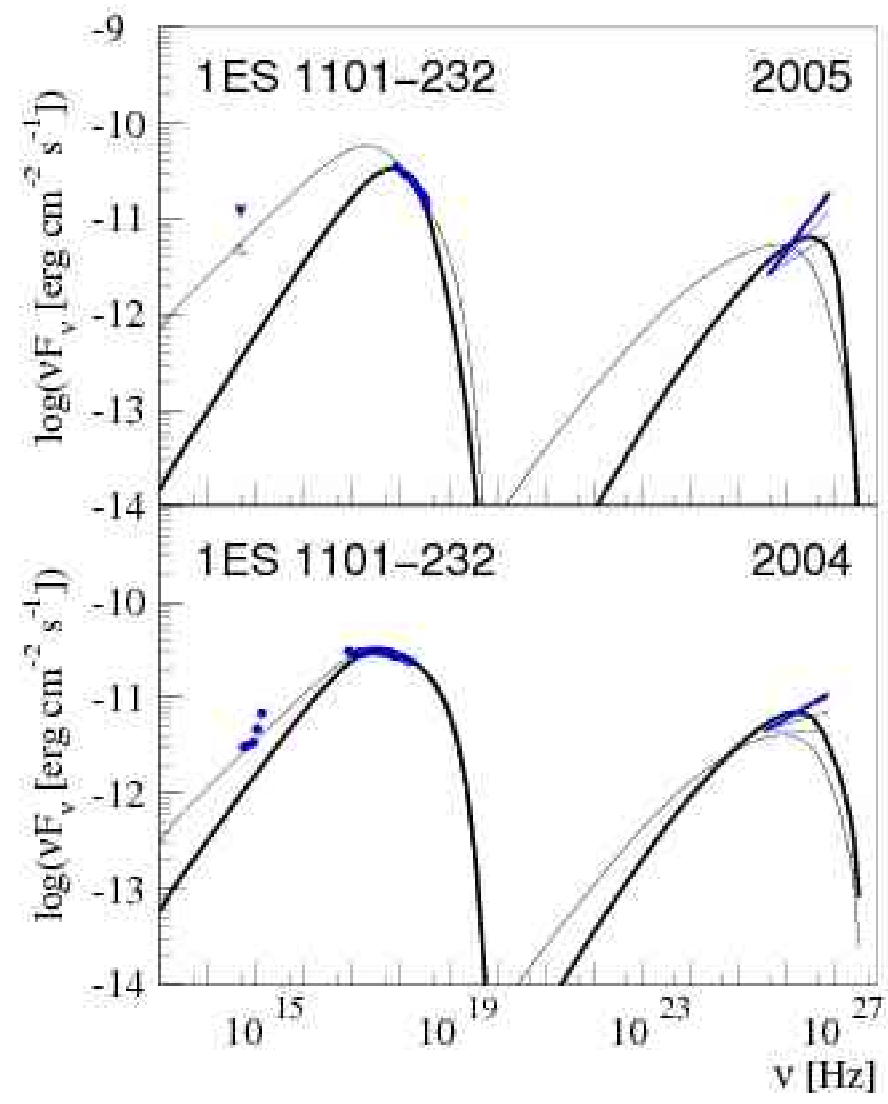


1ES 1101-232

1ES 1101-232: **(PRELIMINARY)**

Simultaneous SEDs during two campaigns, involving
TeV (HESS),
X-Ray (RXTE, XMM), and
optical/UV (ROTSE, OM) data

SED (corrected for minimum absorption, Aharonian et al.)
Highest energy   -ray maxiumum
different synchrotron SEDs

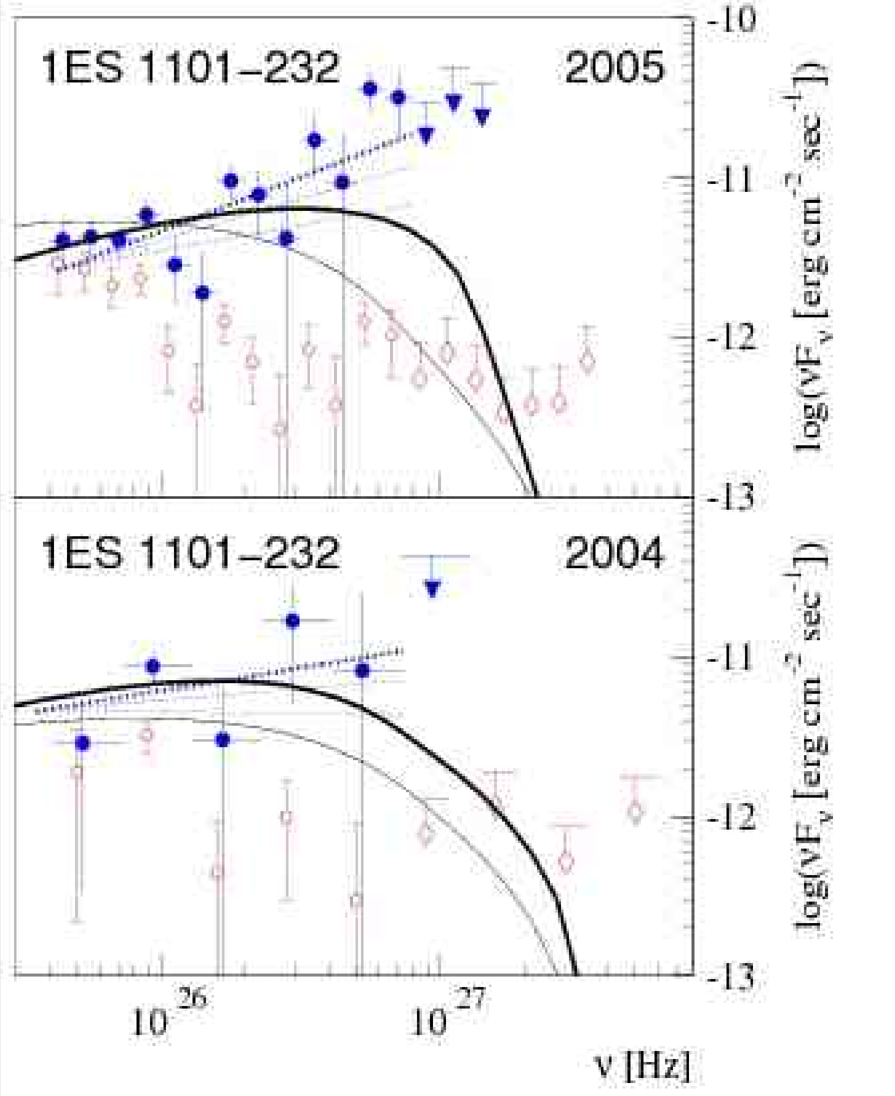


1ES 1101-232

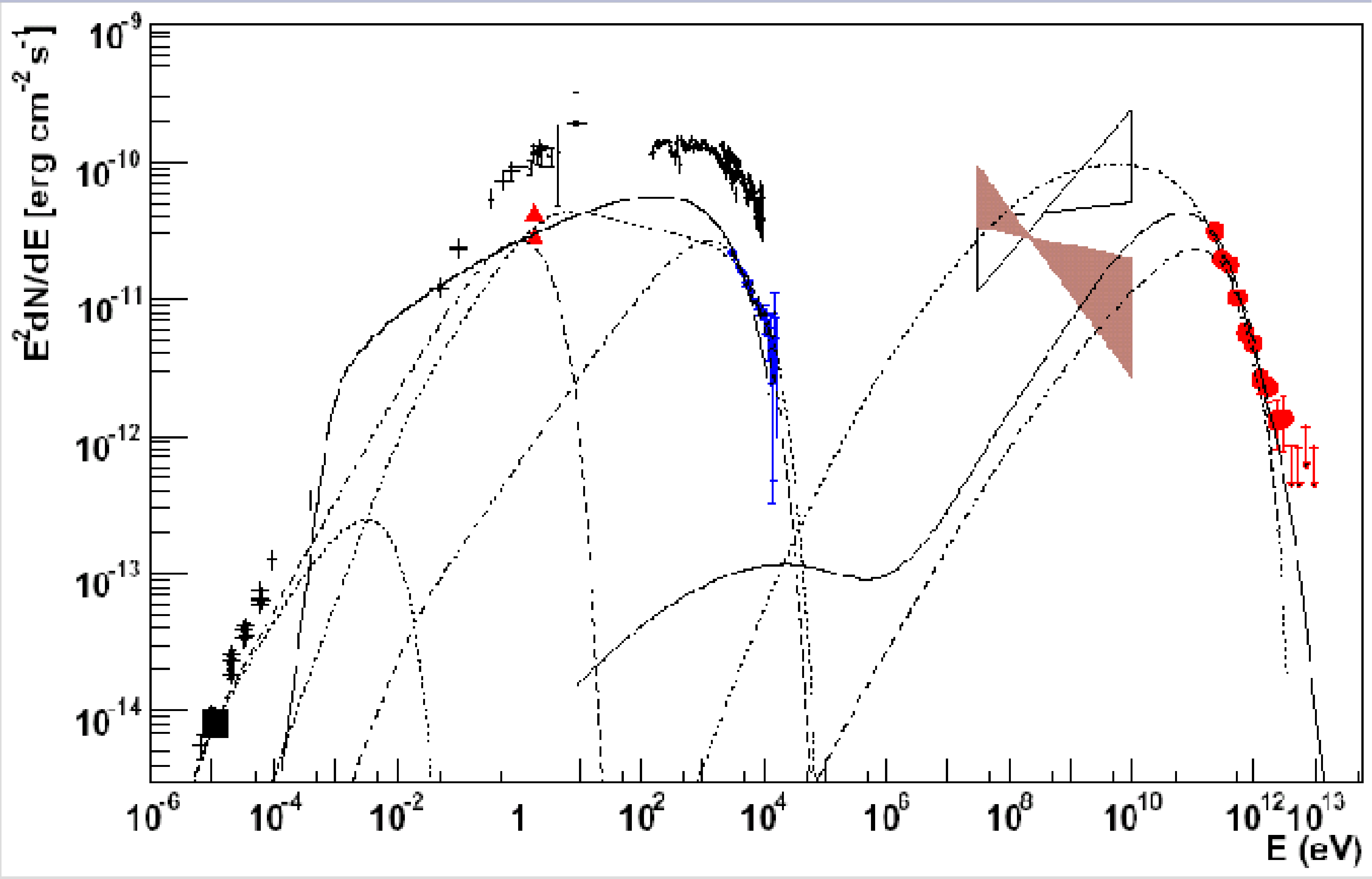
1ES 1101-232: **(PRELIMINARY)**

TeV spectra are extremely hard (even for minimum amount of EBL absorption)

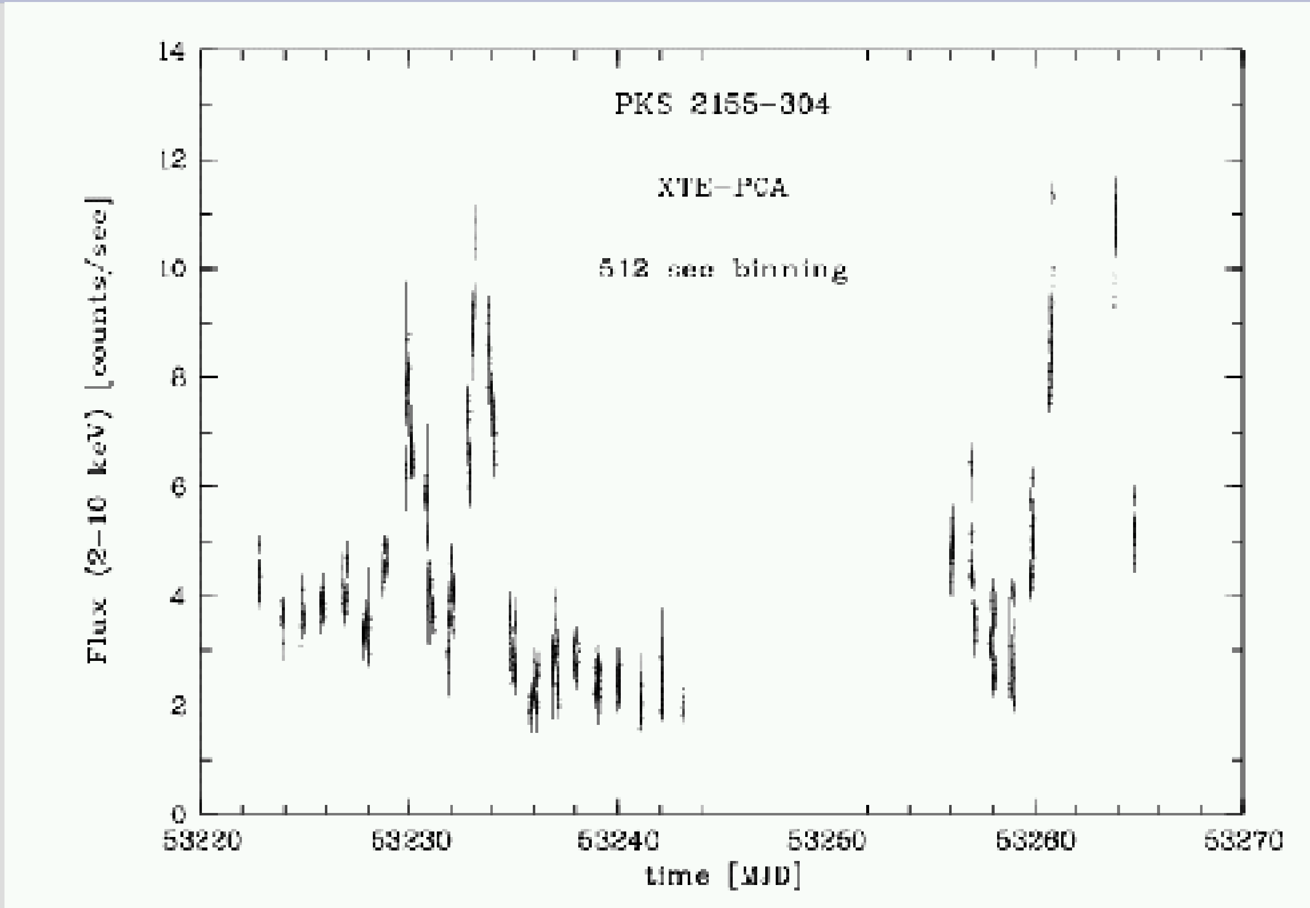
One-zone leptonic emission models are challenged



Modelling PKS 2155-304



PKS 2155-304



Multifrequency campaign

HESS, RXTE, several optical, Spitzer, JCMT, Nancay

longest coverage in all bands

synchrotron properties (X-ray spectral indices, variabiliy time-scales) within range of earlier studies of PKS 2155-304 (Brinkmann et al., Urry et al., Tanihata et al. (1992-2000)

Gamma-Ray Bursts

12 GRB (afterglow) observations,
4 with known redshifts ($z > 1$), upper limits (5-10% Crab)
well below model-extrapolations of EGRET-GRBs

GRB-Remnants?
Atoyan et al. (astro-ph/0509615) suggest HESS J1303-631
might be a 0.1 Myr, 10 kpc distant GRBR

models fit SED constraints but not energy-dependent
extension (PRELIMINARY)

Summary

From 2 years of 4-telescope data

35 H.E.S.S. Sources

broad application to particle acceleration
(Galactic Centre, Diffuse Emission, SNR, SB)

and Winds/Jets (PWNe, GBs, Blazars, GRBs)

...posing interesting challenges

Challenges

Ubiquity of (asymmetric) TeV-bright PWNe

Origin of TeV emission in Gamma Binaries

Prediction of intrinsic Blazar-spectra to constrain/measure the EBL

Radiation Processes in Blazars
(SED diversity, variability characteristics,
(cut-offs, peak energies, “quiescent levels“)

Gamma-emission from extended jets

Prediction of VHE characteristics of GRBs

HESS II

An additional large (28m diameter equivalent) telescope in the centre of the array

Aims: more² light (lower energies)