Multi-wavelength observation of the 2006 TeV active state of PKS2155-304

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on behalf of the **H.E.S.S. Collaboration**
TeVPA 08 Conference
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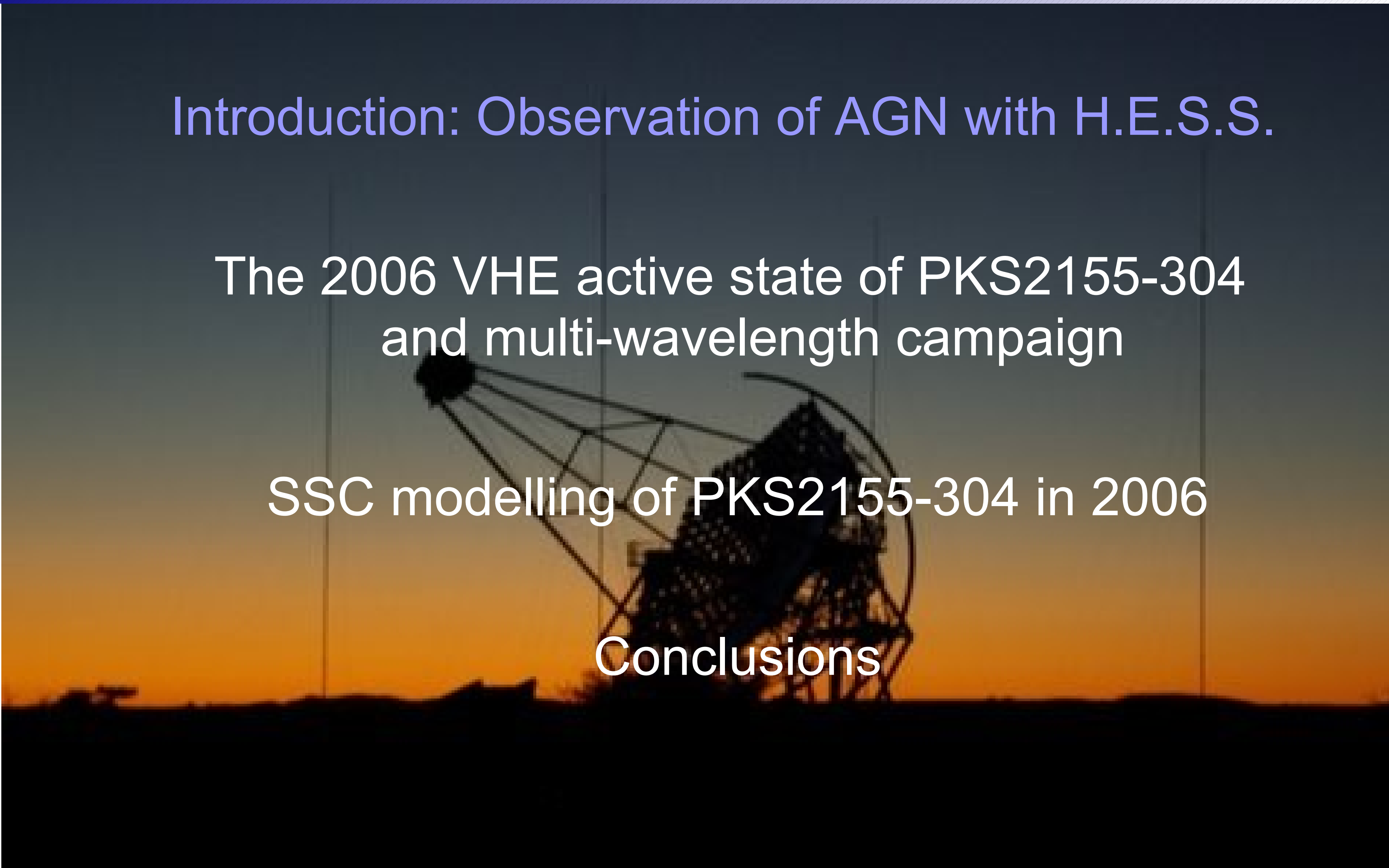
l'Observatoire de Paris | LUTH

Laboratoire de l'Univers et de ses Théories

H E S S

Outline



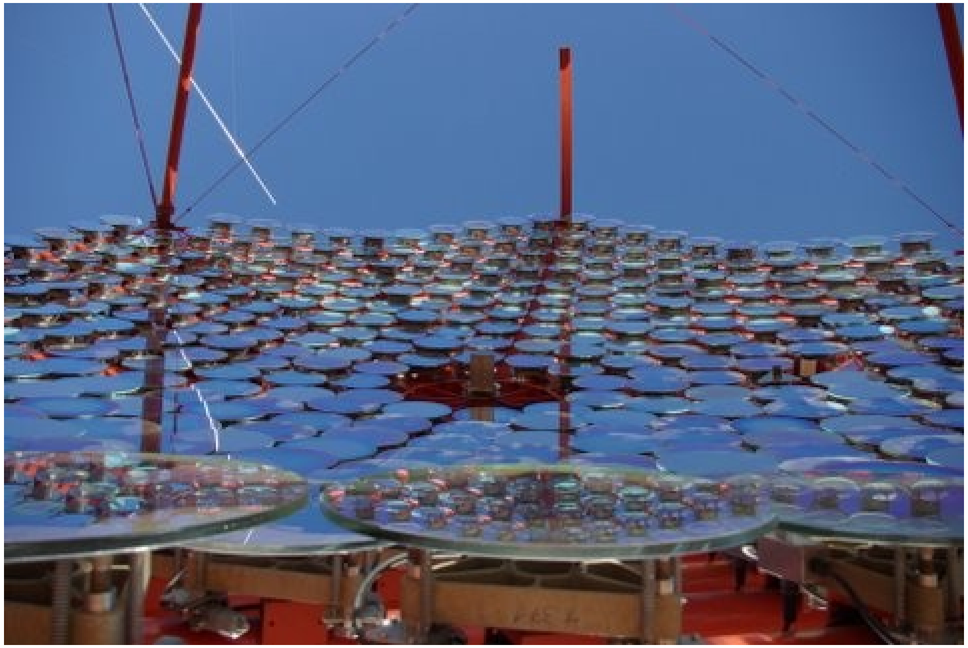
Introduction: Observation of AGN with H.E.S.S.

The 2006 VHE active state of PKS2155-304
and multi-wavelength campaign

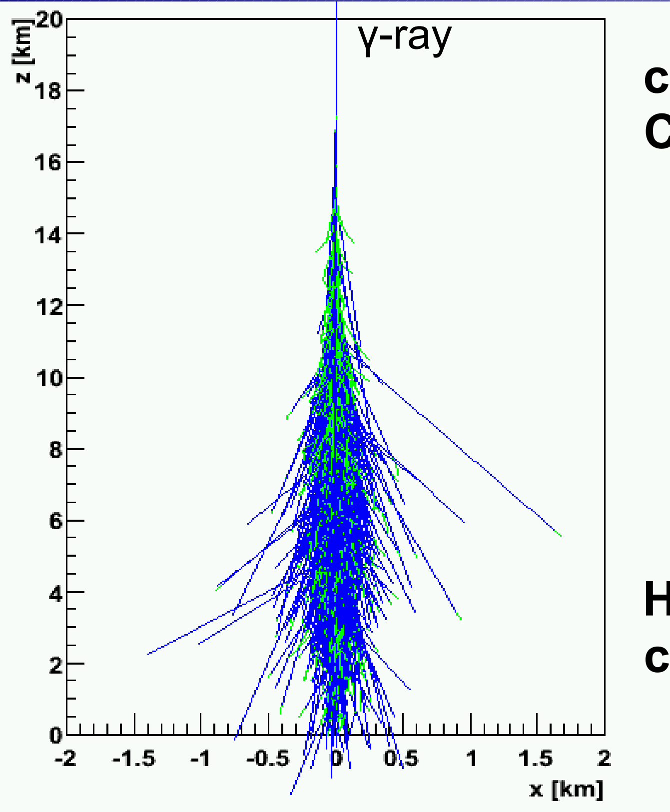
SSC modelling of PKS2155-304 in 2006

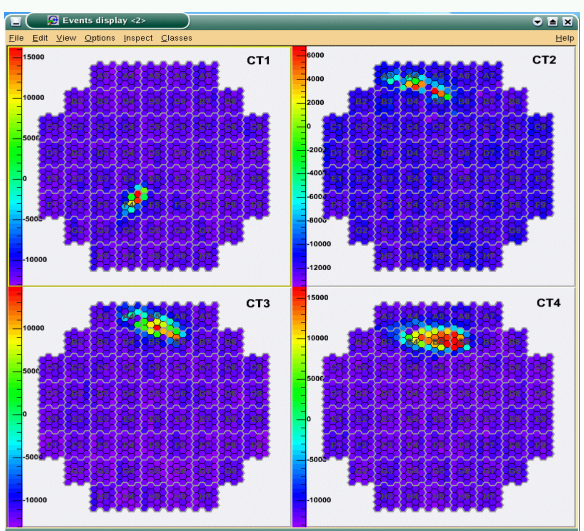
Conclusions

Introduction:
Observation of AGN with H.E.S.S.



The H.E.S.S. Cherenkov Telescope Array





currently four Imaging Air Cherenkov Telescopes

- effective mirror surface 107 m^2, camera f.o.v. 5°
- 960 PMT per camera, f.o.v. 0.16°
- E thresh ~ 100 GeV

H.E.S.S.-II is now under construction

- effective mirror surface 600 m^2, camera f.o.v. 3.5°
- 2048 PMT per camera, f.o.v. 0.08°
- E thresh ~ 50 GeV

=> detect lower energies

-> less absorption by EBL

-> **reach higher redshifts**

Upper limits on AGN observed by H.E.S.S.

Object[a]	T [hrs]	Z_{obs} [°]	On	Off	Norm	Excess	S [σ]	E_{th} [GeV]	$I(>E_{th})$ [10^{-12} cm^{-2} s^{-1}]	Crab %	$P(\chi^2)$
Blazars											
III Zw 2[U]	4.9	38	169	1801	0.0916	4	0.3	430	<2.14	<2.7	0.19
BWE 0210+116[U]	6.0	43	176	3752	0.0504	−13	−0.9	530	<0.72	<1.2	0.74
1ES 0323+022	7.2	27	321	3302	0.0932	13	0.7	300	<2.52	<1.9	0.59
PKS 0521−365[U]	3.1	26	180	1818	0.0928	11	0.8	310	<5.40	<4.2	0.45
3C 273[U]	16.5	29	848	8678	0.0932	39	1.3	300	<1.97	<1.4	0.89
3C 279[U]	2.0	26	100	1012	0.0942	5	0.5	300	<3.98	<2.9	0.44
RBS 1888	2.4	15	184	1625	0.0949	30	2.2	240	<9.26	<4.9	0.39
HS 2250+1926[U]	17.5	44	597	6536	0.0923	−6	−0.2	590	<0.45	<0.9	0.58
PKS 2316−423	4.1	20	299	2910	0.0929	29	1.6	270	<4.74	<3.0	0.58
1ES 2343−151[U]	8.6	17	557	6286	0.0911	−16	−0.6	230	<2.45	<1.2	0.67
Non-blazar											
NGC 1068	1.8	29	75	687	0.0955	9	1.1	330	<5.76	<4.9	0.47
Pictor A	7.9	31	397	4501	0.0932	−23	−1.1	320	<2.45	<2.0	0.54
PKS 0558−504[U]	8.3	28	426	4740	0.0929	−14	−0.7	310	<2.38	<1.8	0.80
NGC 7469	3.4	34	98	1234	0.0909	−14	−1.3	330	<1.38	<1.2	0.59

[a] The superscript U marks the eight VHE upper limits (99.9% c.l.) that are the most constraining ever published for the corresponding objects.

Aharonian et al. 2008, A&A 478, 387-393

\+ upper limits on two known VHE AGN at low altitude (1ES 1218+304 and Mkn421)

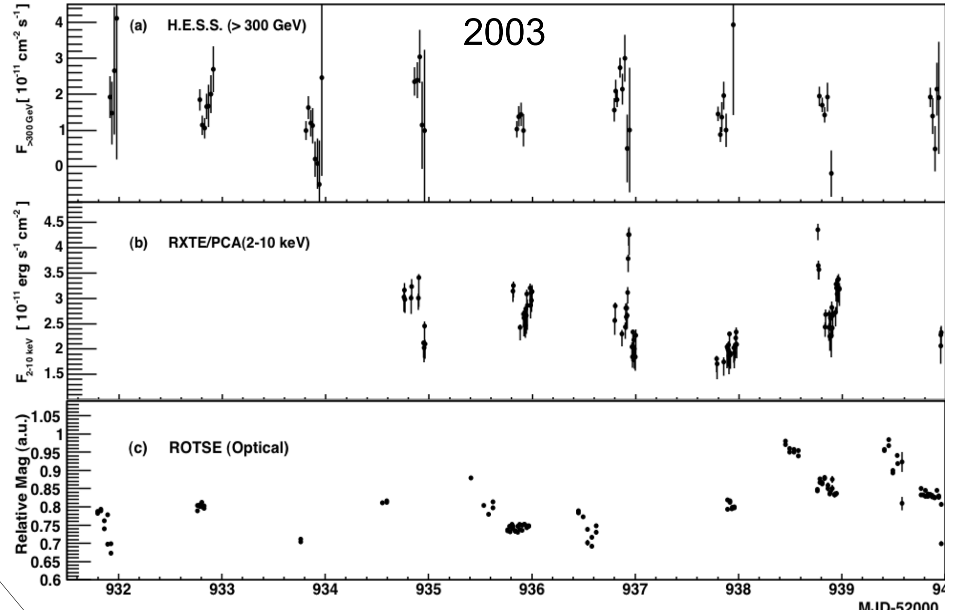
AGN detected by H.E.S.S.

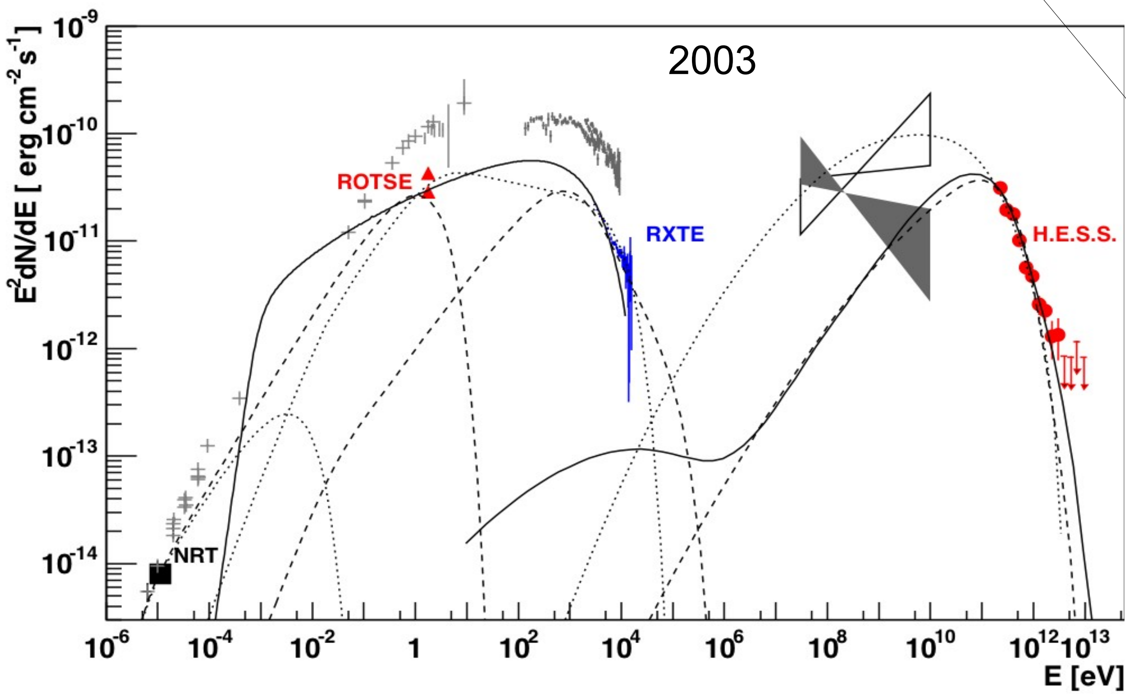
Source	Type	z	discovery	reference
RGBJ0152+017	**BLLac (HBL)**	**0.080**	*	***Aharonian et al 2008, A&A 481, L103***
PKS0548-322	BLLac (HBL)	0.069	*	*Superina et al. 2007, Proc. of ICRC '07*
1ES0229+200	BLLac (HBL)	0.139	*	*Aharonian et al 2007, A&A 475, L9*
1ES1101-232	BLLac (HBL)	0.186	*	*Aharonian et al 2007, A&A 470, 475*
1ES0347-121	BLLac (HBL)	0.188	*	*Aharonian et al 2007, A&A 473, L25*
PG1553+113	BLLac (HBL)	0.360 (?)	*	*Aharonian et al 2006, A&A 448, L19*
M87	AGN (FR I)	0.0042		*Aharonian et al 2006, Science 314, 1424*
H2356-309	BLLac (HBL)	0.165	*	*Aharonian et al 2006, A&A 455, 461*
MKN421	BLLac (HBL)	0.030		*Aharonian et al 2005, A&A 437, 95*
PKS2005-489	BLLac (HBL)	0.071	*	*Aharonian et al 2005, A&A 436, L17*
PKS2155-304	BLLac (HBL)	0.116		*Aharonian et al 2005, A&A 430, 865; ...*

thanks to: L. Gérard

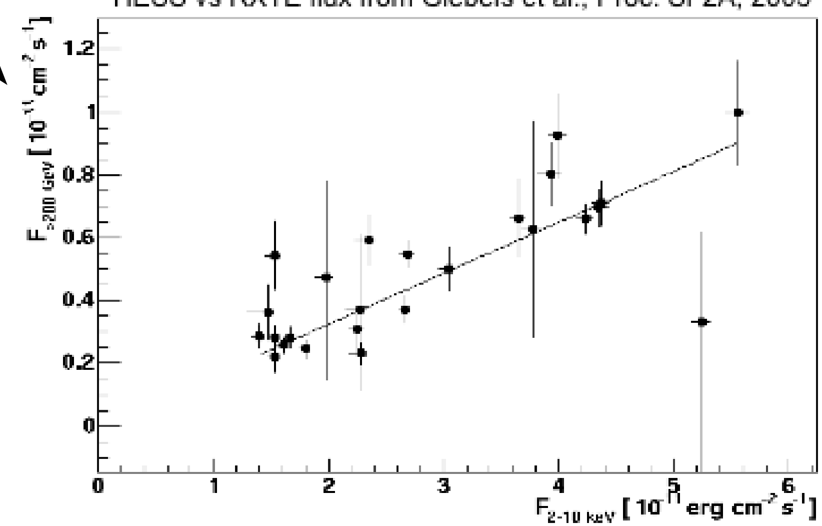
Previous observations of PKS 2155-304 by H.E.S.S.

- VHE discovery by the Durham group (Mark 6 telescope) in 1999
- 2003 MWL campaign (*Aharonian et al. 2005, A&A 430, 865 & 442, 895, ->figures*)
  - low state; no correlation between X-ray, VHE, optical
  - VHE variability up to factor 2.5 in ~2h
  - SSC models: blob-in-jet -> X-ray and VHE, VLBI core -> radio (and optical)
  - hadronic model: synchrotron proton blazar
- 2004 data : linear correlation VHE and X-ray

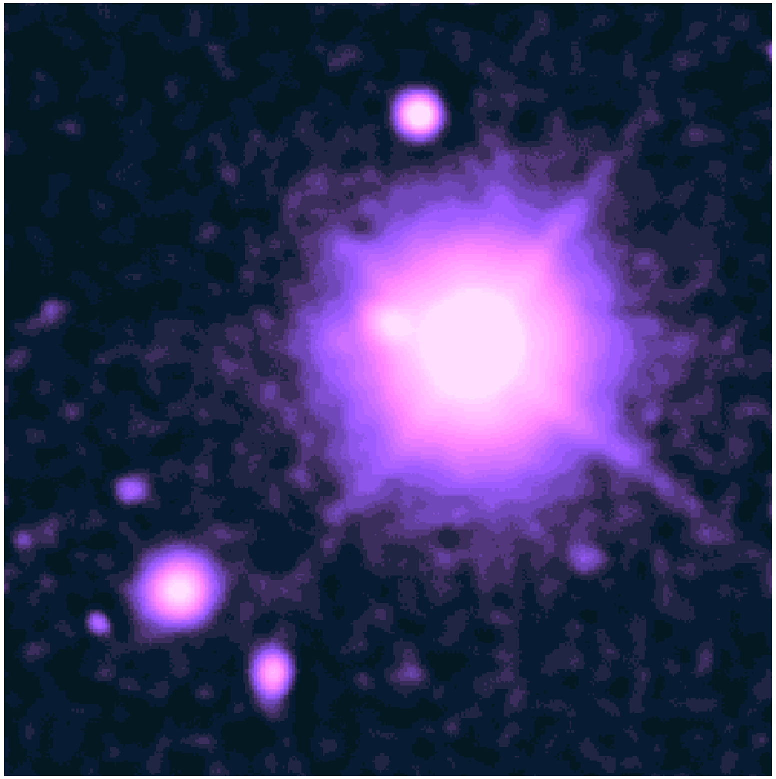




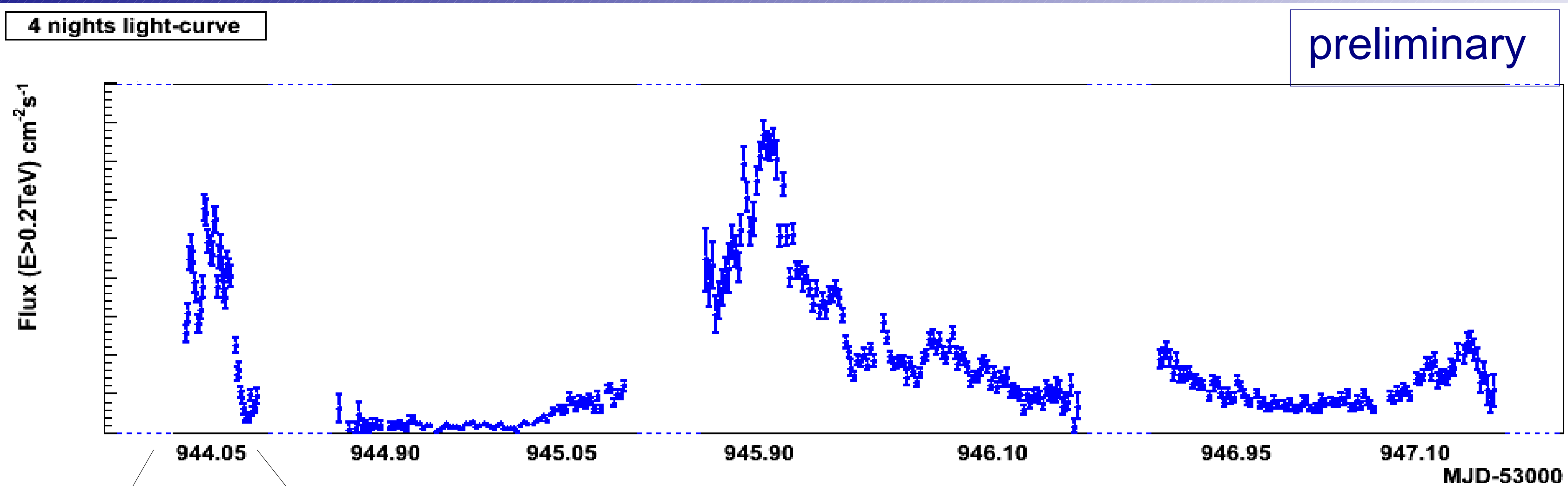
HESS vs RXTE flux from Giebels et al., Proc. SF2A, 2005

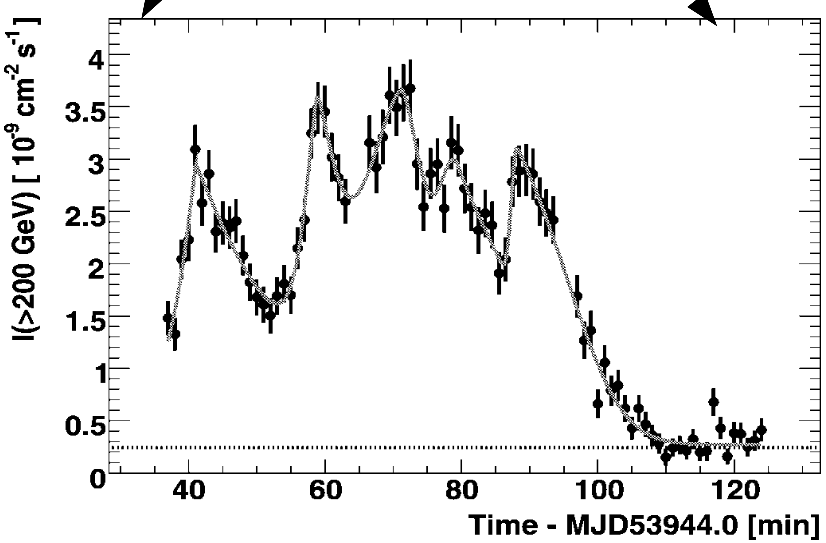


The 2006 TeV high state of PKS 2155-304 and multi-wavelength campaign



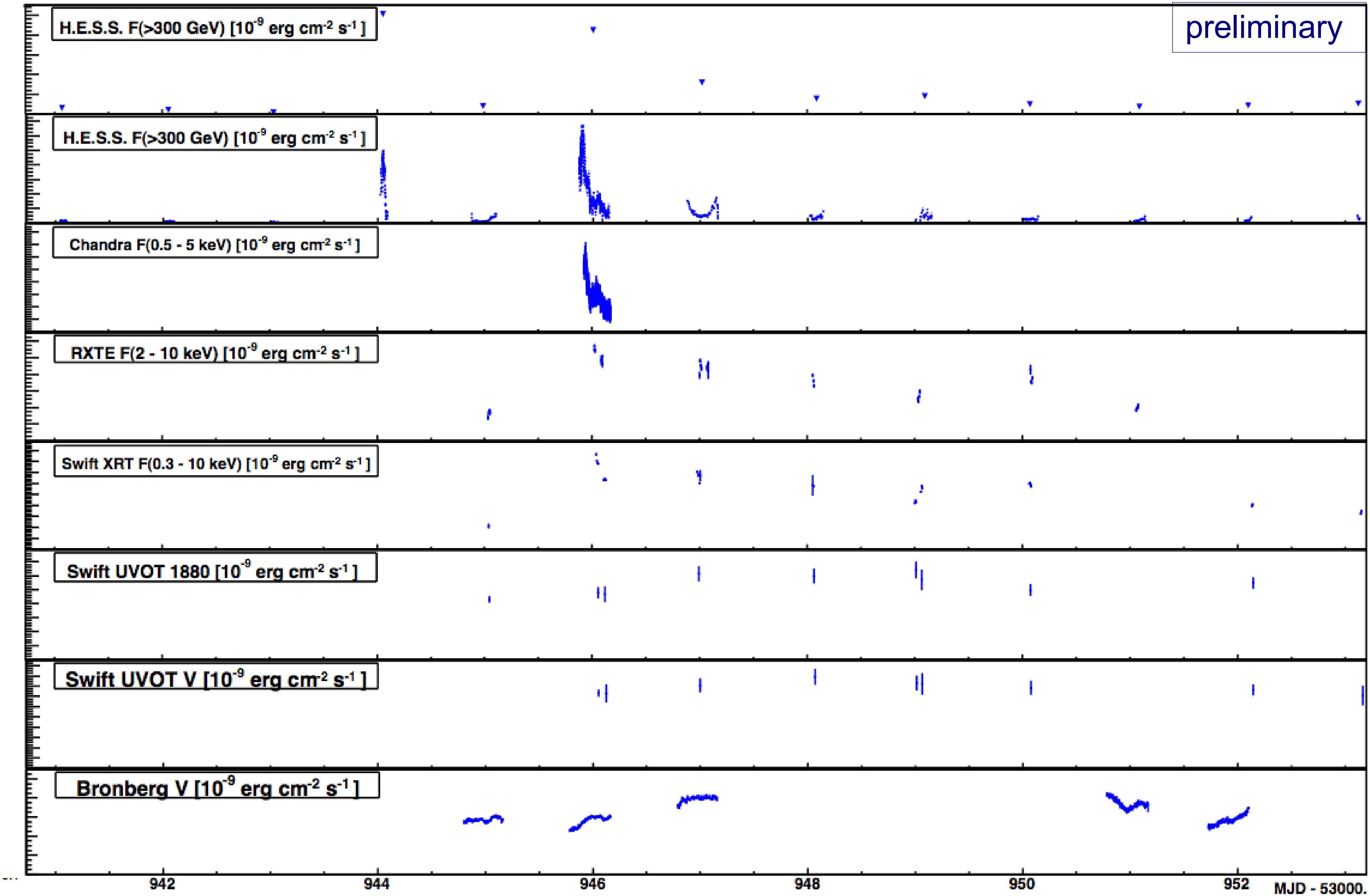
Two exceptional VHE flares



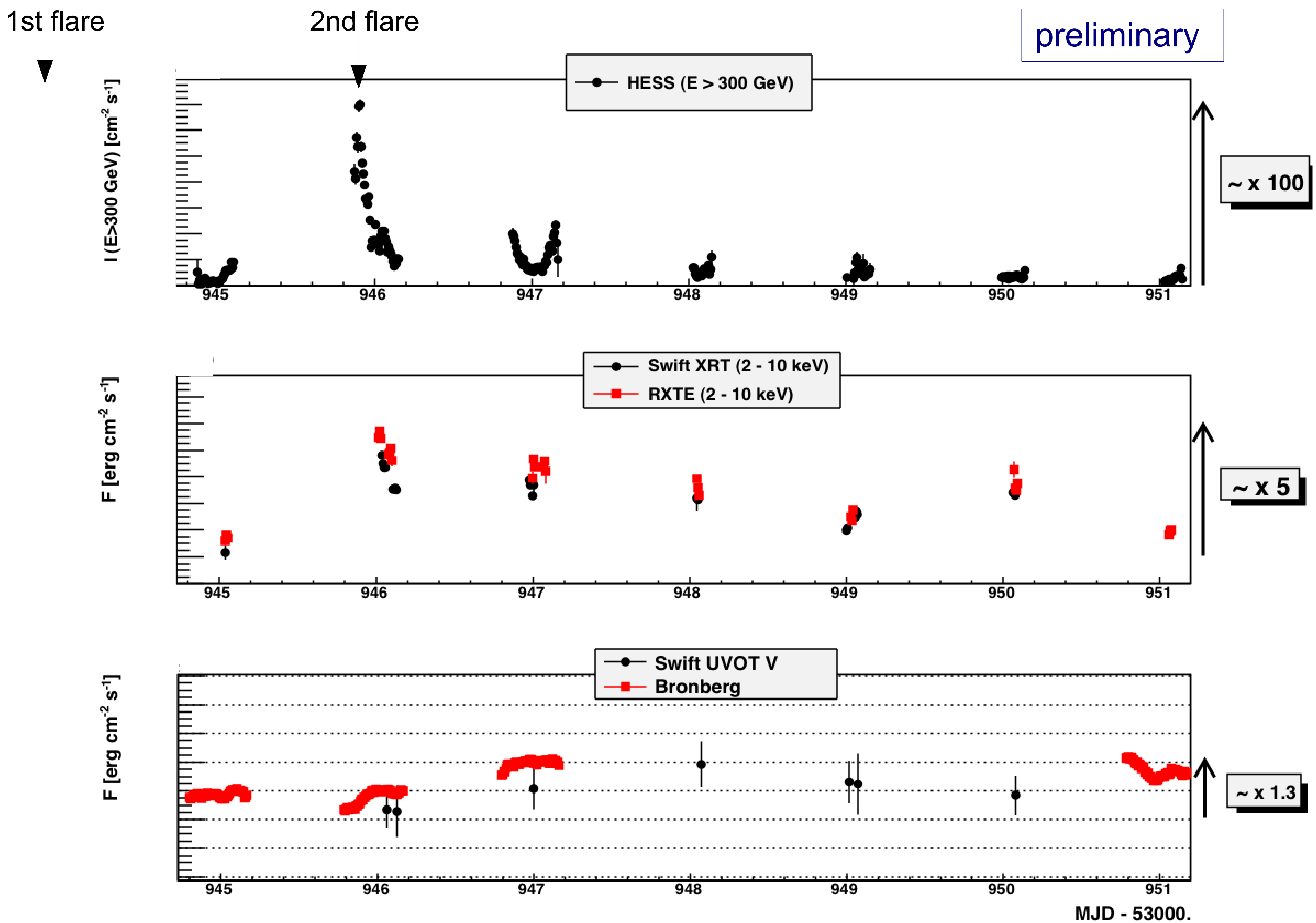


- **1st flare (July 27/28)** (Aharonian et al. (2007), ApJ 664, L71):
  - variability down to ~200 s (fastest ever from blazar at VHE)
  - flux varies from 0.65 to 15.1 the Crab flux (>200 GeV)
  - limits on quantum gravity (*paper accepted by PRL*)
- **2nd flare (July 29/30)** (*paper in preparation*) :
  - very short time scale variability
  - again very large flux variation during the night
  - simultaneous X-ray and optical data available
    -> correlation with X-ray data (Chandra); no time lag

Multi-wavelength data

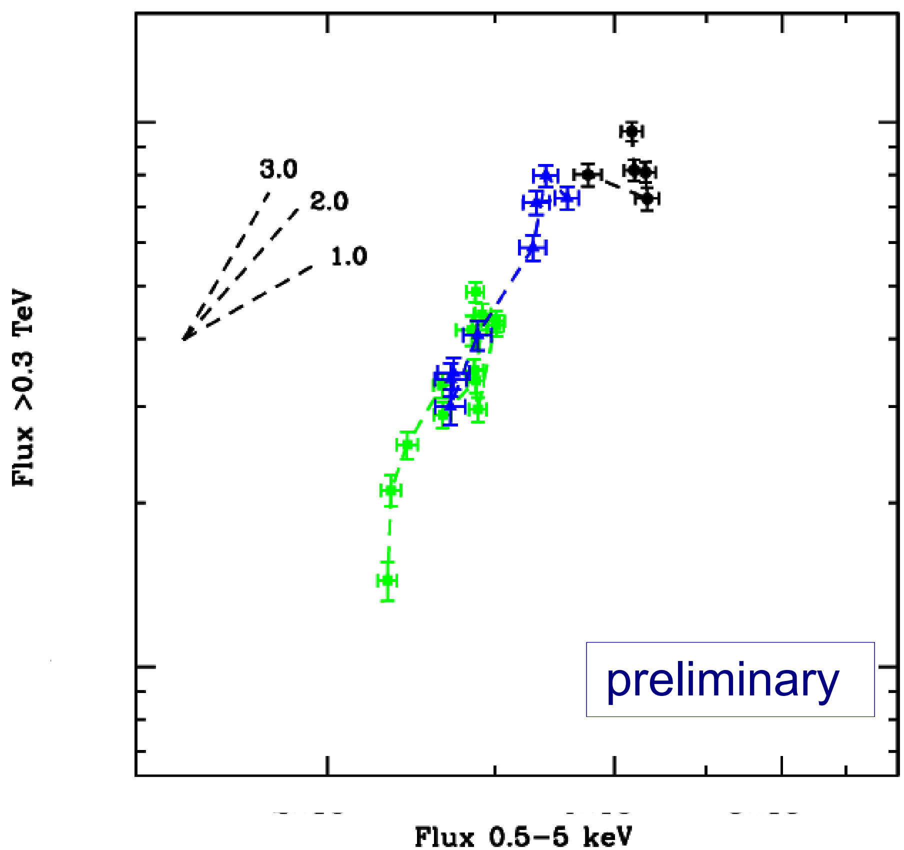


VHE / X-ray / optical band

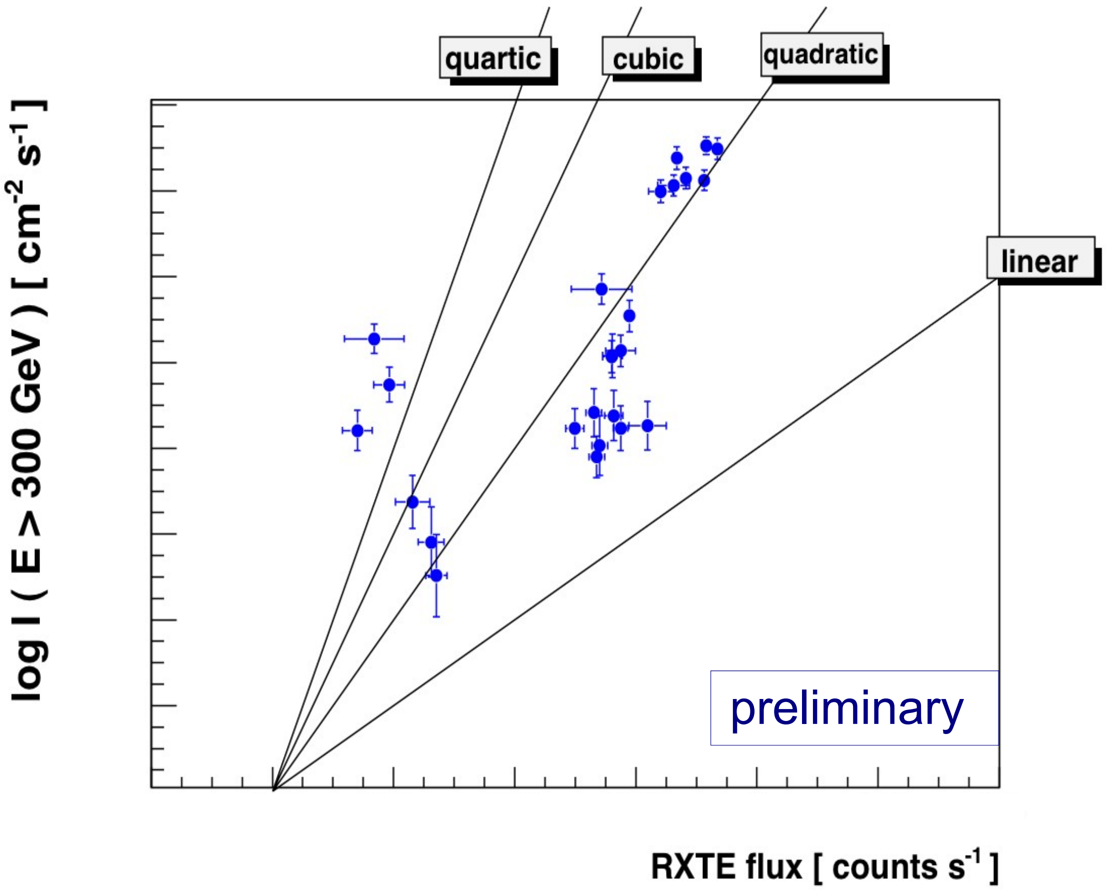


A closer look at VHE/X-ray correlation

very steep correlation between X-ray and VHE in the decaying phase
=> serious problem for one-zone SSC models



L. Costamante for H.E.S.S., workshop in Dublin, 2007

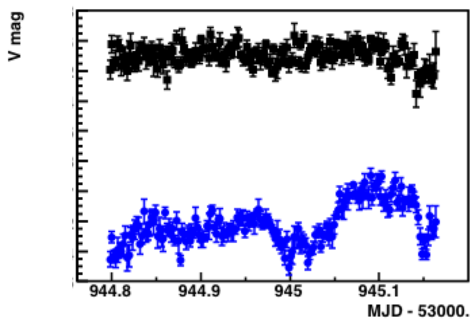


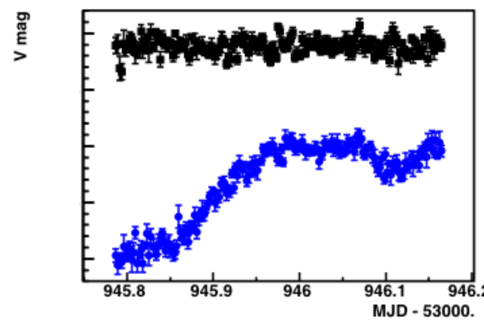
VHE vs. X-ray flux for the night of the second flare (left) and for the whole 2006 campaign (right).

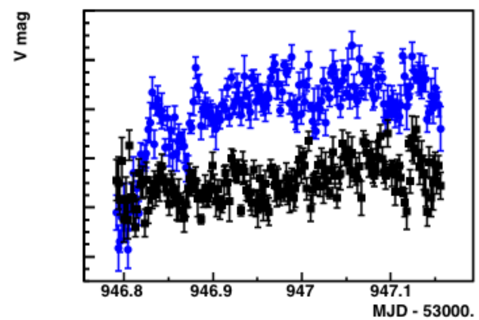
Optical light curve (Bronberg Observatory)

night of 2nd VHE flare

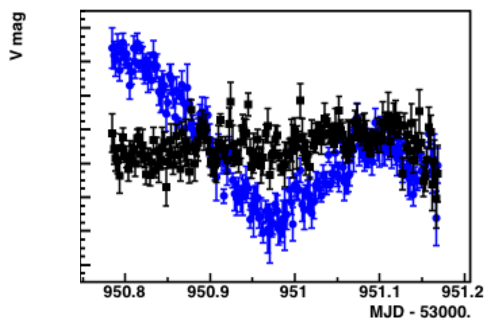
beginning of MWL campaign (MJD 945 - 947)

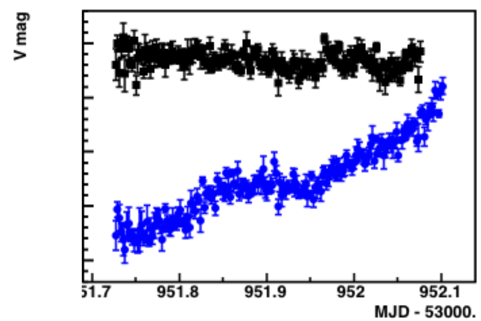






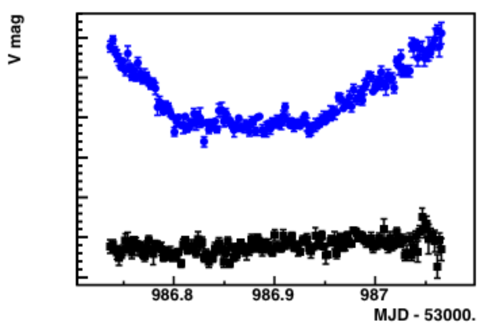
end of MWL campaign (MJD 951 - 952)

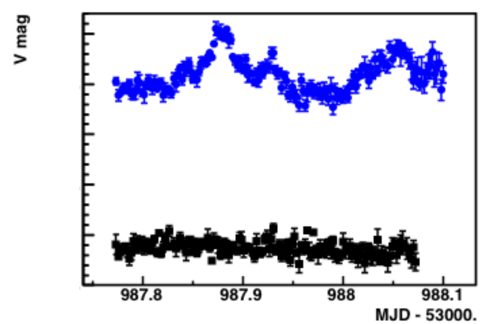


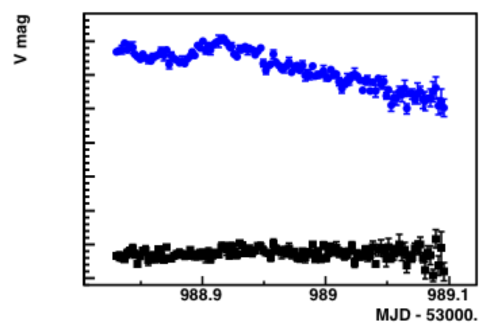


preliminary

after MWL campaign (MJD 987 - 989)

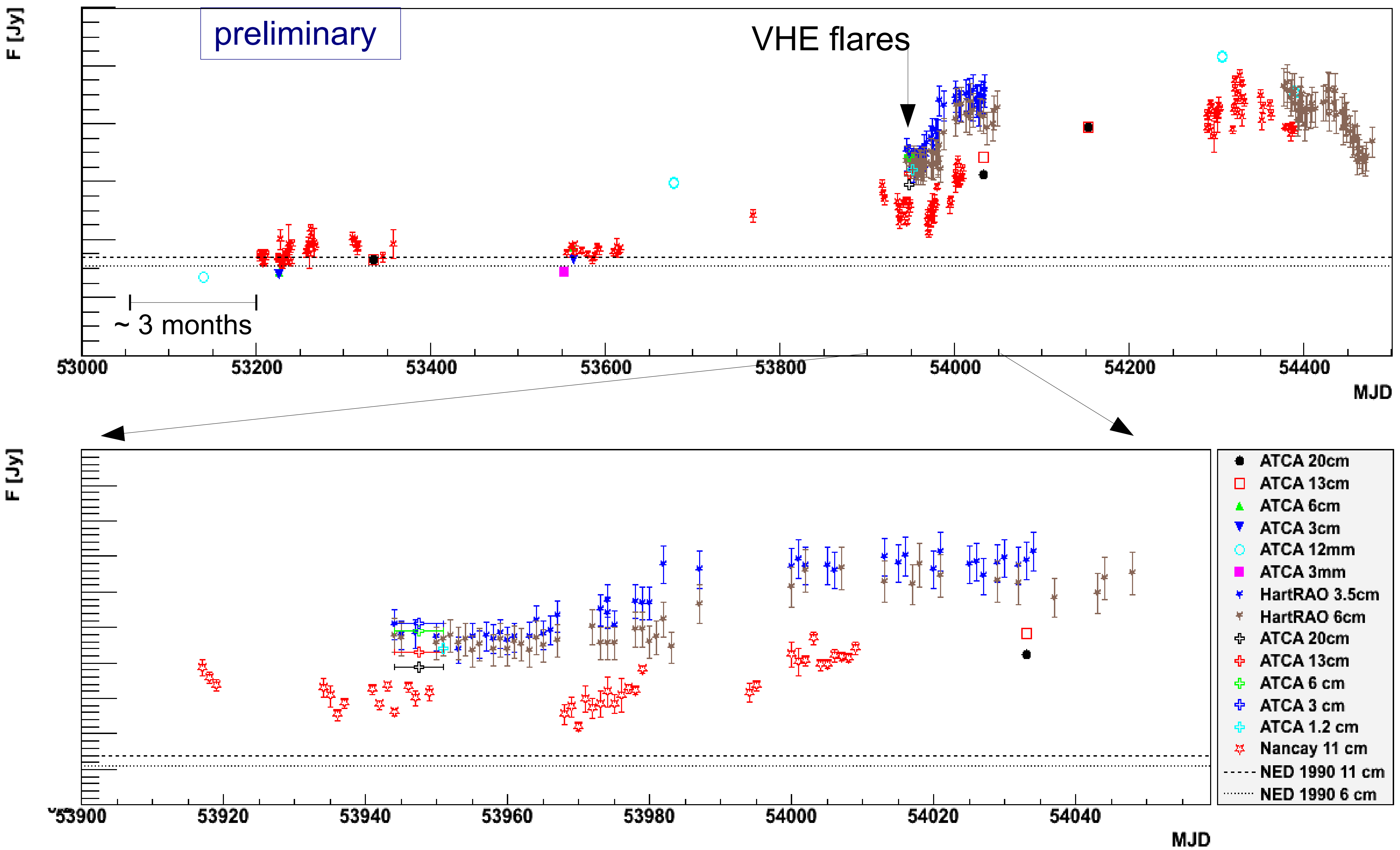




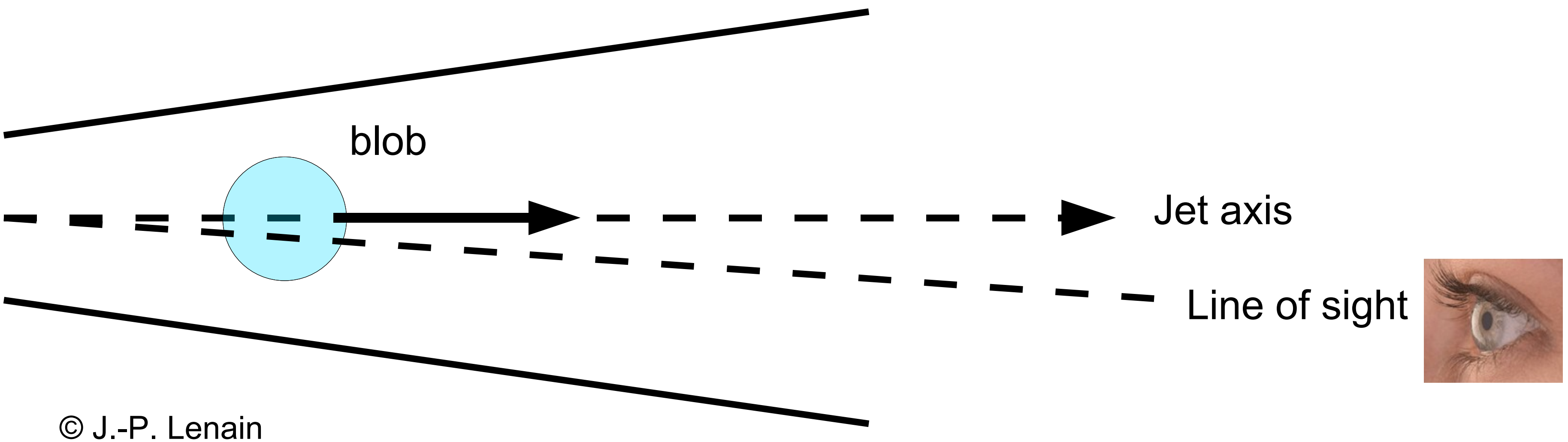


blue: PKS2155, black: reference star

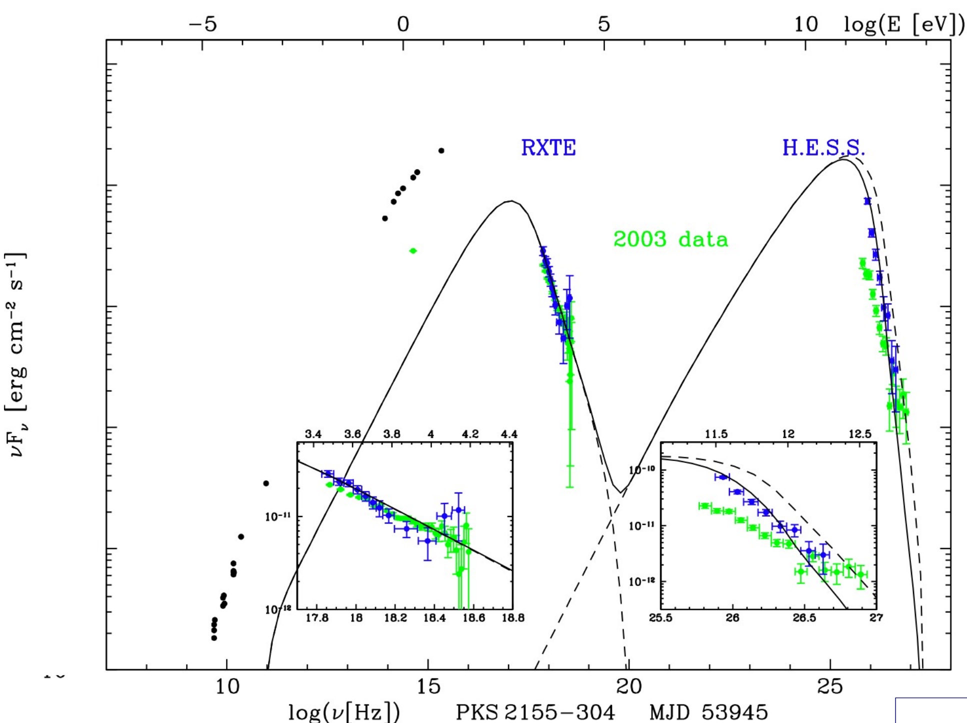
Radio light curve

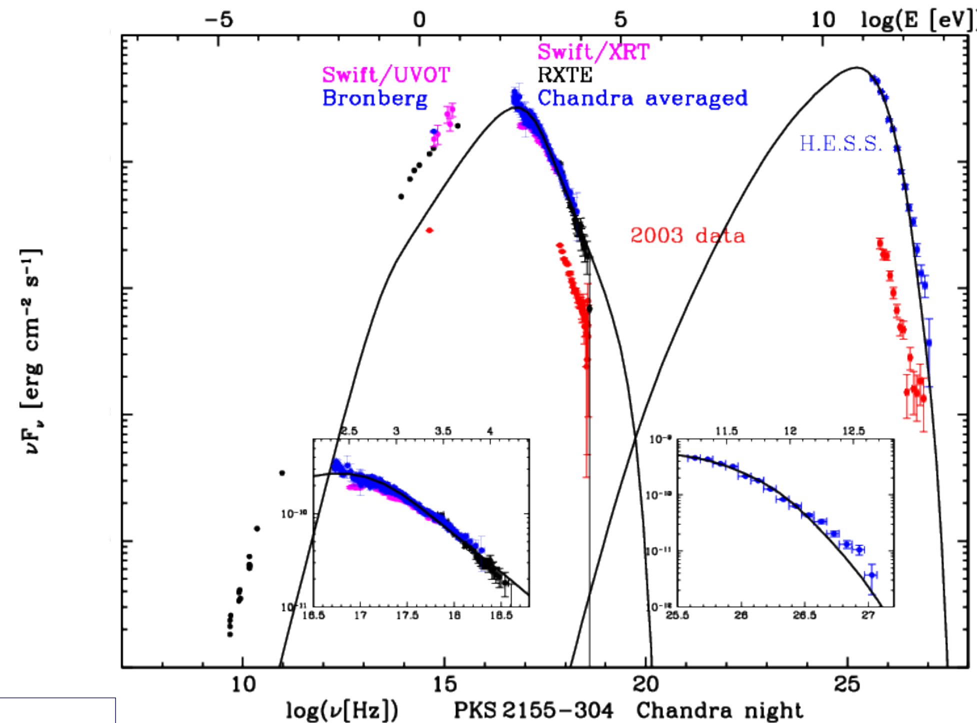


Synchrotron Self-Compton (SSC) modelling of PKS2155-304



Stationary SSC modelling





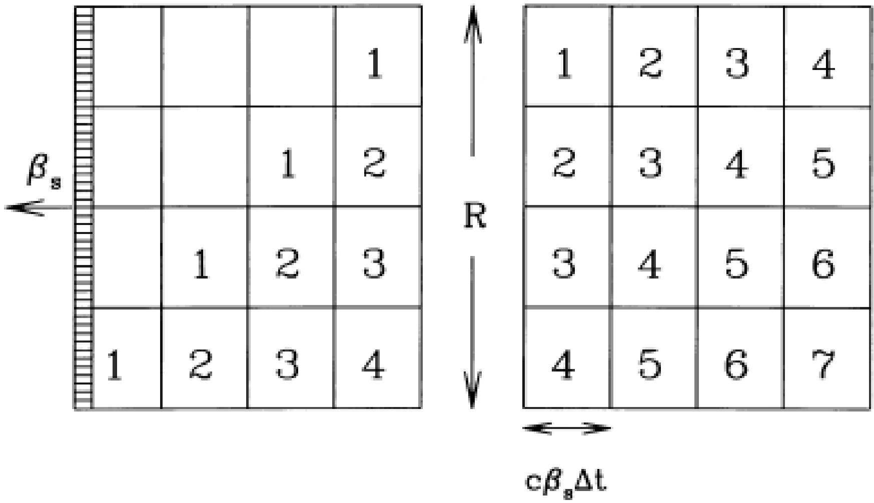
preliminary

based on *Katarzynski, Sol, Kus (2001)*, to be published in the *upcoming MWL paper*

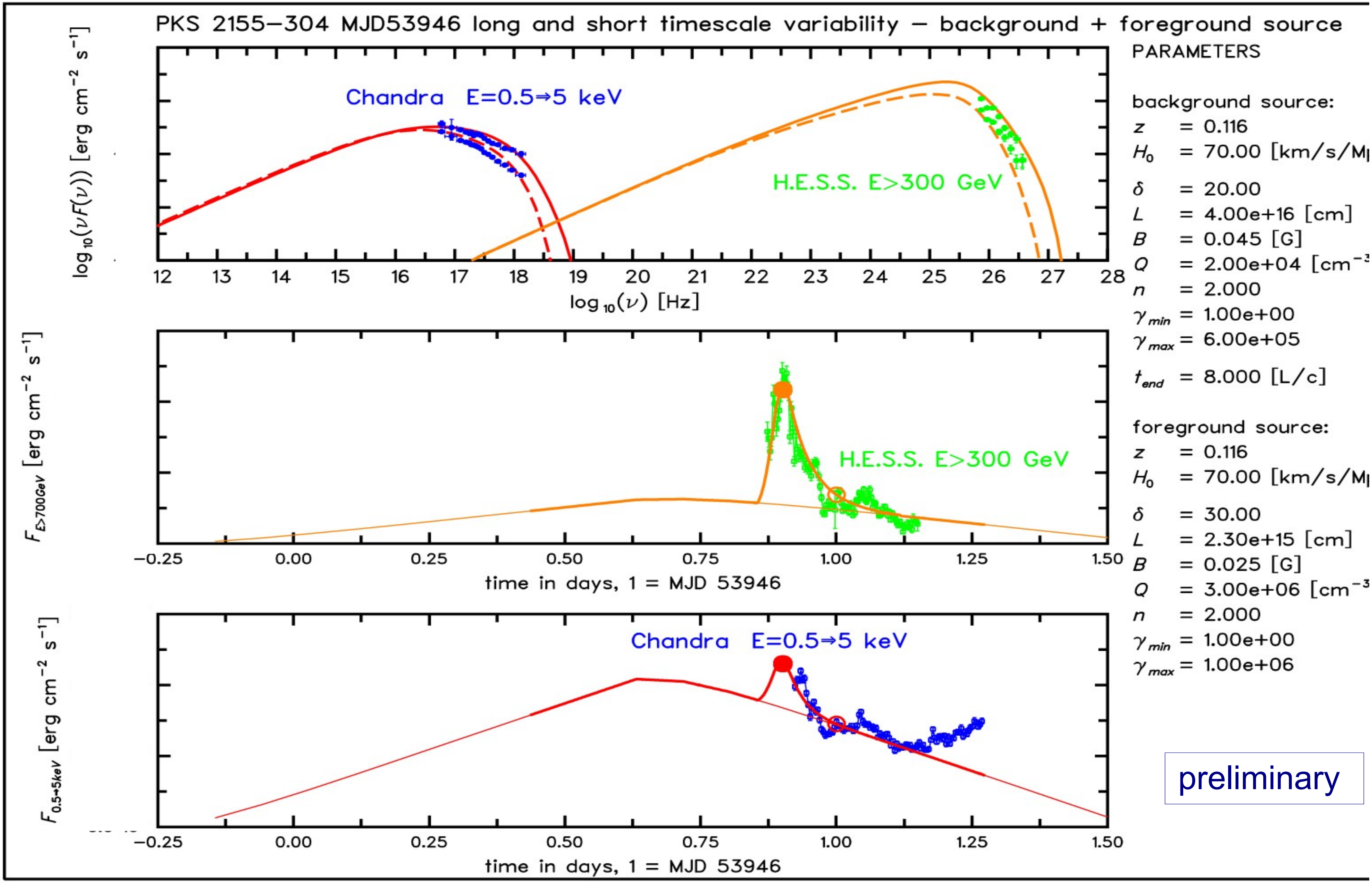
Date (MJD)	(2003)	53945	53946	53947	53948	53949	53950
Figure	see Aharonian et al. (2005b)	9	10	-	-	11	-
δ_b	25	25	60	25	25	25	25
B [G]	0.25	0.25	0.10	0.25	0.25	0.25	0.25
r_b [cm]	1.5×10^{15}	2.25×10^{15}	2.3×10^{15}	1.7×10^{15}	2.4×10^{15}	3.5×10^{15}	3.1×10^{15}
K_1 [cm^{-3}]	2.0×10^{3}	2.82×10^{3}	6.30×10^{4}	6.86×10^{3}	2.44×10^{3}	2.25×10^{3}	1.13×10^{3}

Time-dependent model 1

- **dynamic 2-zone SSC model**
  based on *Chiaberge & Ghisellini (2002) MNRAS 306, 3, p. 551ff. (->figure)*, with modifications described in *Katarzynski et al. (2008), MNRAS,* application to 2nd flare to be published in the *upcoming MWL paper*
- **applied to 2nd flare night:**
  - **a large source dominates X-ray**
  - **a small, dense source dominates VHE**
- **source development:**
  - source = homogeneous slices of area RxR and length r << R,
  - Injection of a power law electron energy spectrum with index 2 (e.g. shock wave)
  - radiative cooling: synchrotron, IC
- **treats external light-crossing time effect**
  => broken power law in synchrotron spectrum
- **absorption by pair production in source**

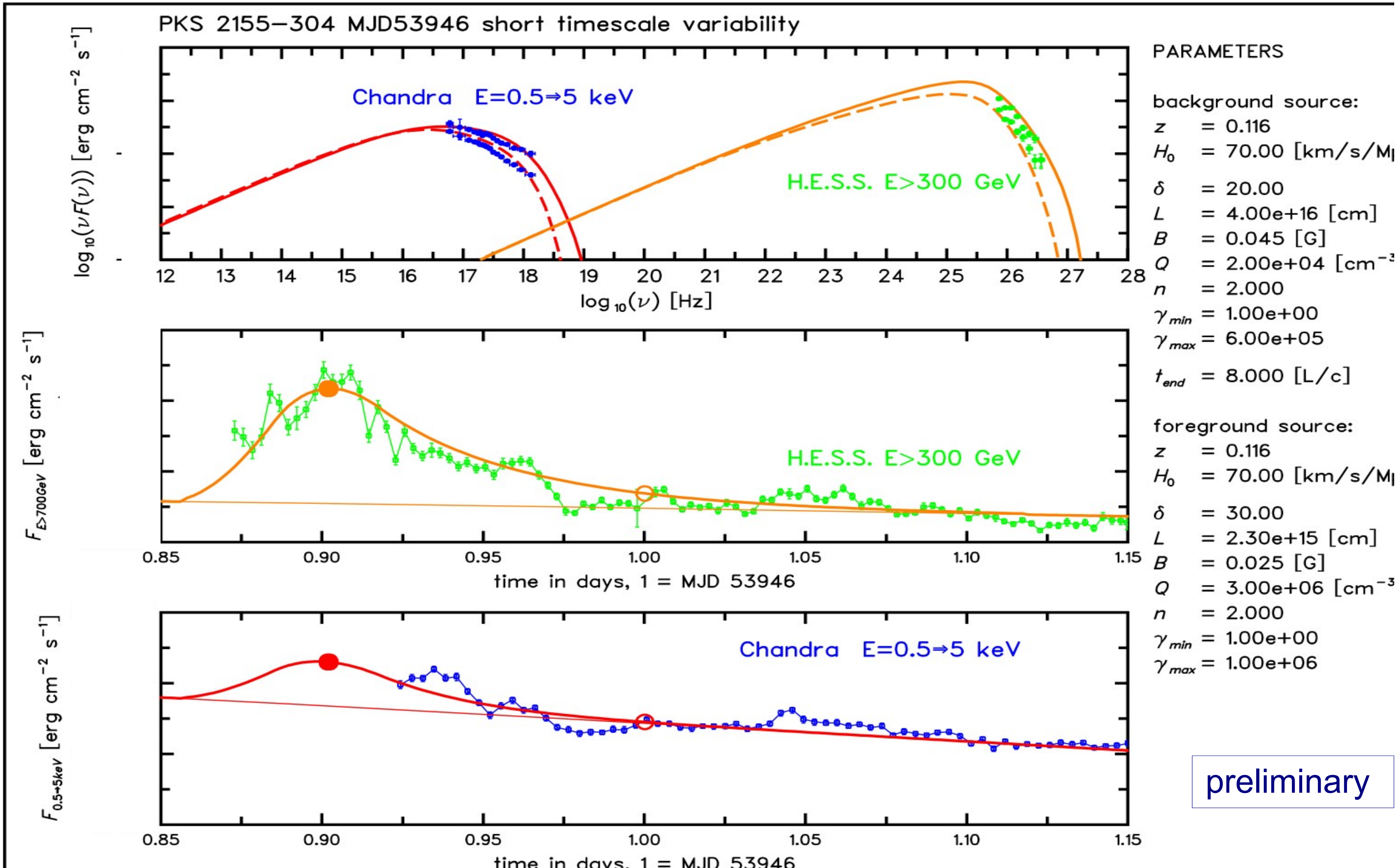


Time-dependent SSC modelling of the 2nd flare (model 1)



preliminary

Time-dependent SSC modelling of the 2nd flare (model 1, zoom on the VHE flare)

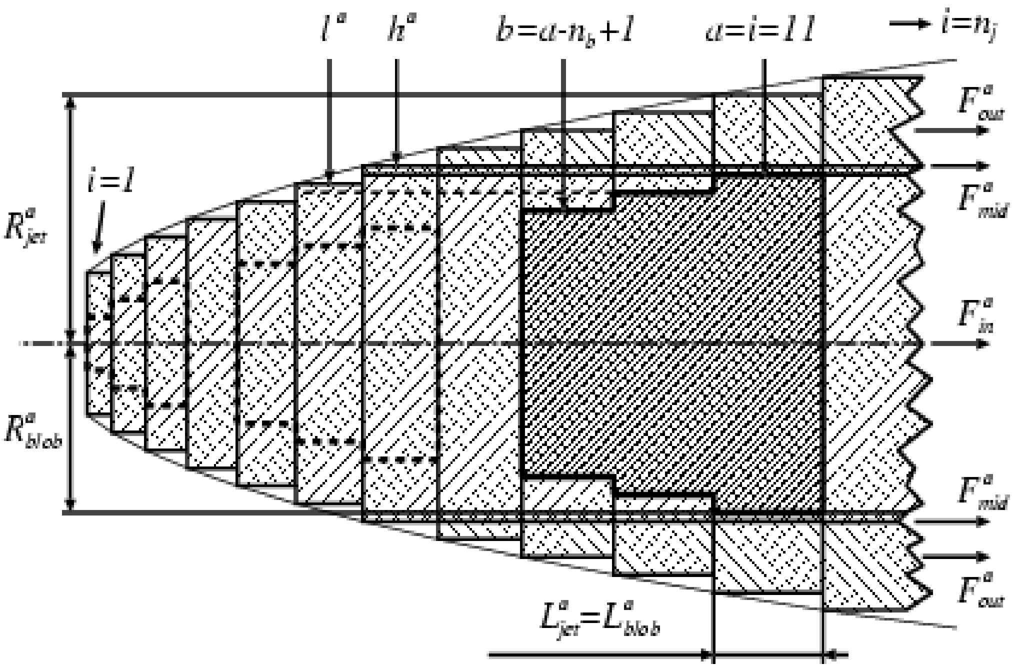


Time-dependent model 2

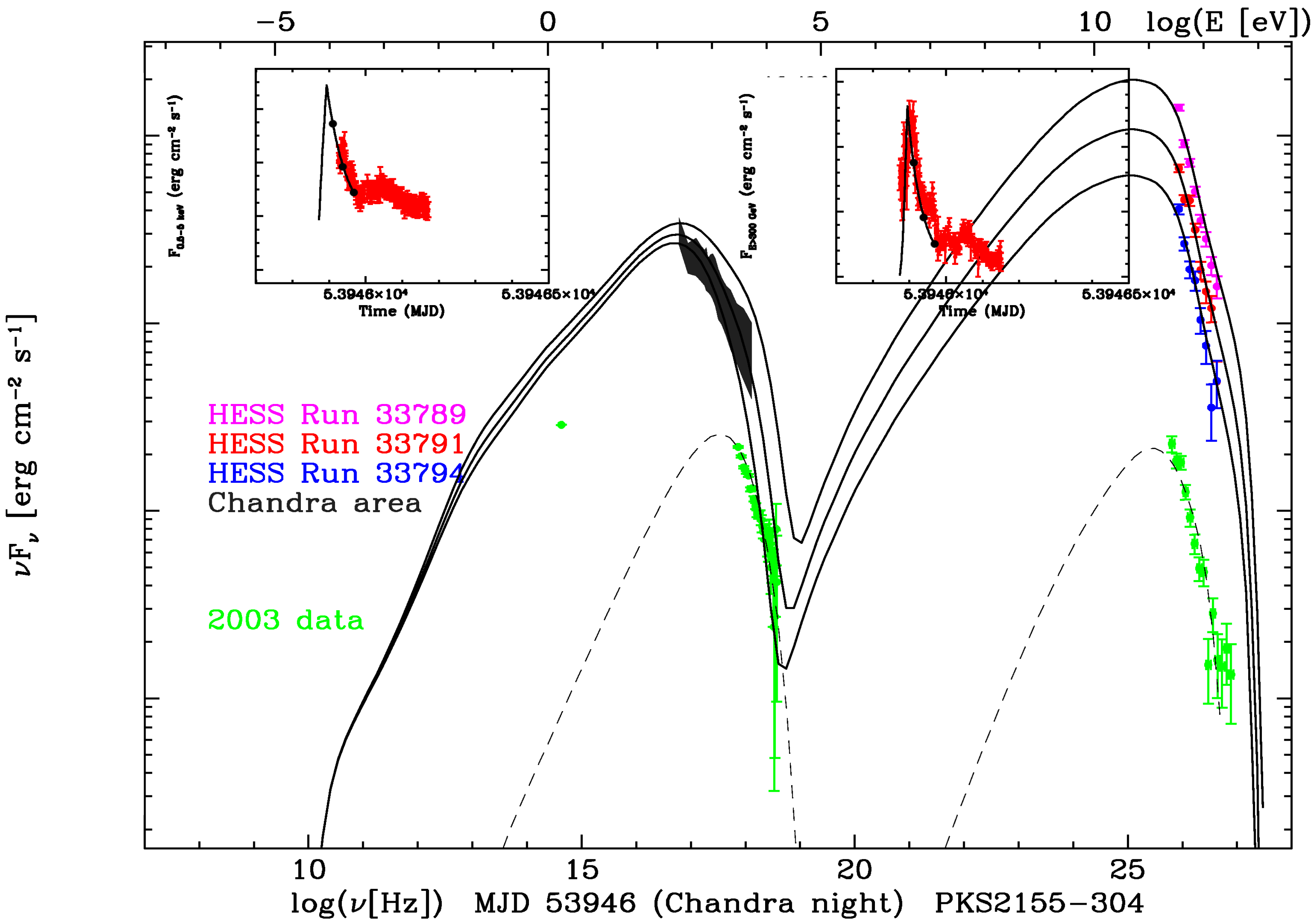
- **dynamic 2-zone SSC model**
  based on *Katarzynski, Sol, Kus (2003) A&A 410, 101* *(->figure)*, see also *J.P. Lenain et al. (for H.E.S.S.) , Proc. of Gamma 08*, update to be published in the *upcoming MWL paper*

- **more realistic source description:**
  - Conical jet (cylindrical slices): only synchrotron emission -> X-ray peak
  - Blob-in-jet: dense region inside jet -> synchrotron + IC emission
  - Injection of electron energy spectrum
  - Radiative cooling (synchrotron + IC), adiabatic cooling

- **treats radiative transfer (pair production, electron absorption) between slices**



Time-dependent SSC modelling of the 2nd flare (model 2)



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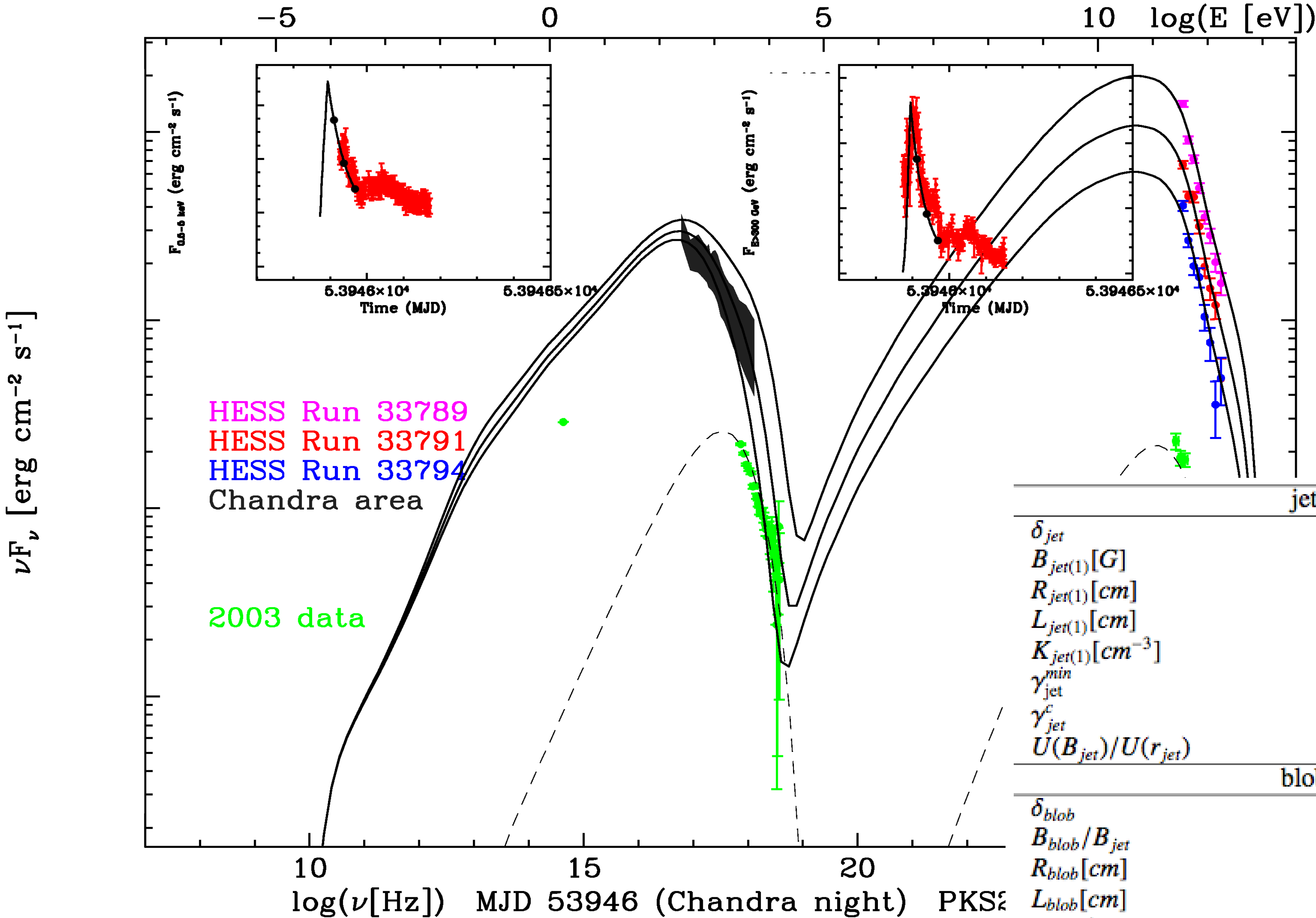
Time-dependent SSC modelling of the 2nd flare (model 2)



preliminary

jet parameters	
δ_{jet}	50
$B_{jet(1)}[G]$	1.0×10^{-2}
$R_{jet(1)}[cm]$	6.0×10^{16}
$L_{jet(1)}[cm]$	2.0×10^{14}
$K_{jet(1)}[cm^{-3}]$	2.3×10^{3}
γ_{jet}^{min}	1.0
γ_{jet}^{c}	4.0×10^{5}
$U(B_{jet})/U(r_{jet})$	1.0×10^{3}
blob parameters	
δ_{blob}	50
B_{blob}/B_{jet}	3.30
$R_{blob}[cm]$	6.0×10^{15}
$L_{blob}[cm]$	2.0×10^{14}
K_{blob}/K_{jet}	4.2×10^{3}
γ_{blob}^{min}	1.0×10^{3}
$\gamma_{blob}^{c}/\gamma_{jet}^{c}$	1.84
n_{blob}	2.45
$U(B_{blob})/U(r_{blob})$	2.0

Conclusions

- very rich data-set stresses the importance of coordinated MWL campaigns
- **stationary one-zone SSC model explains average nightly behaviour**
- **steep correlation VHE/X-ray** during the second flare night poses a serious problem for one-zone SSC models at intra-night scales
- **time-dependent two-zone SSC models can explain the evolution of VHE and X-rays during the night of the 2nd flare**

=> A third model has been developped by a group within the H.E.S.S. collaboration: stratified jet approach (see *T. Boutelier, G. Henri, P-O Petrucci, MNRAS Letters (2008) MN-08-0848-L.R1, astro-ph/0807.4998* and *upcoming MWL paper*)

Special Thanks

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