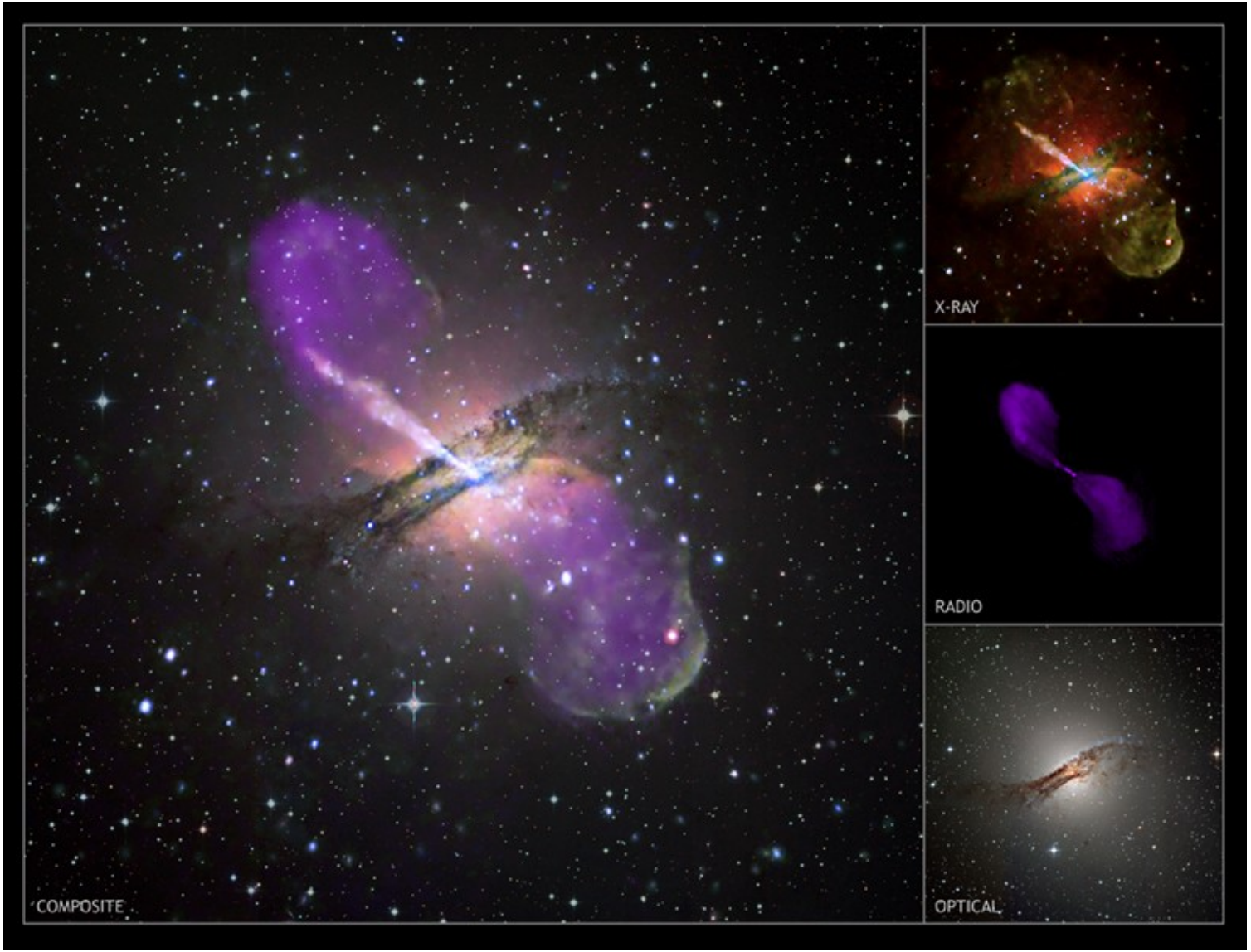
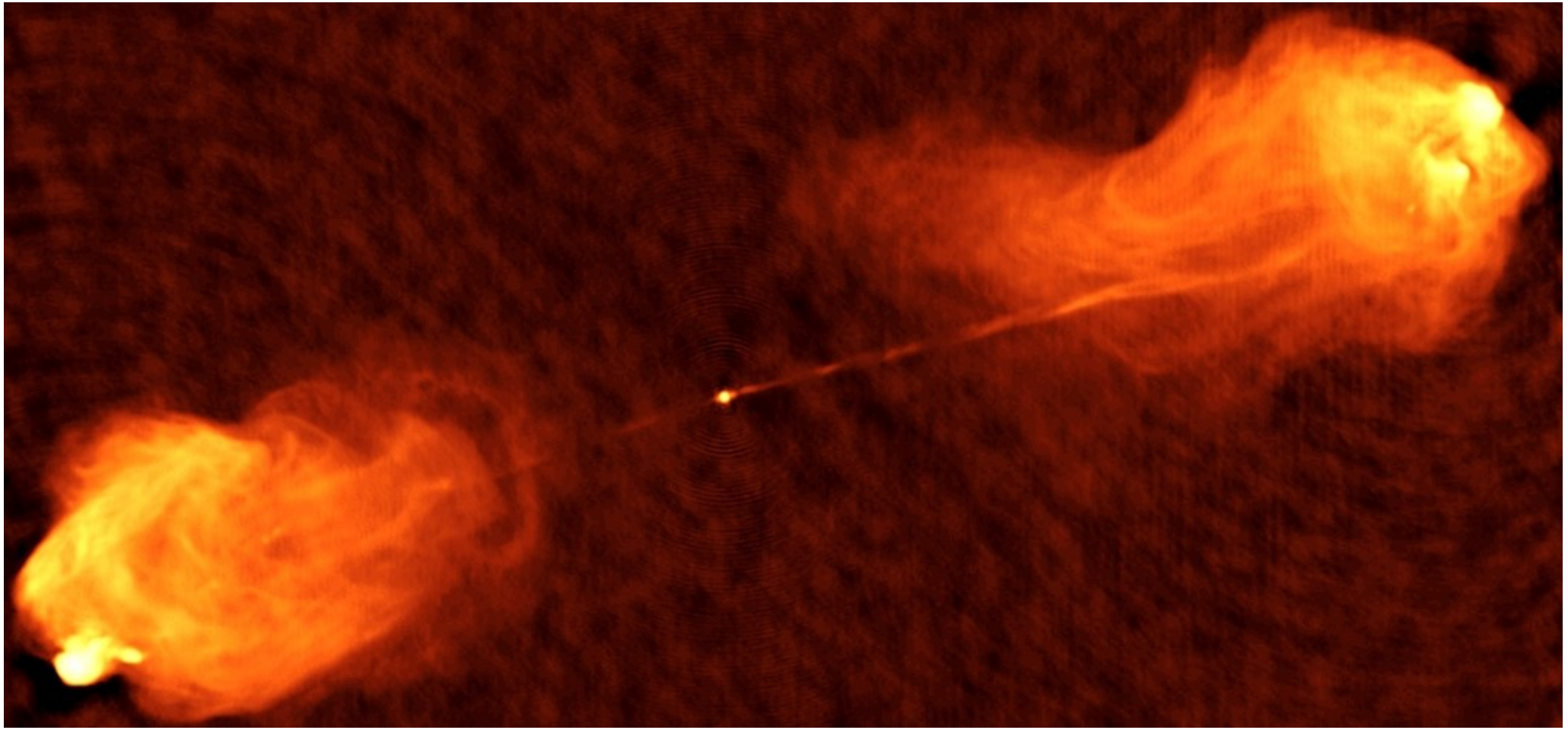
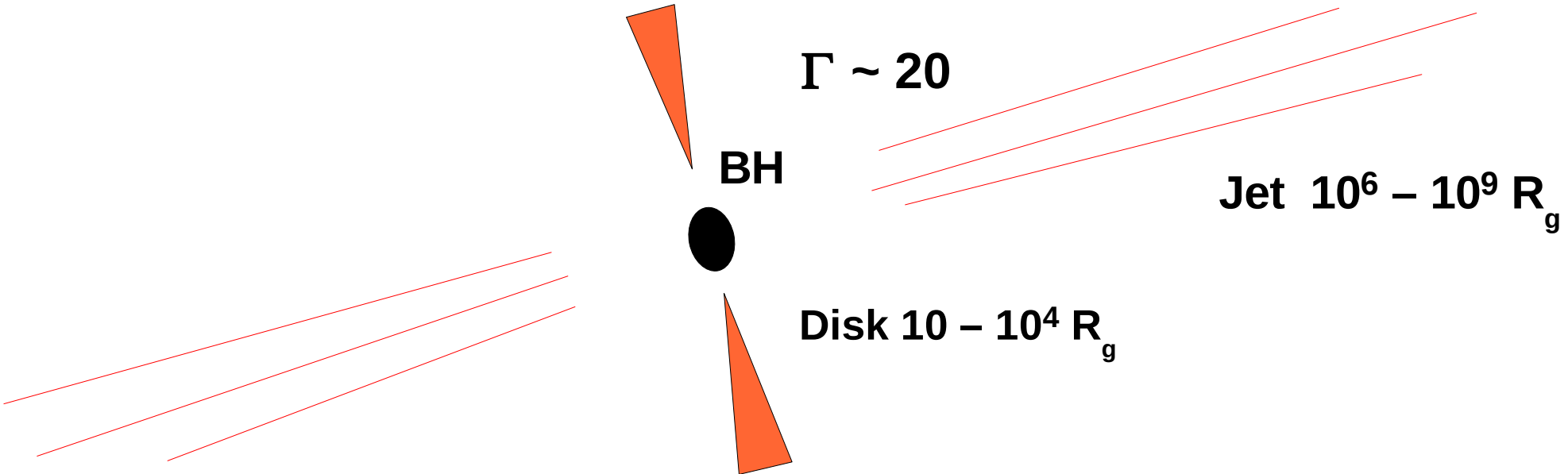
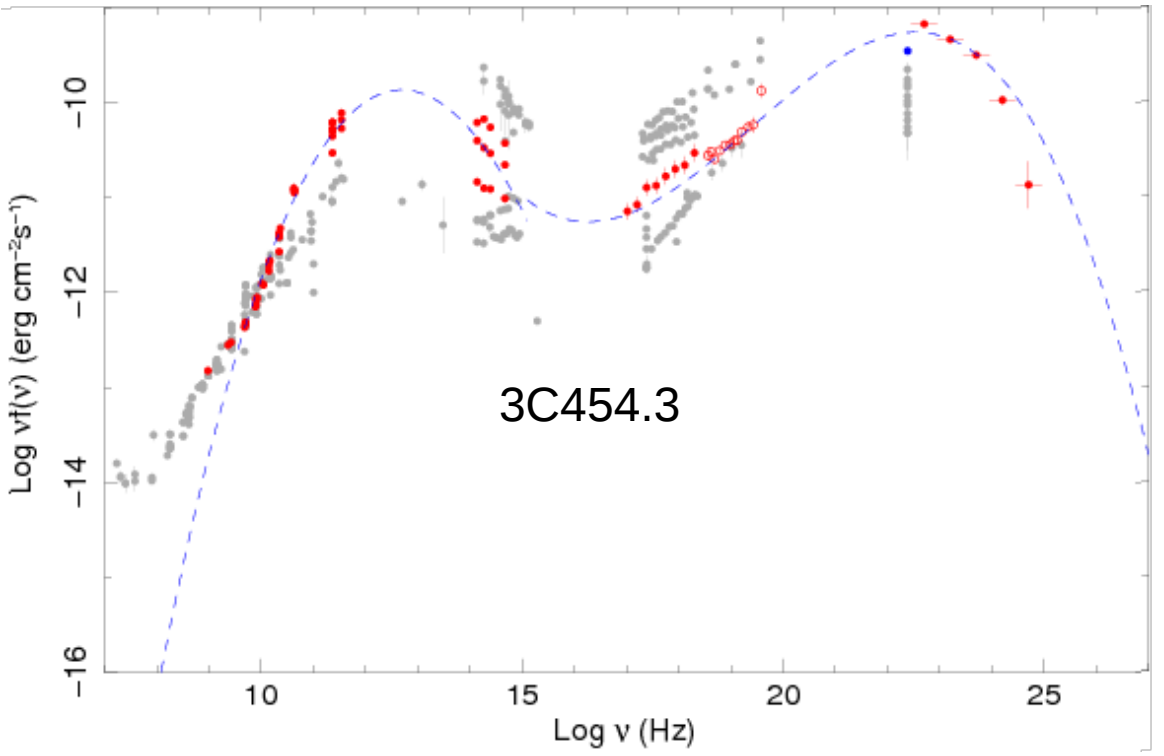
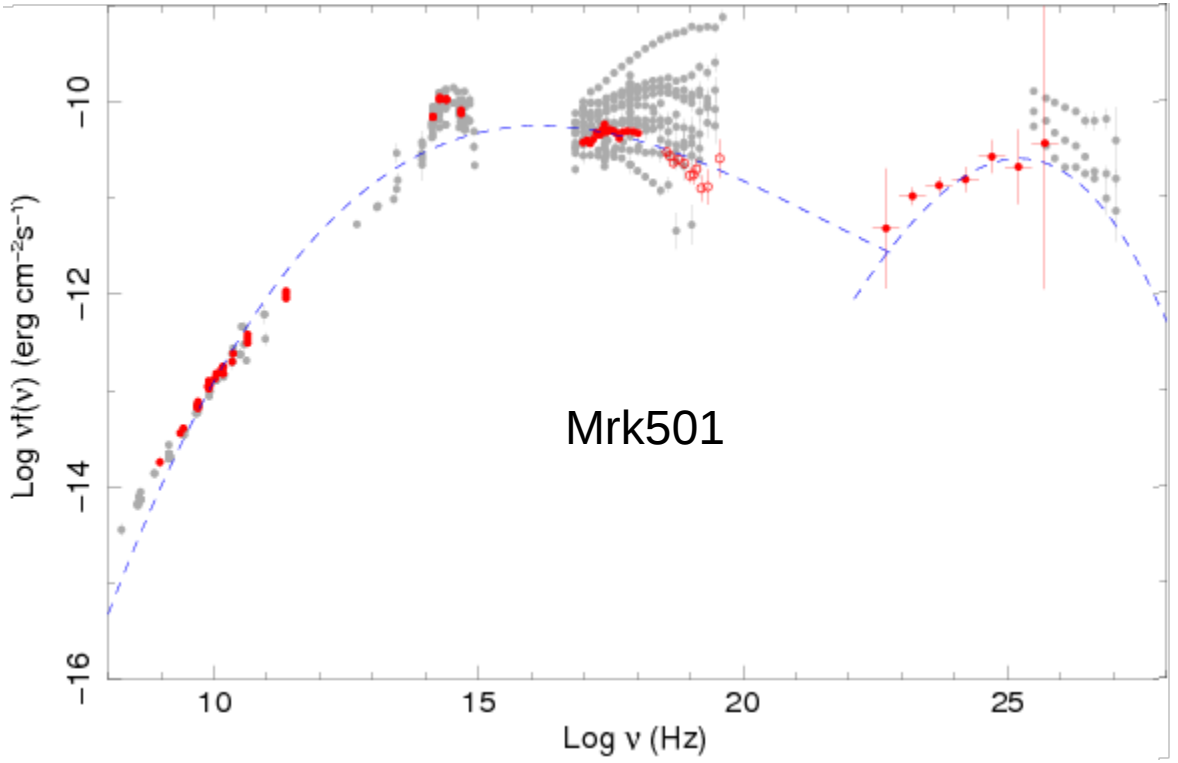
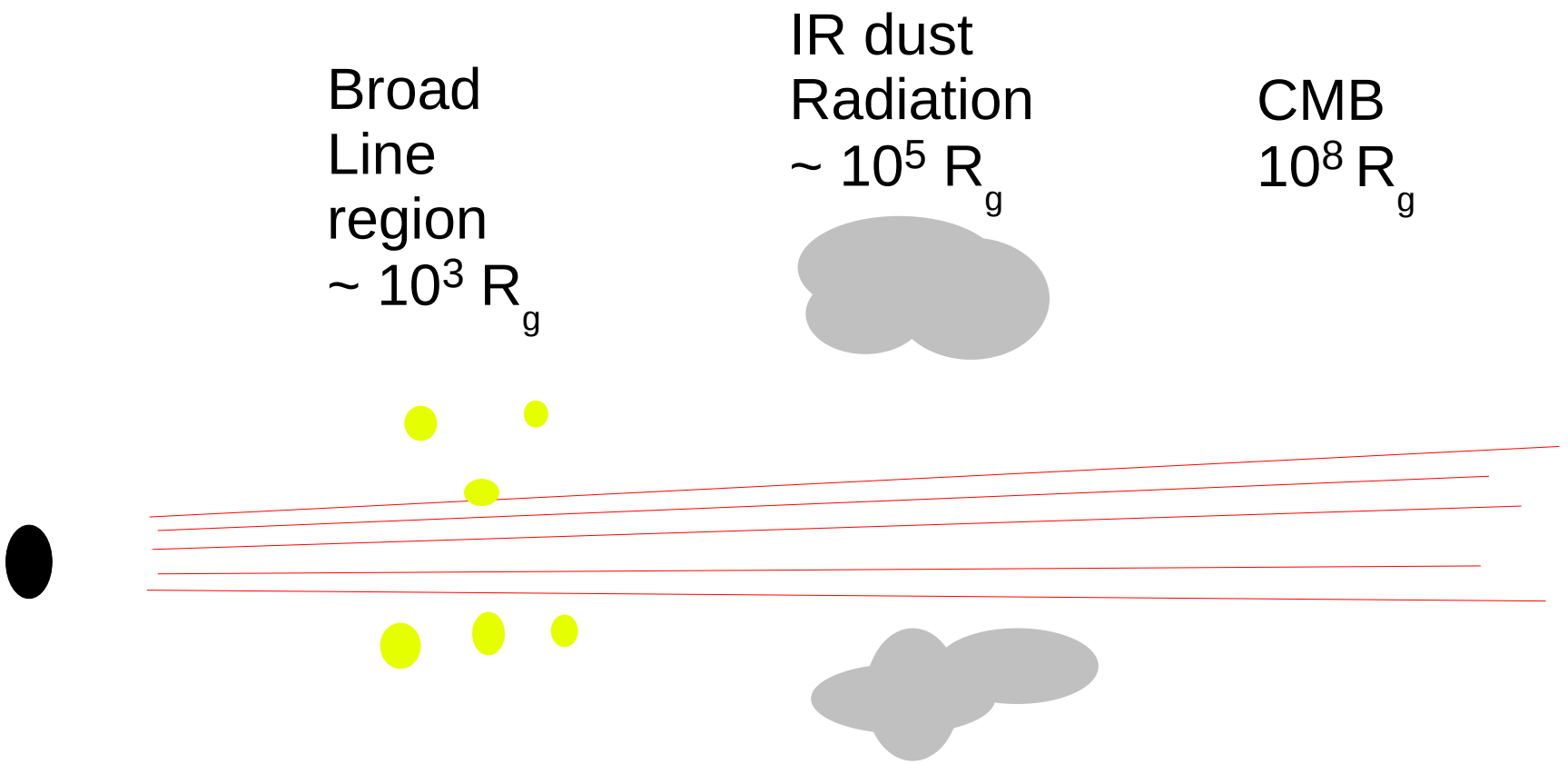

COMPOSITE
X-RAY
RADIO
OPTICAL




Γ ~ 20
BH
Jet 10^6 – 10^9 R_g
Disk 10 – 10^4 R_g

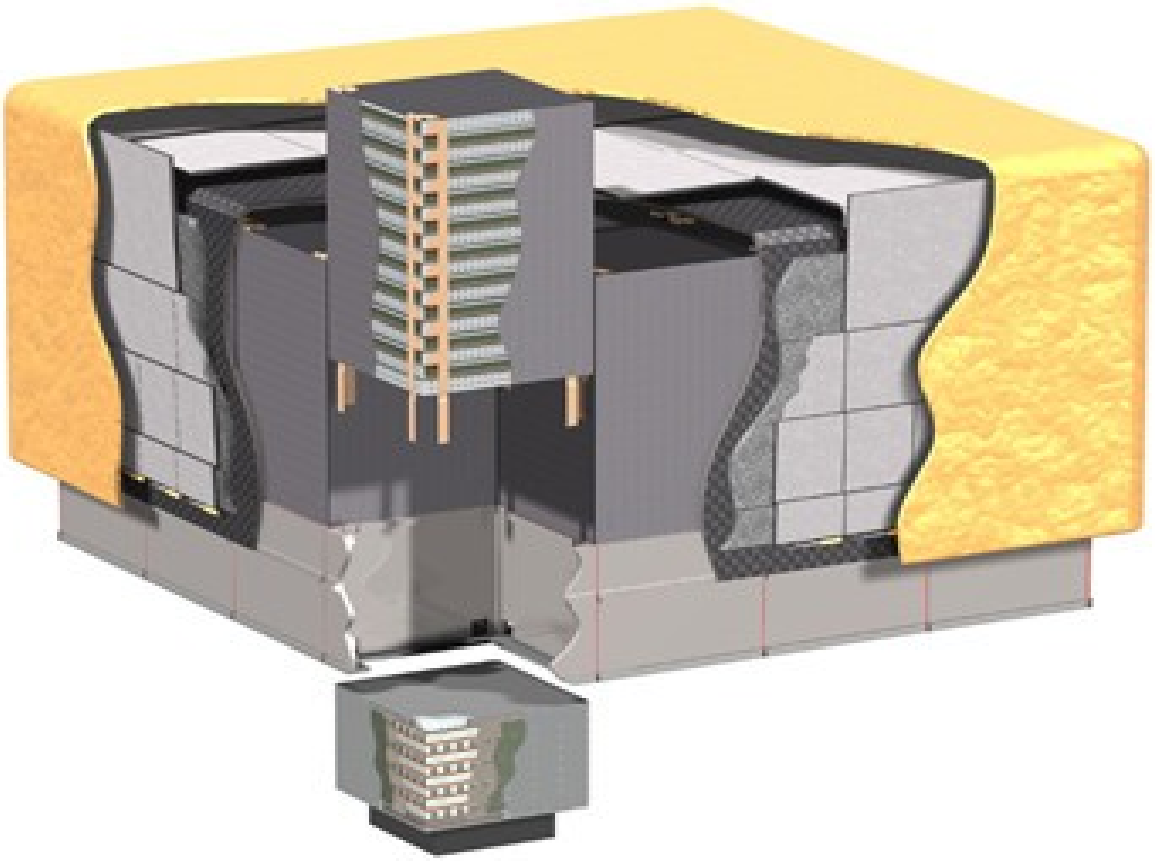

3C454.3
Log νf(ν) (erg cm⁻²s⁻¹)
−10
−12
−14
−16
10
15
20
25
Log ν (Hz)

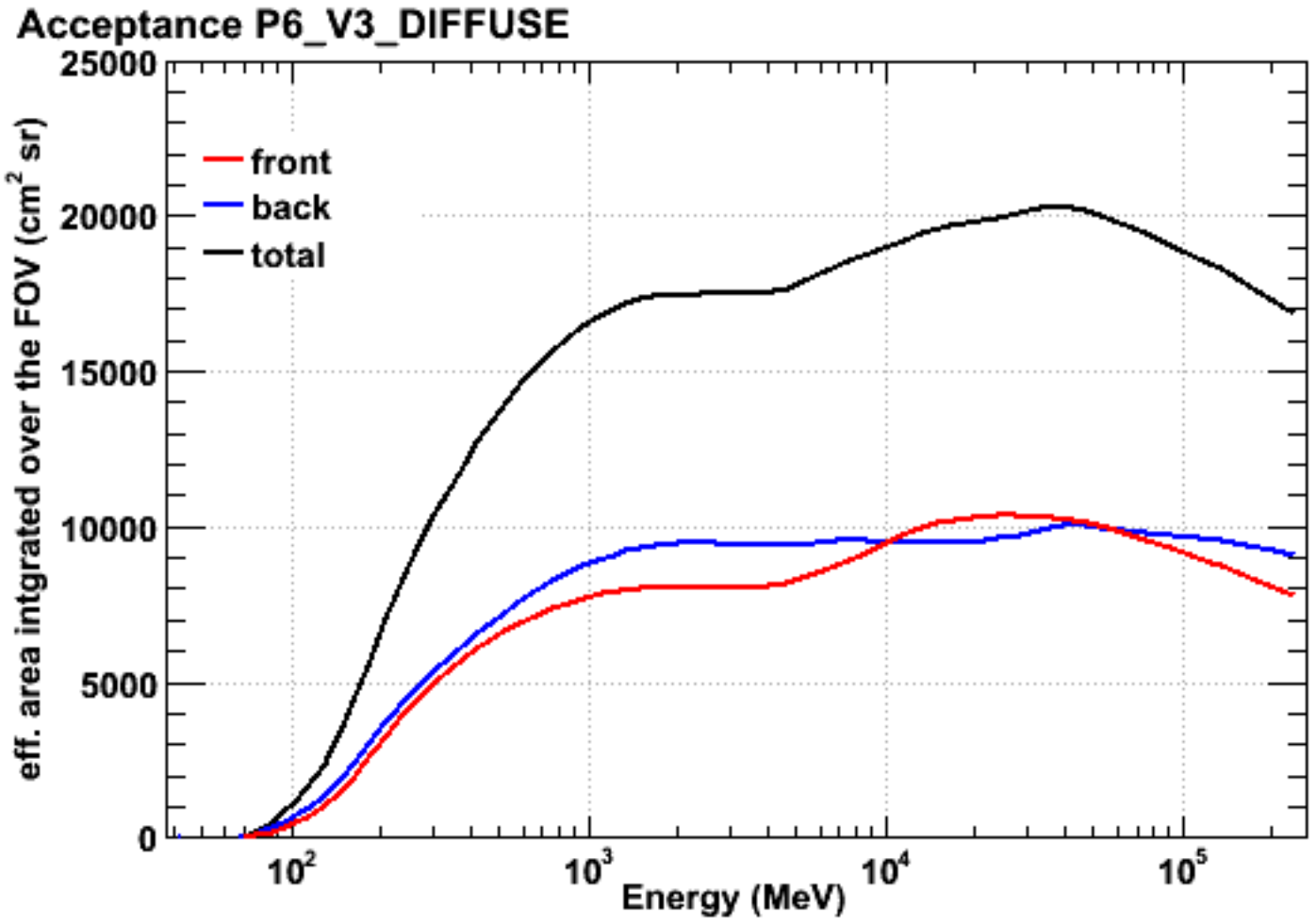

Mrk501
Log νf(ν) (erg cm⁻²s⁻¹)
−10
−12
−14
−16
10
15
20
25
Log ν (Hz)

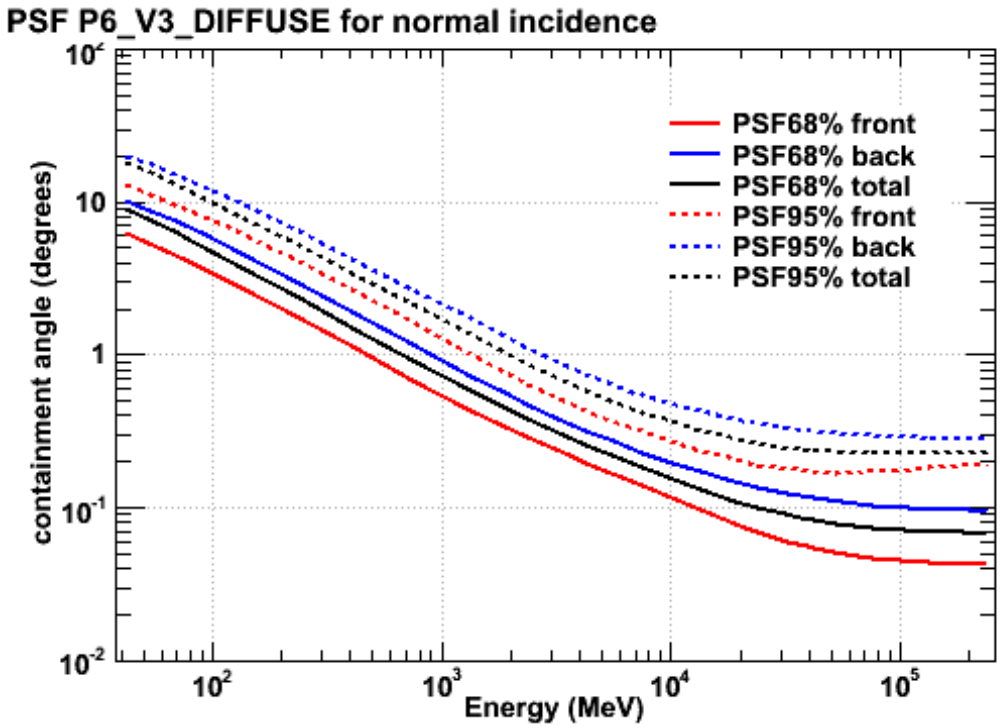


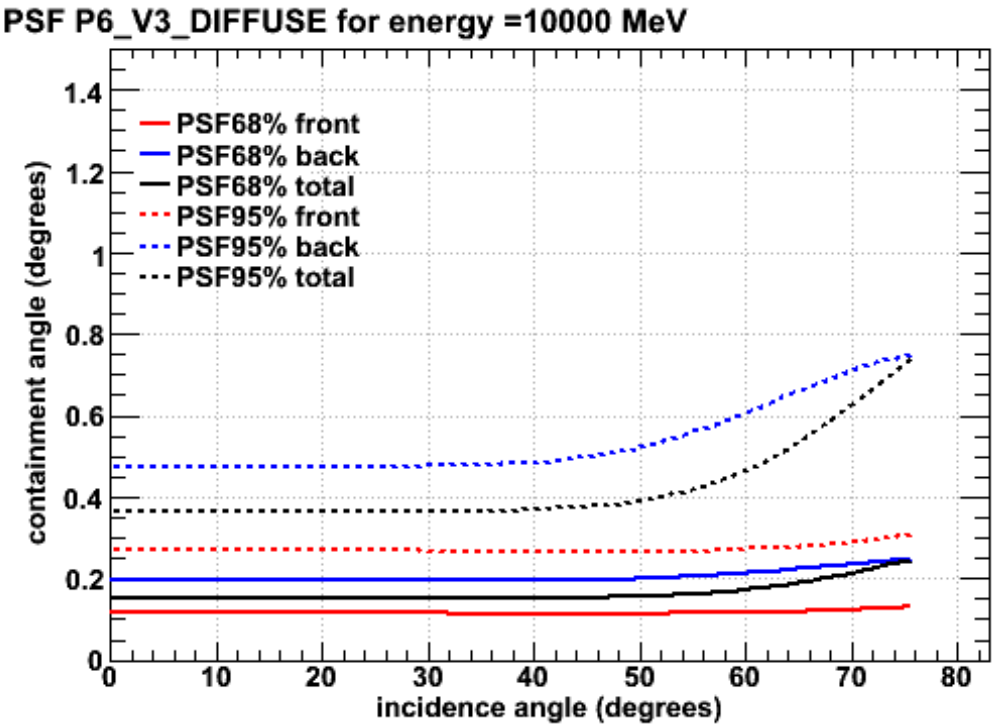
Where the GeV radiation comes from?

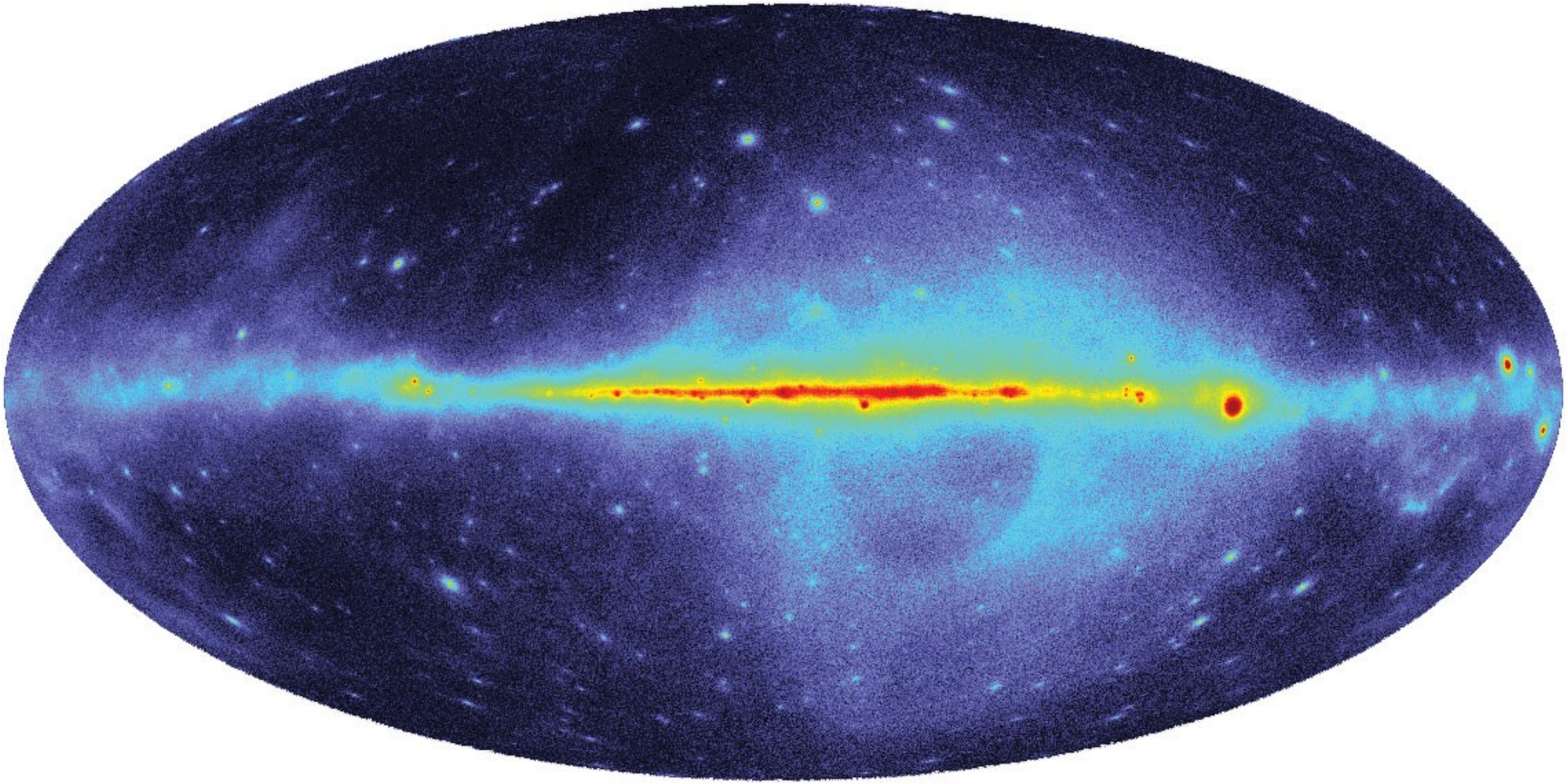
Fermi Large Area Telescope



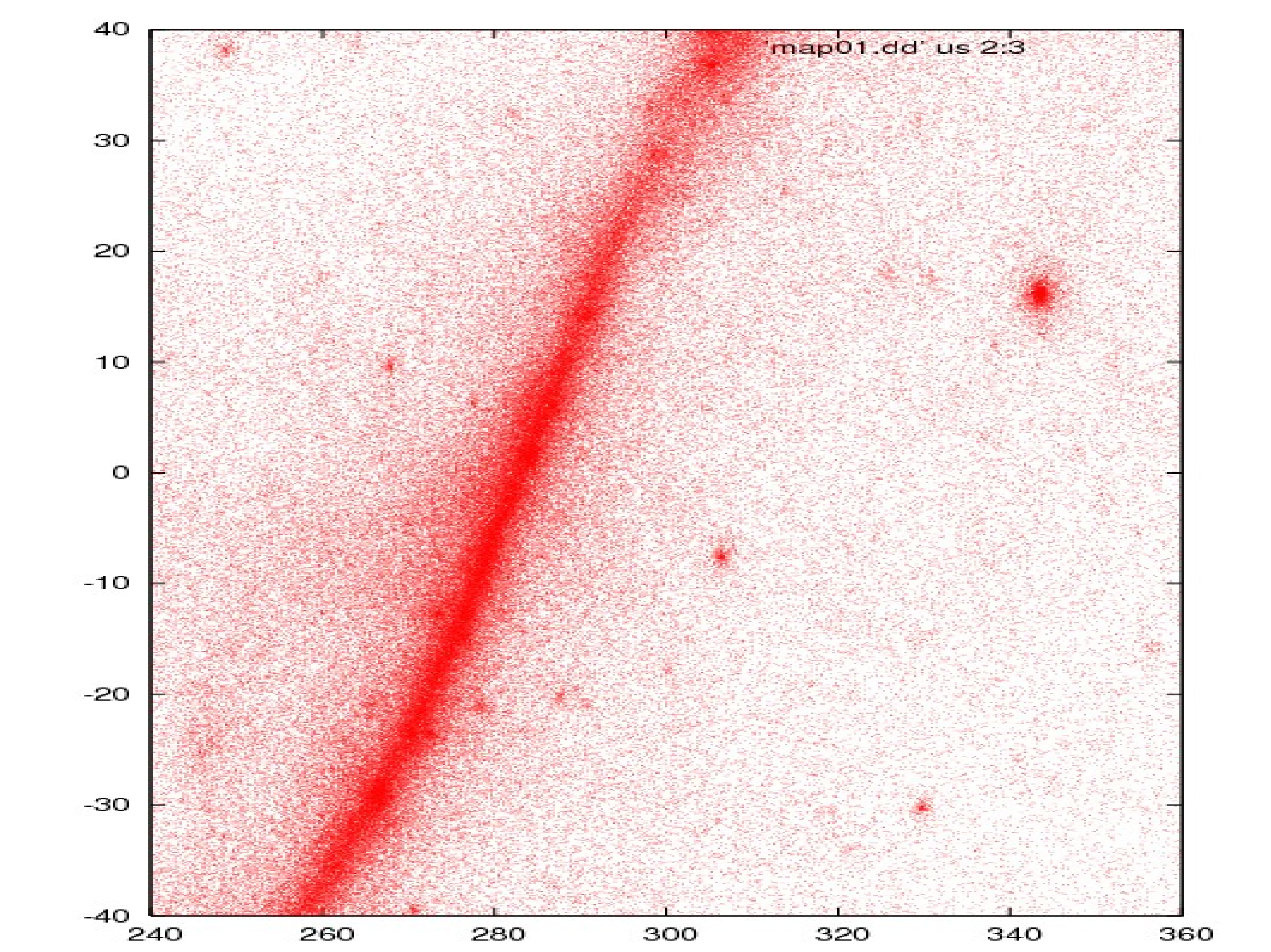

Acceptance P6_V3_DIFFUSE
eff. area intgrated over the FOV (cm^2 sr)
25000
20000
15000
10000
5000
0
front
back
total
10^2
10^3
10^4
10^5
Energy (MeV)

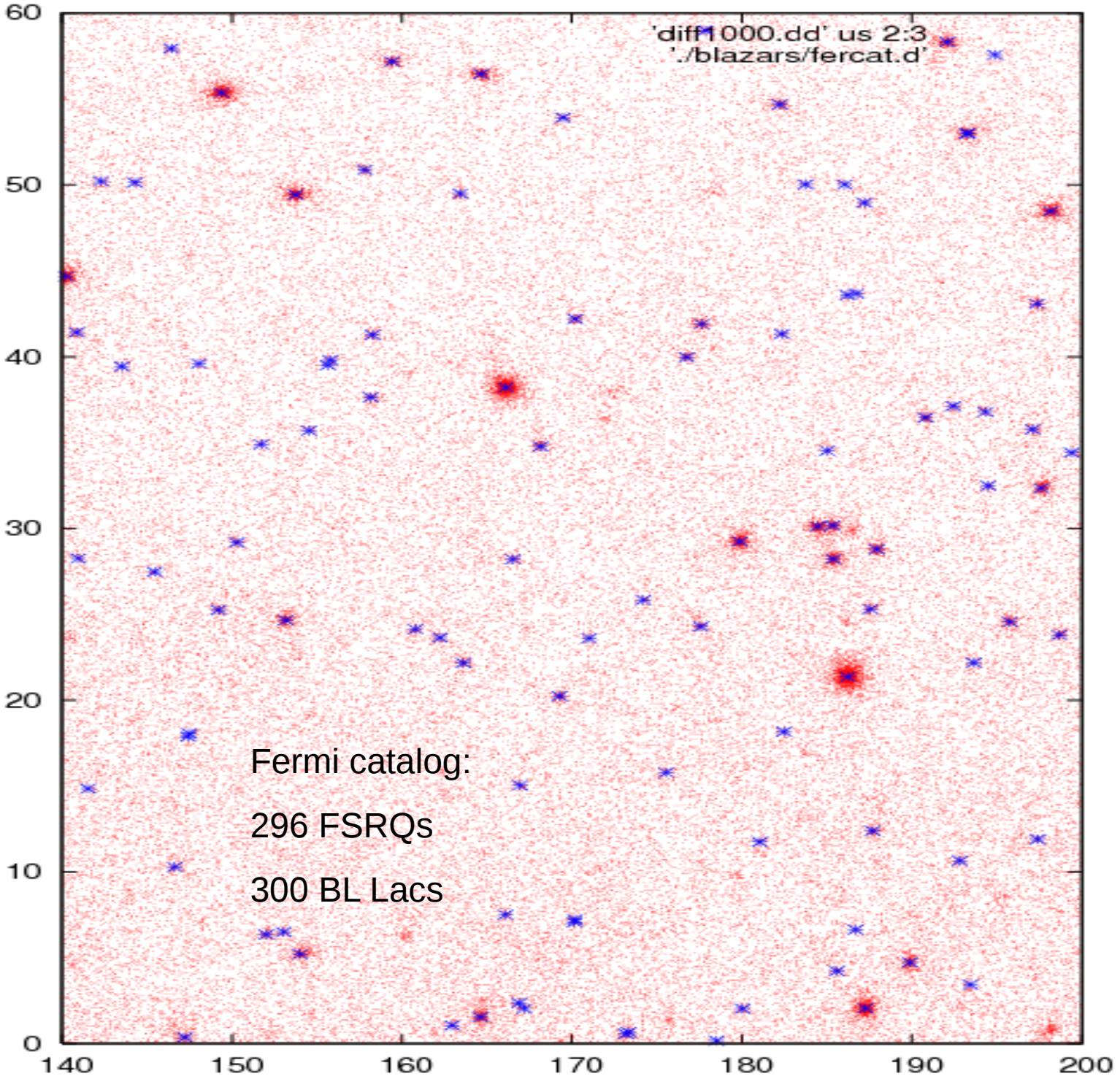

PSF P6_V3_DIFFUSE for normal incidence
containment angle (degrees)
Energy (MeV)
PSF68% front
PSF68% back
PSF68% total
PSF95% front
PSF95% back
PSF95% total

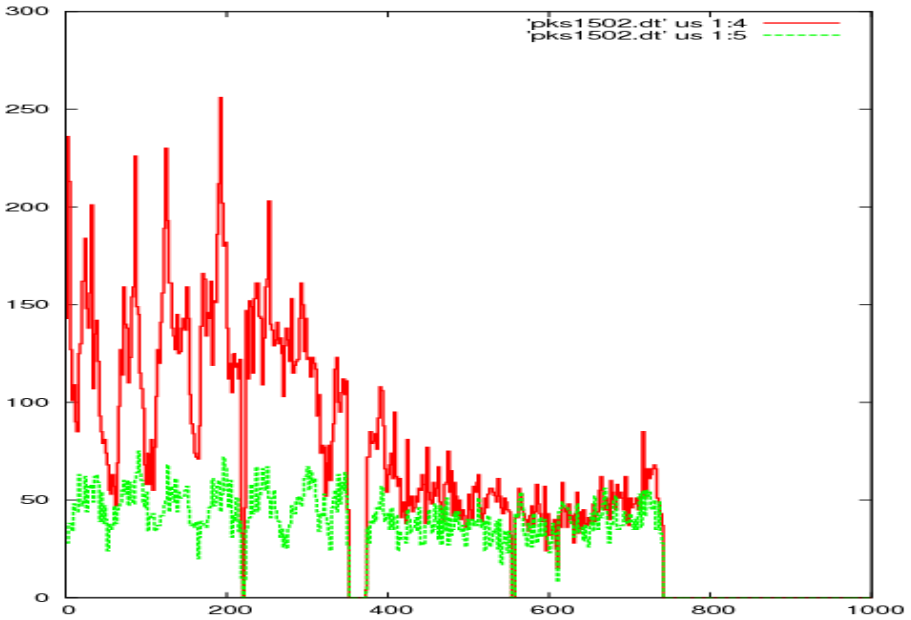

PSF P6_V3_DIFFUSE for energy =10000 MeV
containment angle (degrees)
incidence angle (degrees)
PSF68% front
PSF68% back
PSF68% total
PSF95% front
PSF95% back
PSF95% total

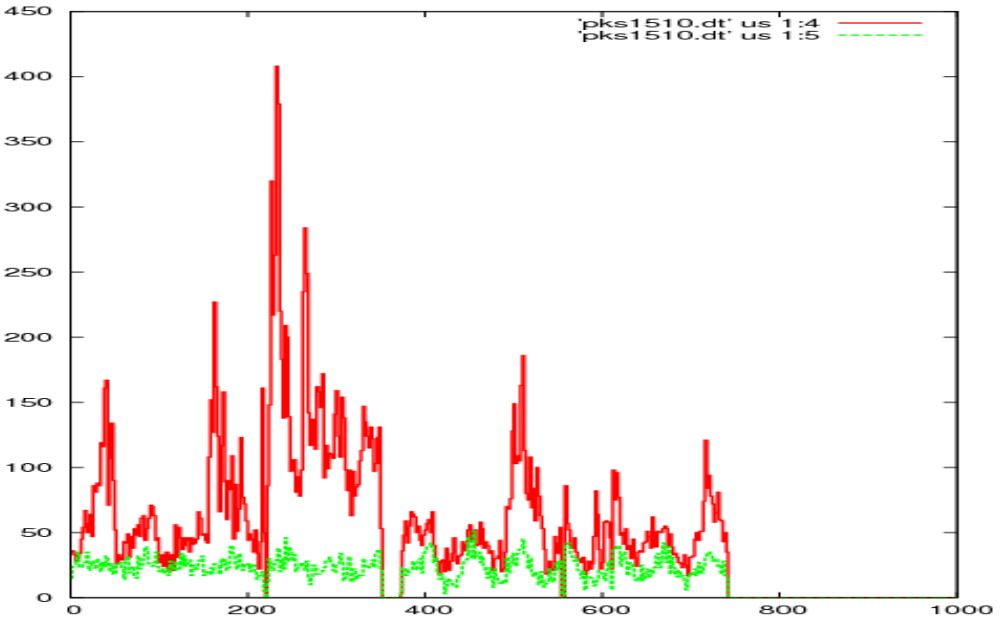


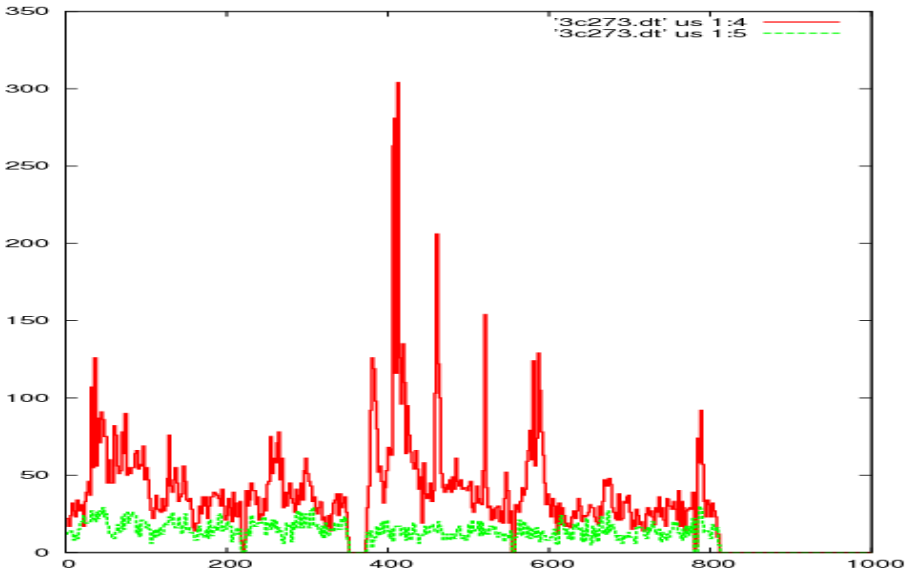
Only “good” (class 3) photon events ~2 10^7

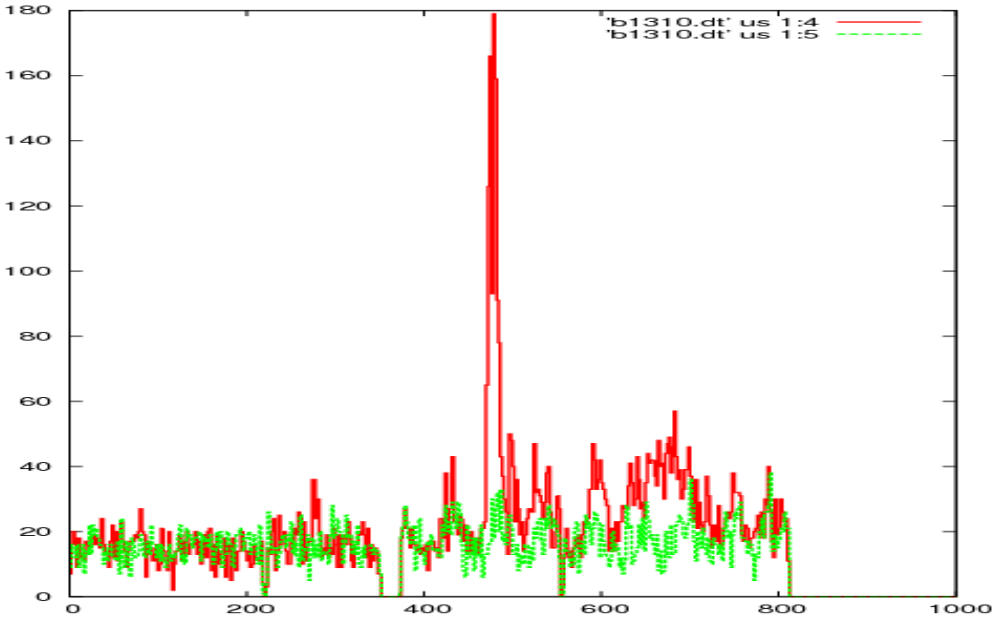

'map01.dd' us 2:3
40
30
20
10
0
-10
-20
-30
-40
240
260
280
300
320
340
360


'diff1000.dd' us 2:3
'./blazars/fercat.d'
60
50
40
30
20
10
0
140
150
160
170
180
190
200
Fermi catalog:
296 FSRQs
300 BL Lacs


'pks1502.dt' us 1:4
'pks1502.dt' us 1:5
300
250
200
150
100
50
0
0
200
400
600
800
1000

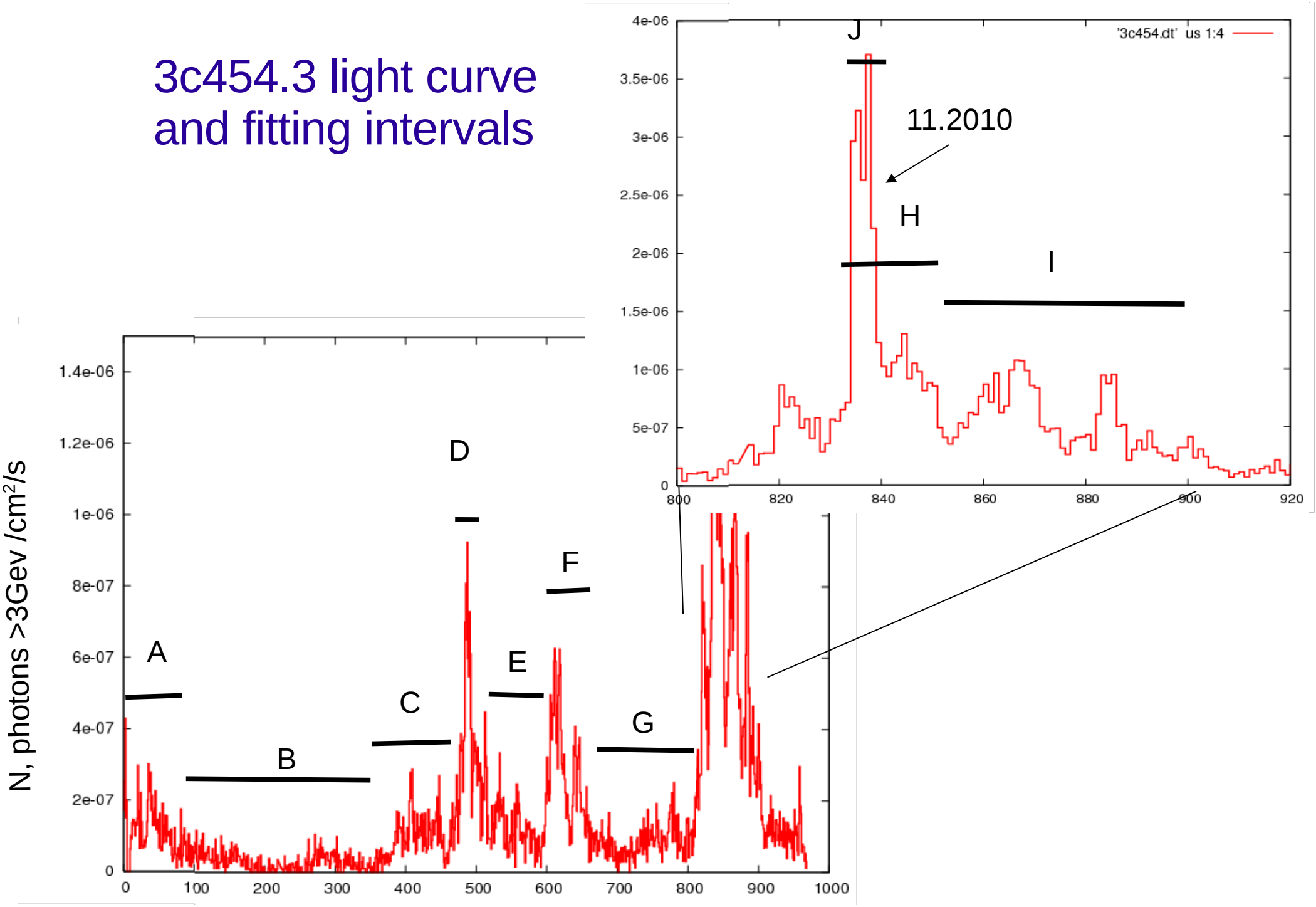

'pks1510.dt' us 1:4
'pks1510.dt' us 1:5
450
400
350
300
250
200
150
100
50
0
0
200
400
600
800
1000

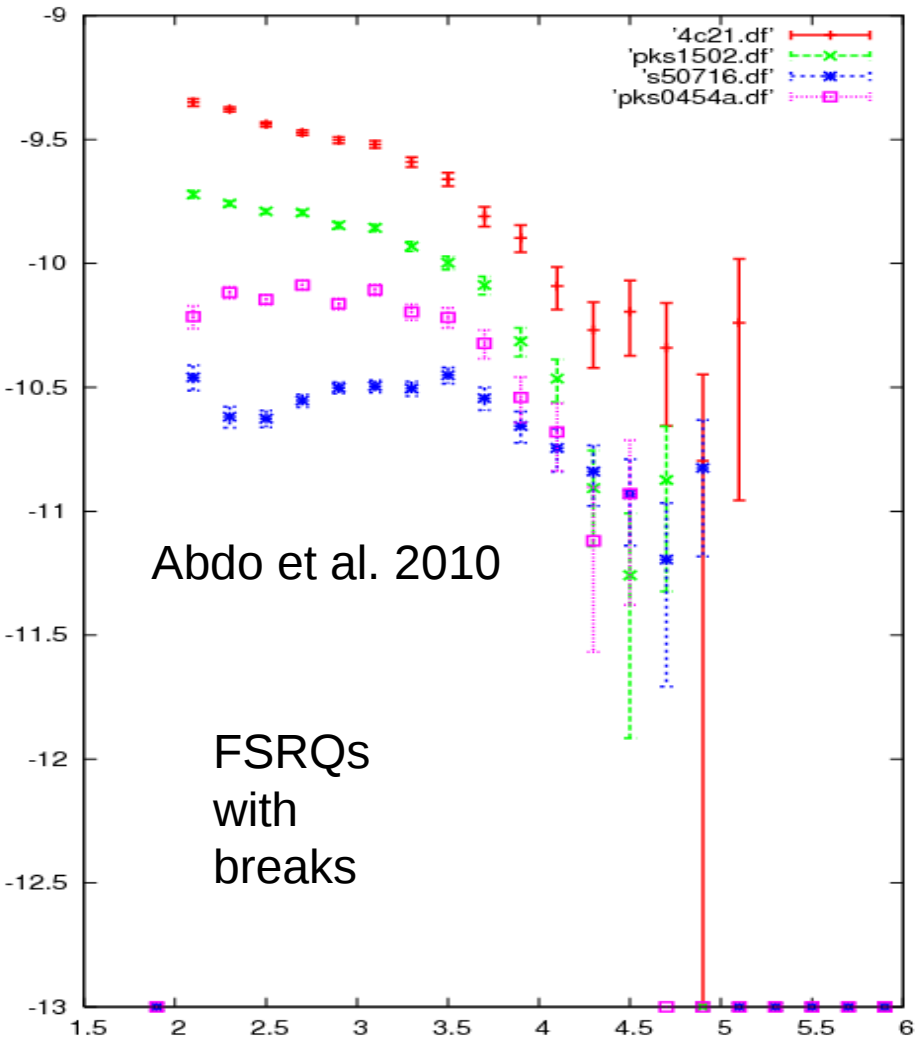

'3c273.dt' us 1:4
'3c273.dt' us 1:5
350
300
250
200
150
100
50
0
0
200
400
600
800
1000

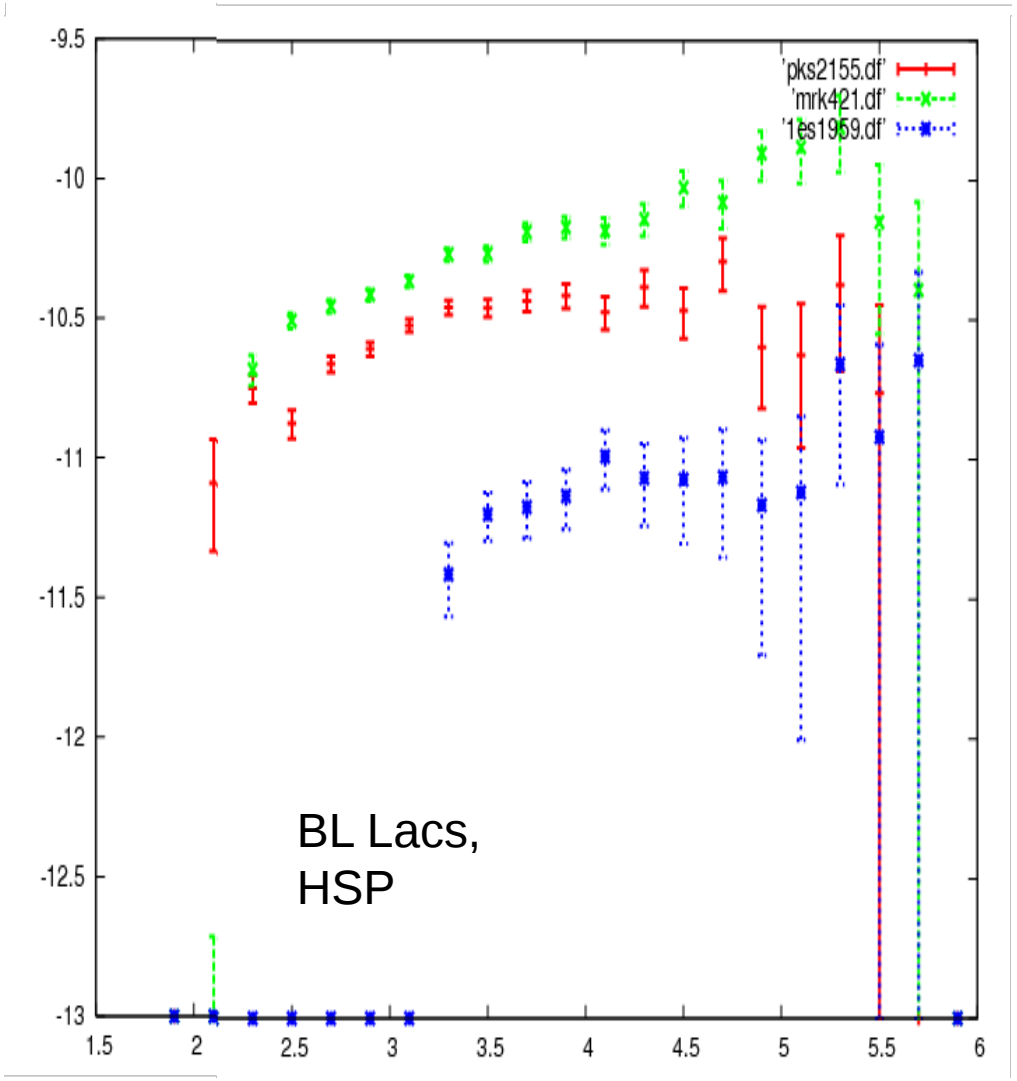

'b1310.dt' us 1:4
'b1310.dt' us 1:5
180
160
140
120
100
80
60
40
20
0
0
200
400
600
800
1000

Days

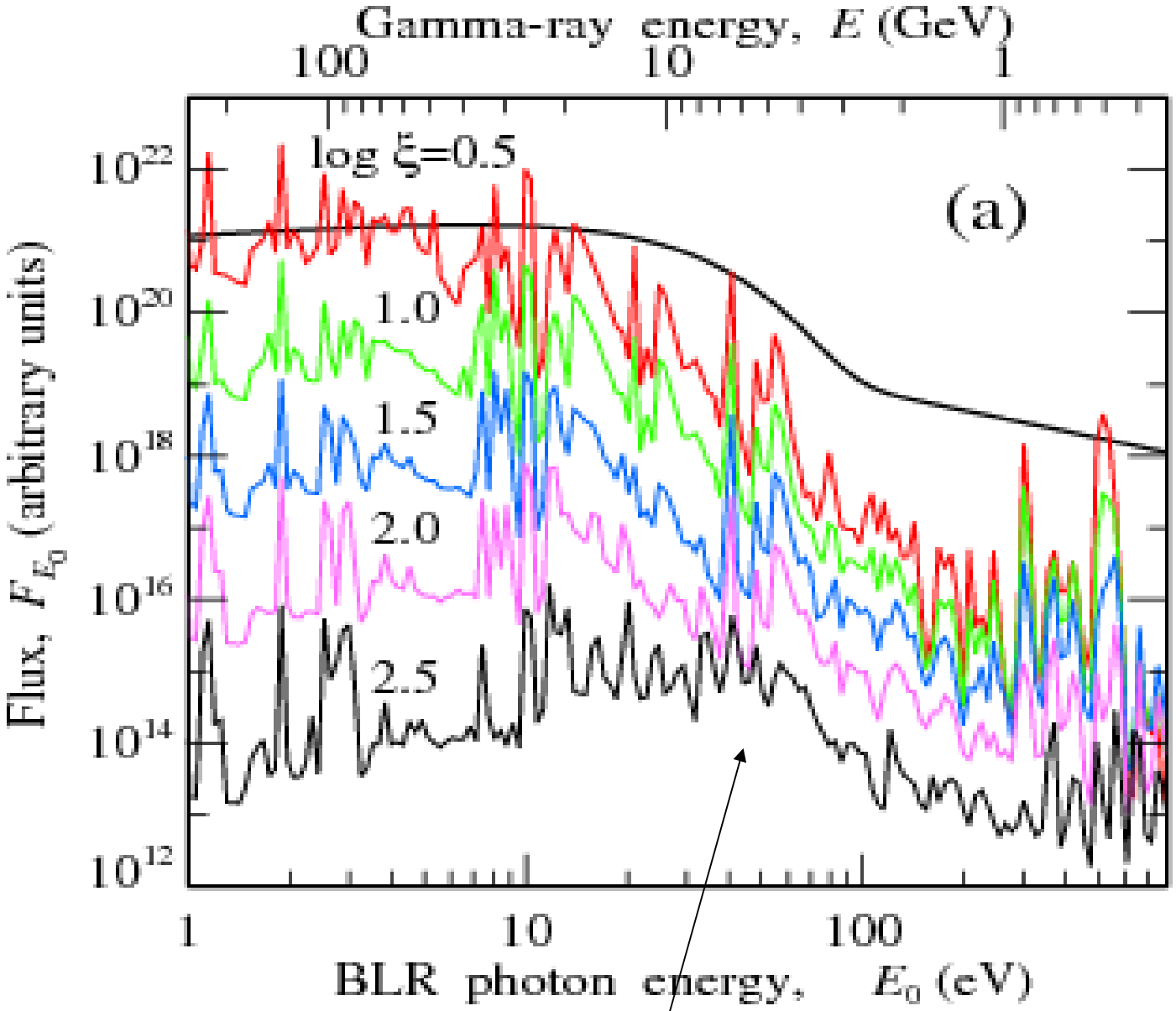
3c454.3 light curve and fitting intervals



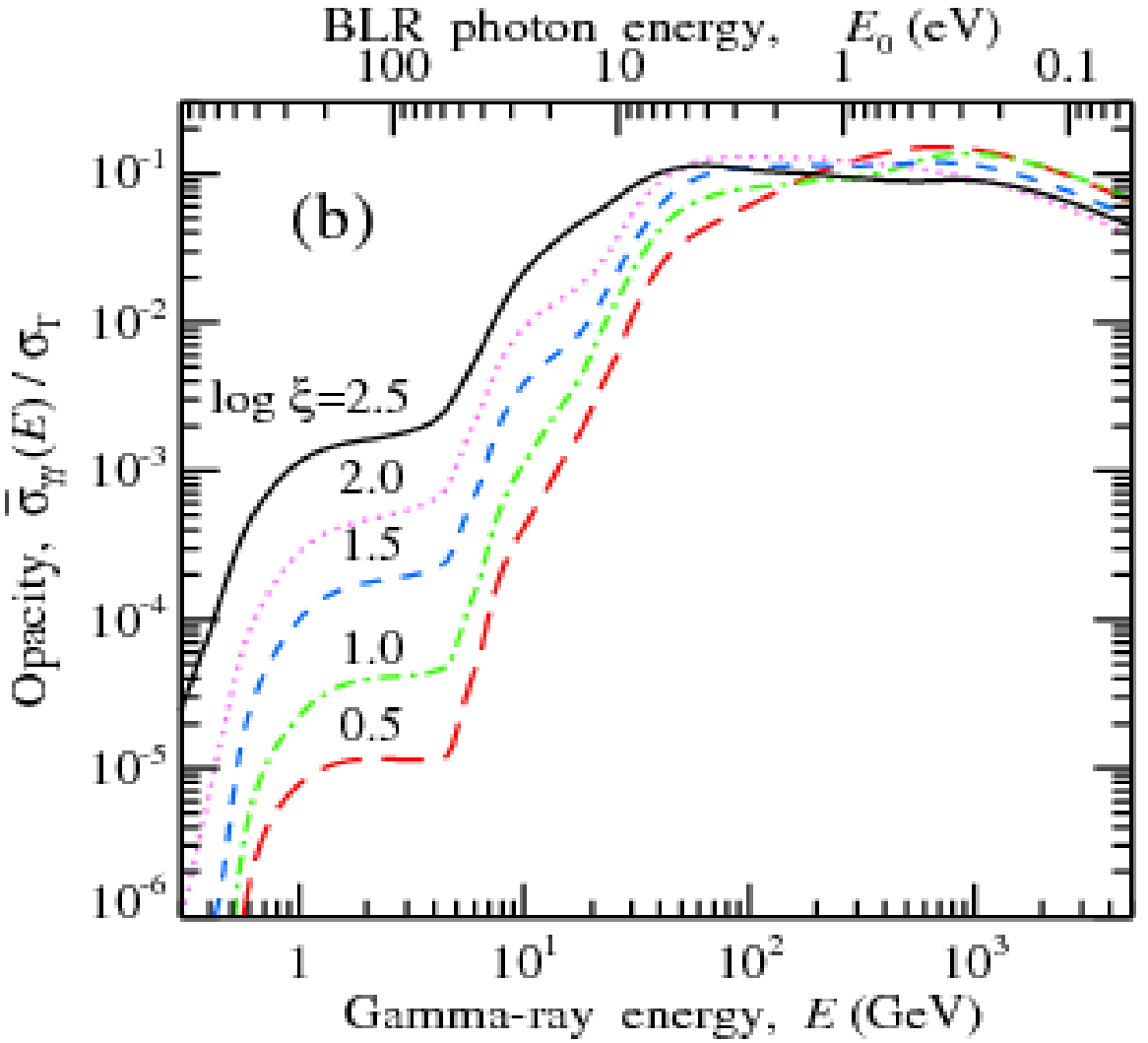




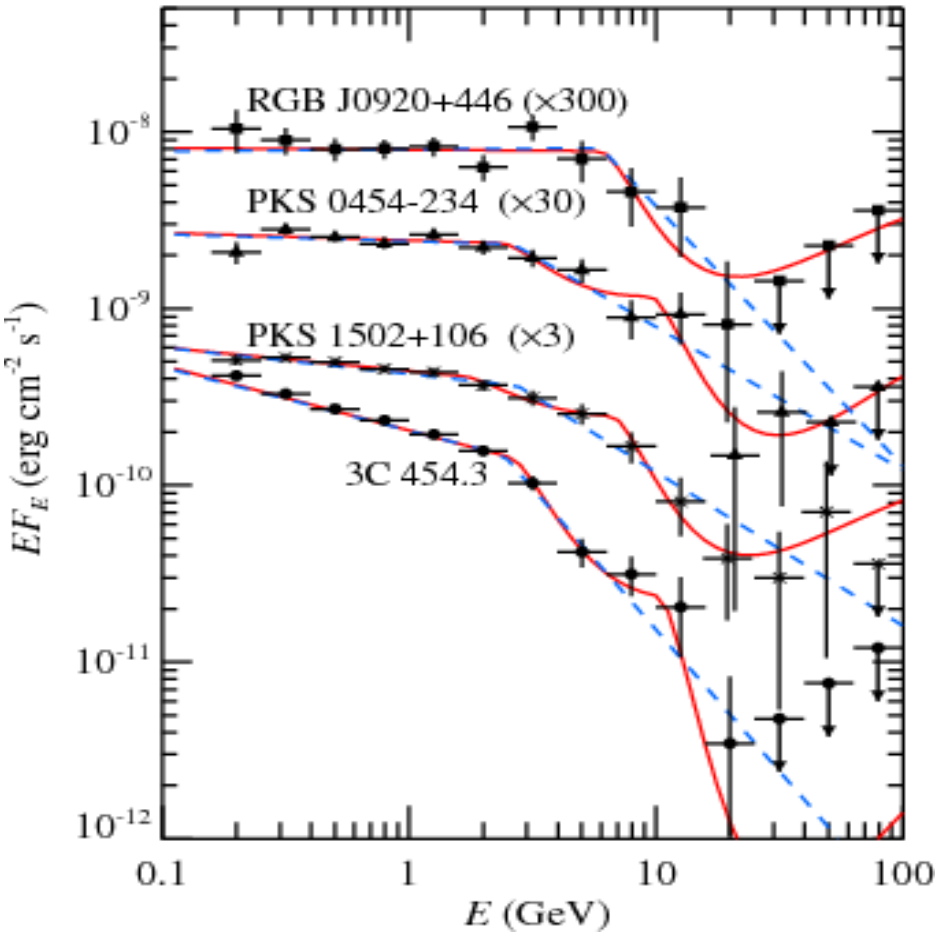
Fermi team: there is no a proper absorber at this energy - H Ly a is too soft,
Therefore this is some trick in particle acceleration



Poutanen & Stern 2010: There is such absorber! Hell La

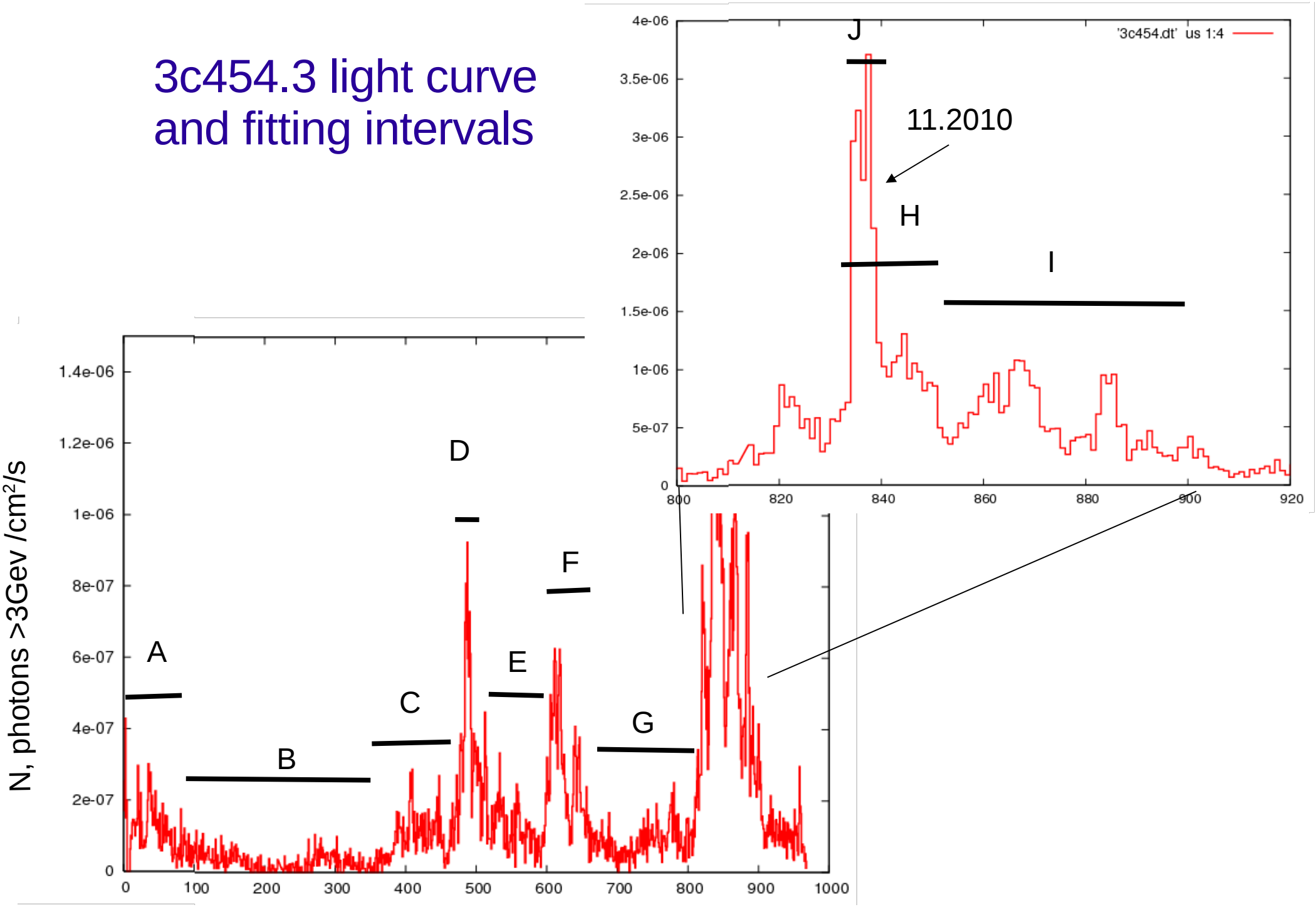

BLR photon energy, E_0 (eV)
100
10
1
0.1
(b)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Opacity, $\bar{\sigma}_{\gamma\gamma}(E) / \sigma_T$
log ξ=2.5
2.0
1.5
1.0
0.5
1
10^1
10^2
10^3
Gamma-ray energy, E (GeV)

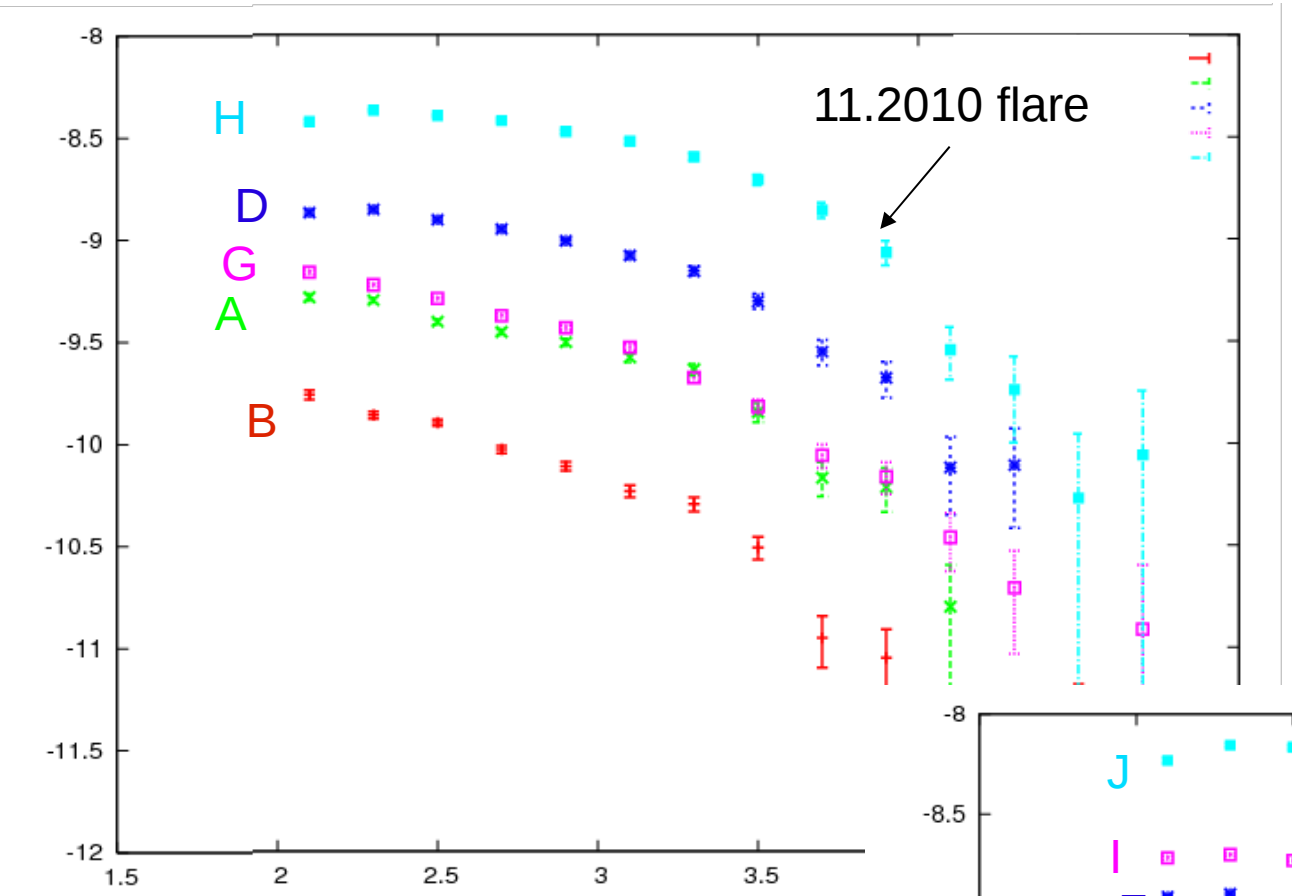
Poutanen & Stern 2010: if the break is significant it is usually at 3 – 4 GeV



November 2009 – December 2010: exceptionally bright flares of 3C 454.3

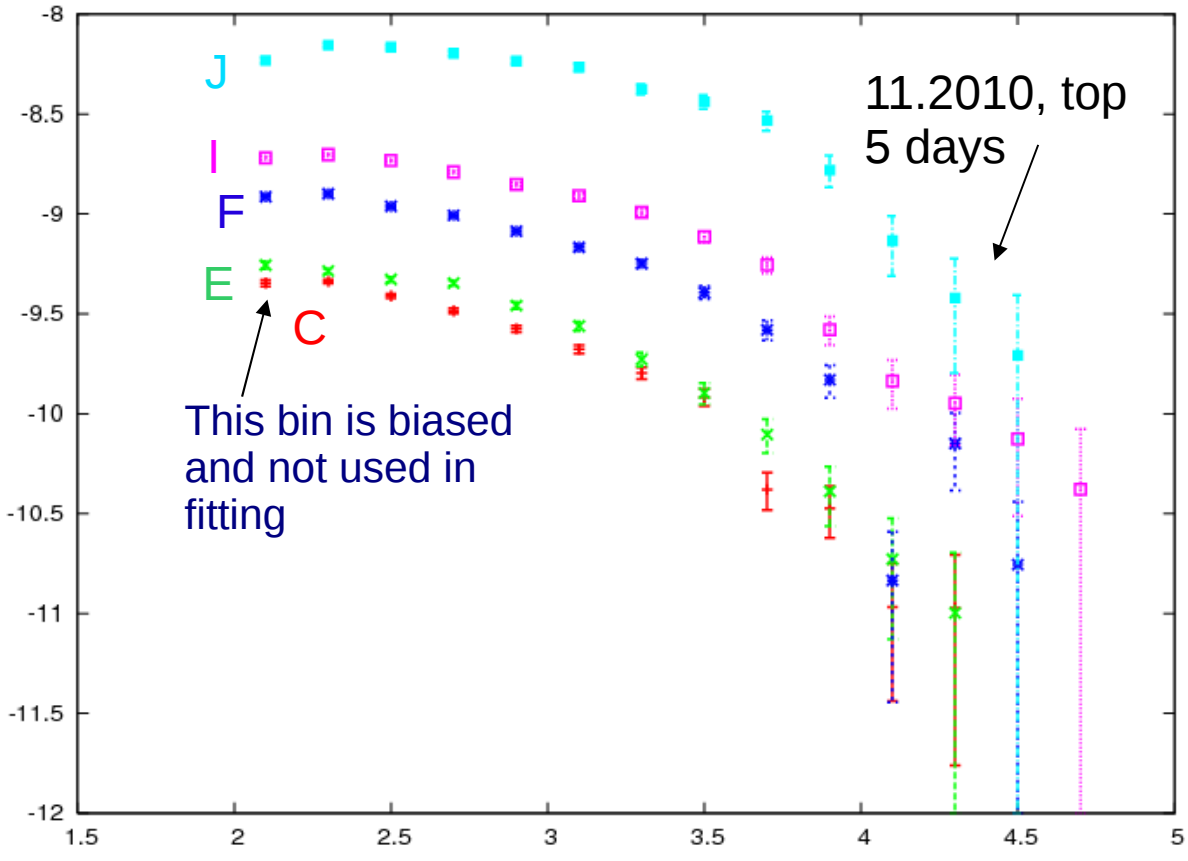
3c454.3 light curve and fitting intervals

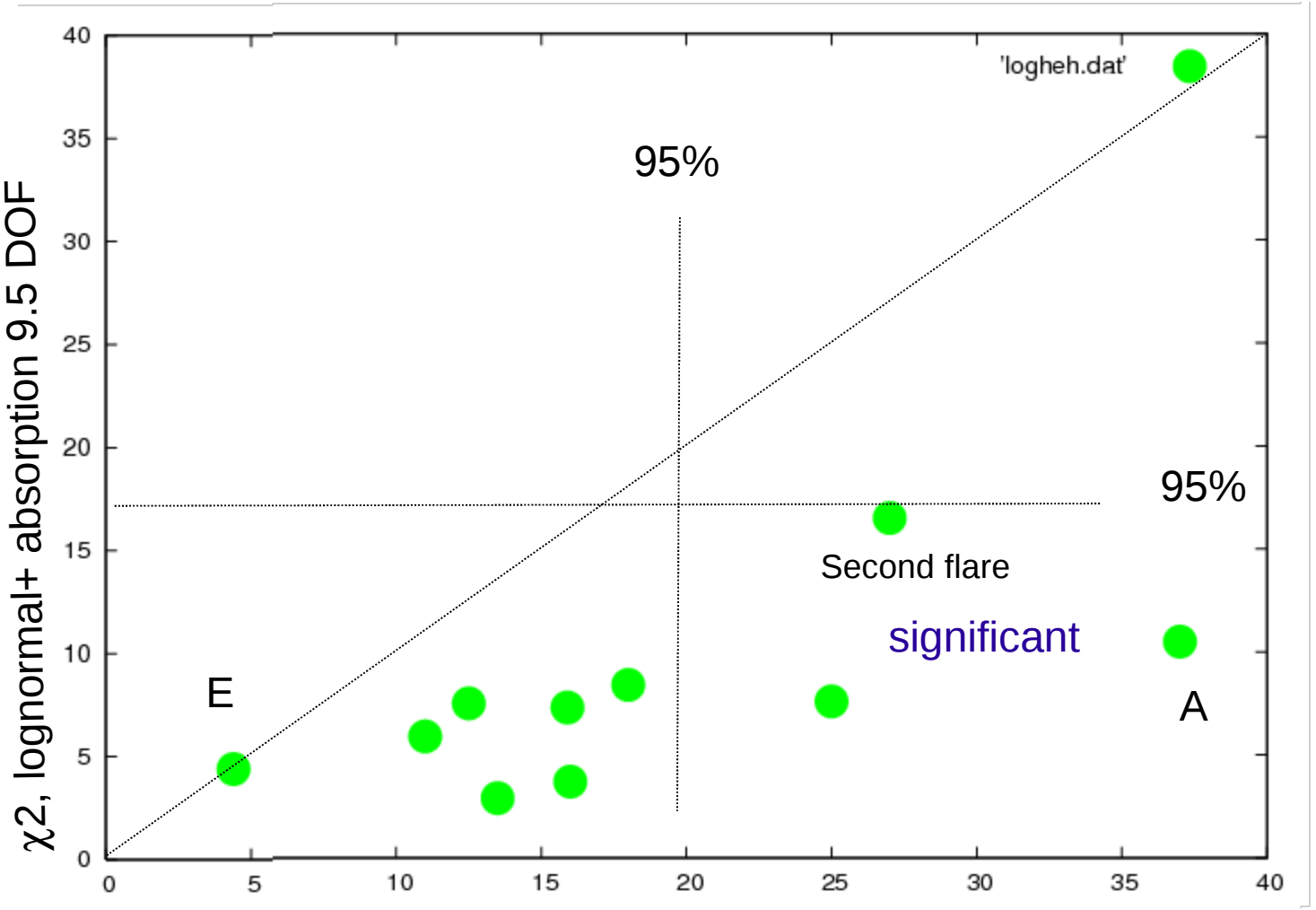




Log E(Mev)

Breaks are seen almost everywhere, what about their significance?



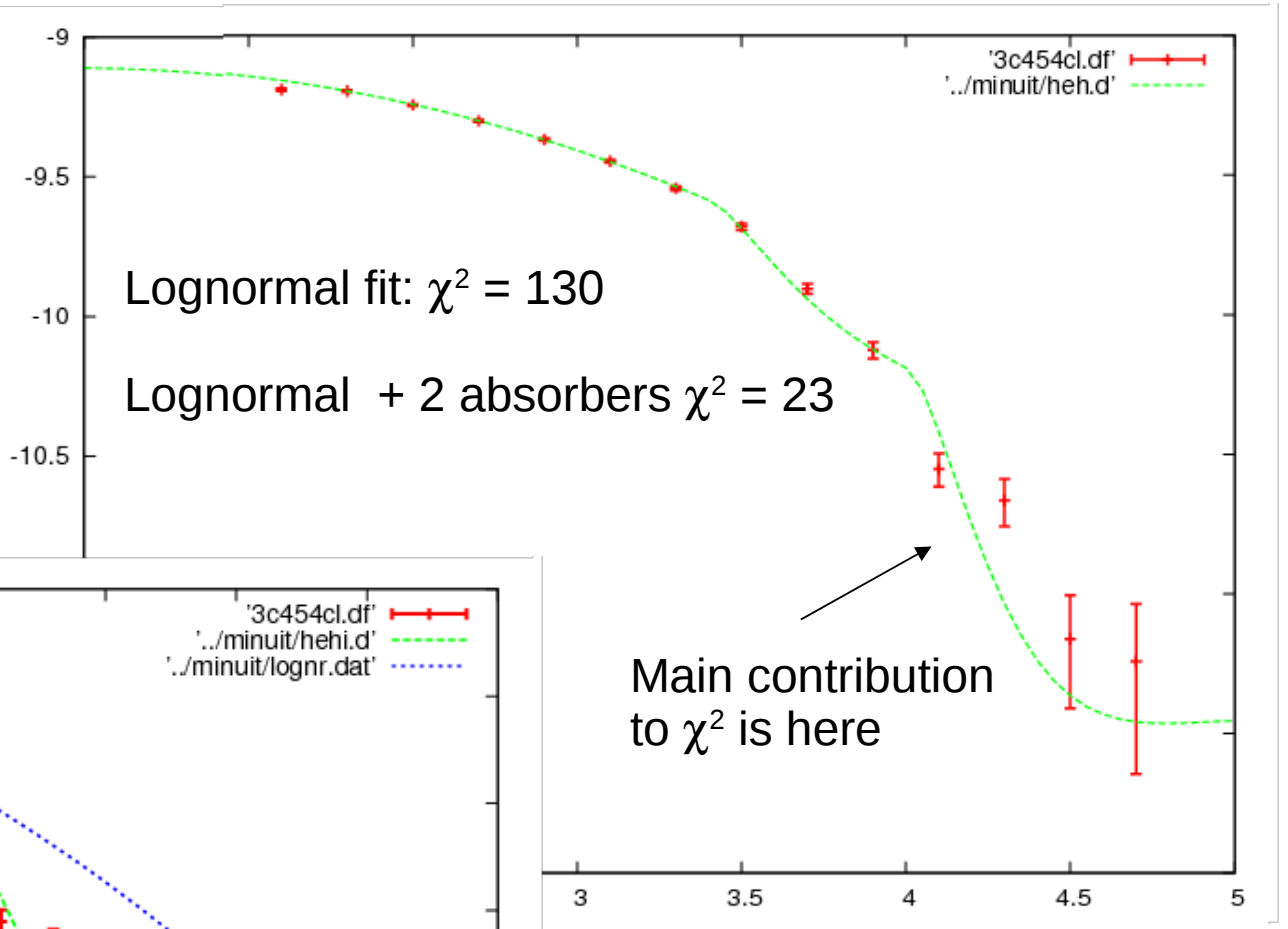


If the feature is stable, it should grow in significance when piling up spectra

$\nu F \nu = 10^{(\log E - \mathrm{Log}\, Ep)^2/s^2}$

What about total average 3c454.3 spectrum?

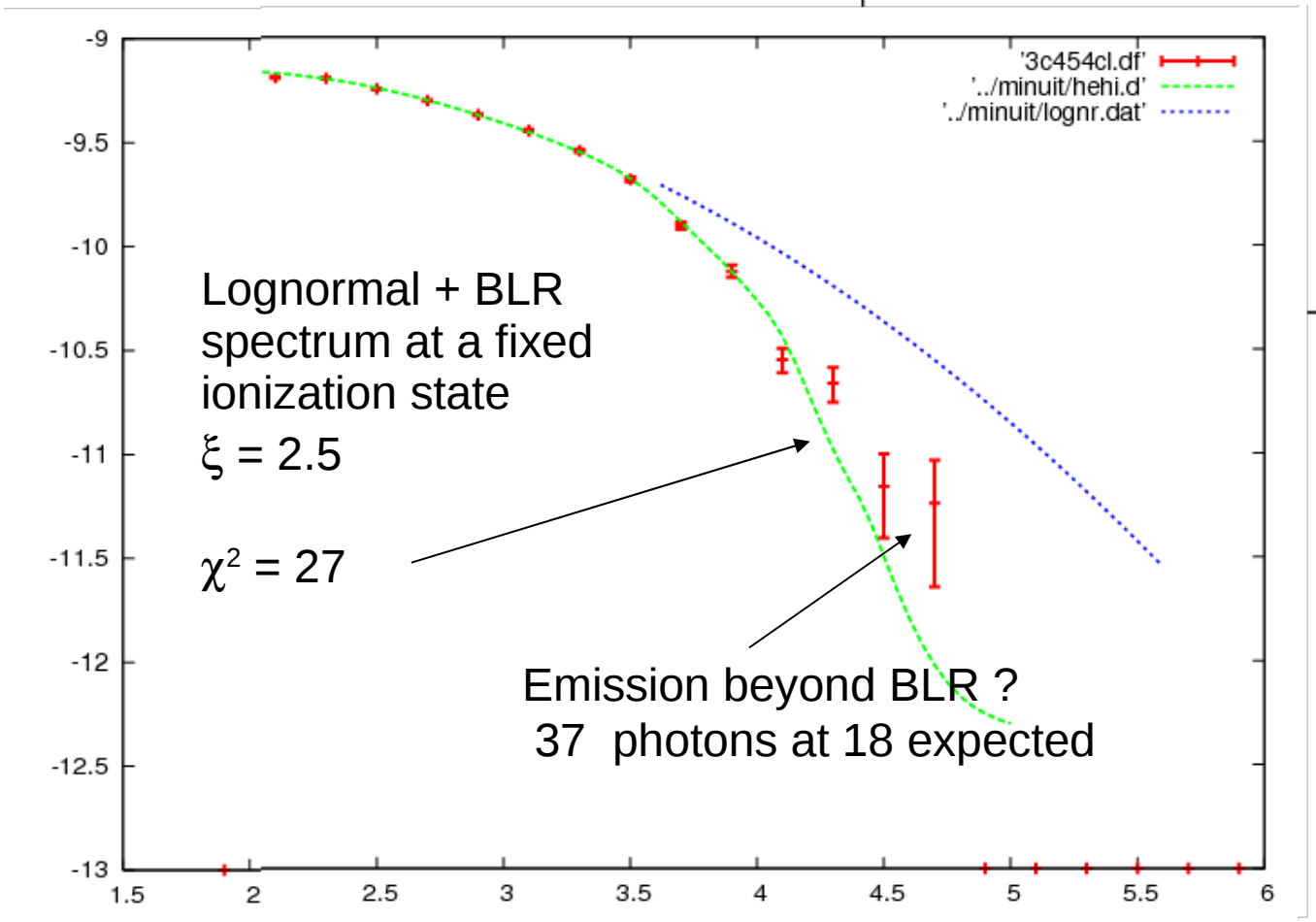
Yes!



Lognormal fit: $\chi^2 = 130$

Lognormal + 2 absorbers $\chi^2 = 23$

Main contribution to χ^2 is here



Lognormal + BLR spectrum at a fixed ionization state

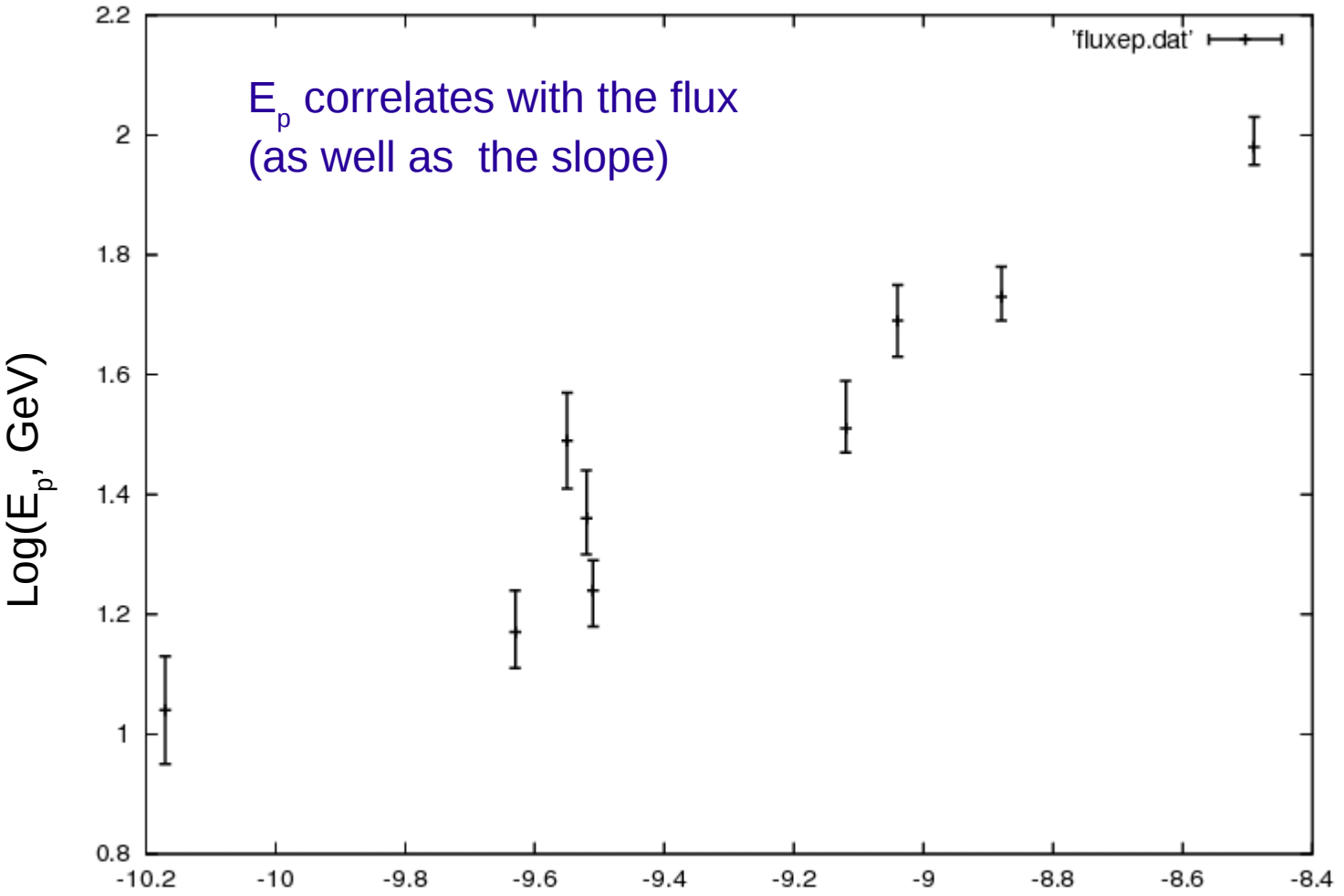
$\xi = 2.5$

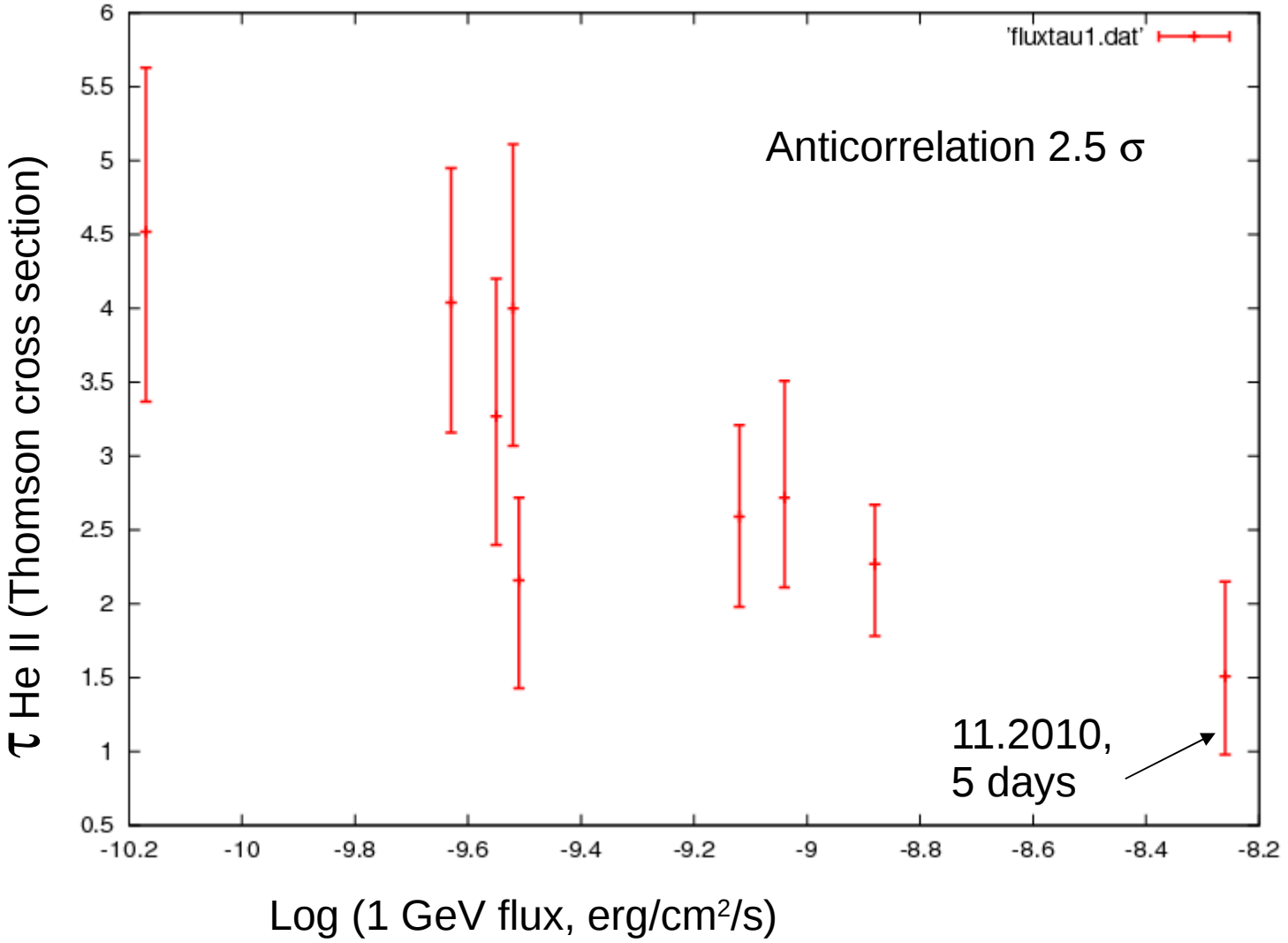
$\chi^2 = 27$

Emission beyond BLR ?
37 photons at 18 expected

The fit below 15 Gev is just good!

$\chi^2 = 11/7$ DOF


'fluxep.dat'
E_p correlates with the flux
(as well as the slope)
Log(E_p, GeV)
Log (1GeV flux, erg/cm^2/s)
2.2
2
1.8
1.6
1.4
1.2
1
0.8
-10.2
-10
-9.8
-9.6
-9.4
-9.2
-9
-8.8
-8.6
-8.4


'fluxtau1.dat'
Anticorrelation 2.5 σ
11.2010,
5 days
τ He II (Thomson cross section)
Log (1 GeV flux, erg/cm²/s)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
-10.2
-10
-9.8
-9.6
-9.4
-9.2
-9
-8.8
-8.6
-8.4
-8.2

Conclusions

1. He II absorption break has a huge significance and precise agreement with data

2. The photon-photon opacity is not very large, ~ 0.3 - 1.0, the emission region probably spans a long range from inner beyond outer BLR

3. The underlying spectrum can be described well as a lognormal distribution with sigma ~ 3 (decimal)

4. The jet “breaths” with power variation: the emission region moves outward at a high state

Stern & Poutanen 2012

Summing up blazar spectra

There is a situation when a sum of different spectra gives more information than individual spectra:

A stable emission or absorption feature.

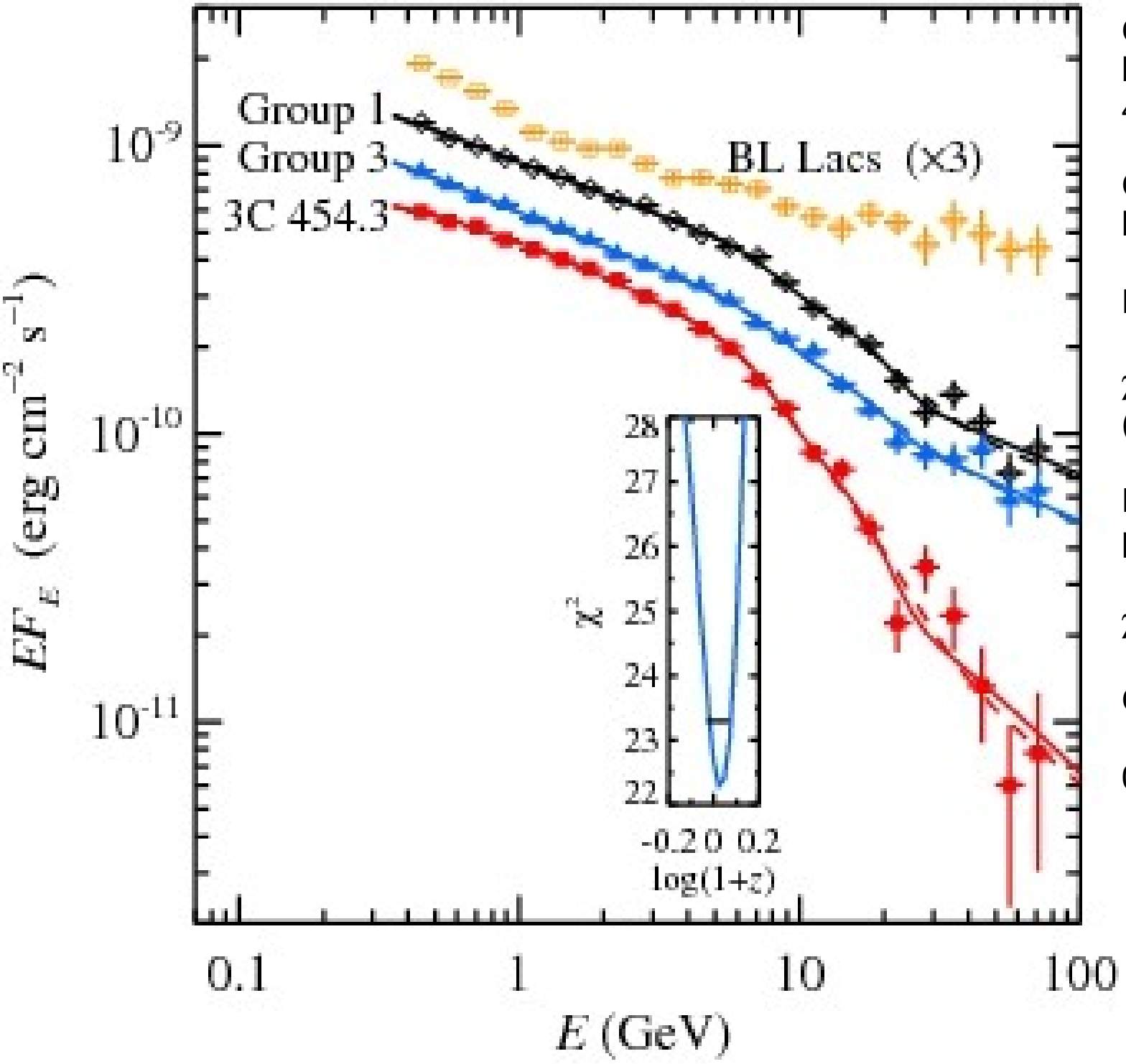
The sample:

- 1-st Fermi catalog. Flat spectrum radio quasars or “low peak” BL Lacs,
- z > 0.4
- detection significance > 20 sigma.

39 objects

2 brightness groups 11 brightest except 3C454
27 next brightest

	Np >1Gev	z	χ^2_{PL}	χ^2_{Lgnr}	$\chi^2_{Lgnr+abs}$	
3c279a	2200	0.536	109	11.9	11.2	
4c21	2600	0.454	100	14.6	5.1	
4c38	1700	1.81	192	23	18.	
pks0235	1600	0.94	52	6.4	6.0	
pks0426	2200	1.03	46	38	34	
pks0454	1400	1.00	75	23.7	21.5	
pks0537	3600	0.892	56	37	33	
pks1424	1500	1.52	23	17.8	14.2	(tau1=0)
pks1502	2800	1.84	200	16	6.9	
txs1520	1900	1.48	42	6.4	3.1	
pks1510	3500	0.36	120	9.5	4.7	



Group1 – 11 brightest blazars except 3C 454.3

Group3 – next 27 brightest blazars

Lognormal:

χ^2 = 89, 41, 112 (20 dof)

BLR absorption x = 2.5, partial covering:

χ^2 = 22, 15, 24 (18 dof)

Covering:

0.64, 0.5, 0.8

Conclusions

- A fraction (> 0.5) of blazar gamma-ray emission is produced in the inner (high ionization) part of BLR.

- This means that the jet is accelerated to $\Gamma > 10$ within 1000 Rg.

- As far as acceleration is quite slow ($\Gamma \sim \sqrt{(R/R_o)} * f$, $f < 1$), $R_o \sim R_g$, i.e. Blandford-Znajek mechanism works. Accretion disk as an inductor is ruled out!

- The one-zone mechanism (synnchrotron-self Compton or synchrotron - external Compton) is ruled out, because the magnetic field is too strong