

Optically Triggered Very High Energy Gamma-ray Observations of blazars by the MAGIC Telescopes

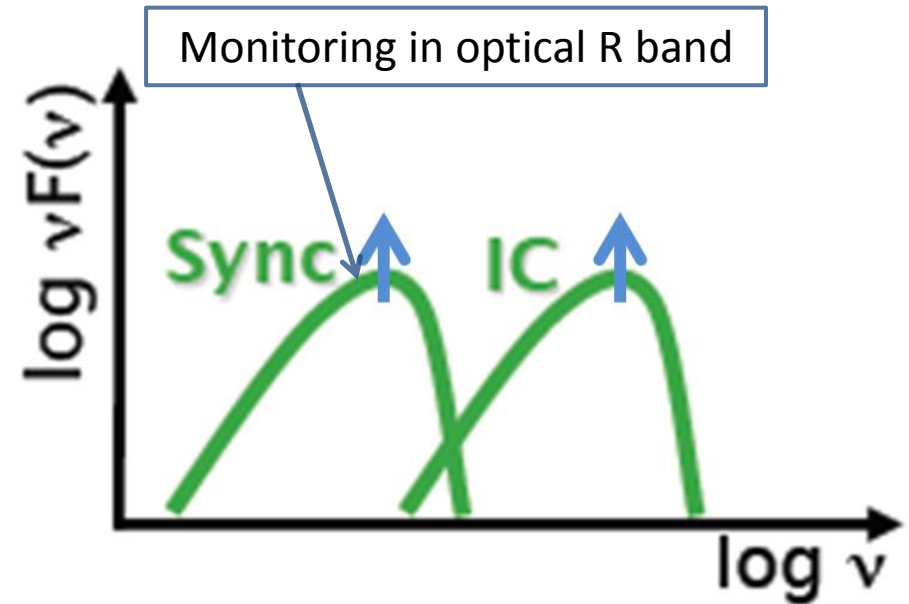
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Tuorla Blazar Monitoring Program

- Started in 2002 in anticipation to commissioning of MAGIC-1 → by now more than 10 years of monitoring data on several known and candidate VHE blazars

- Original sources from Costamante & Ghisellini (2002)
- New promising sources (e.g. Fermi sources) being added increasing the total number of regularly monitored objects to well over 50



Using the
Tuorla 1 m
(in Finland)



... and the KVA
telescopes (on
Canary islands)

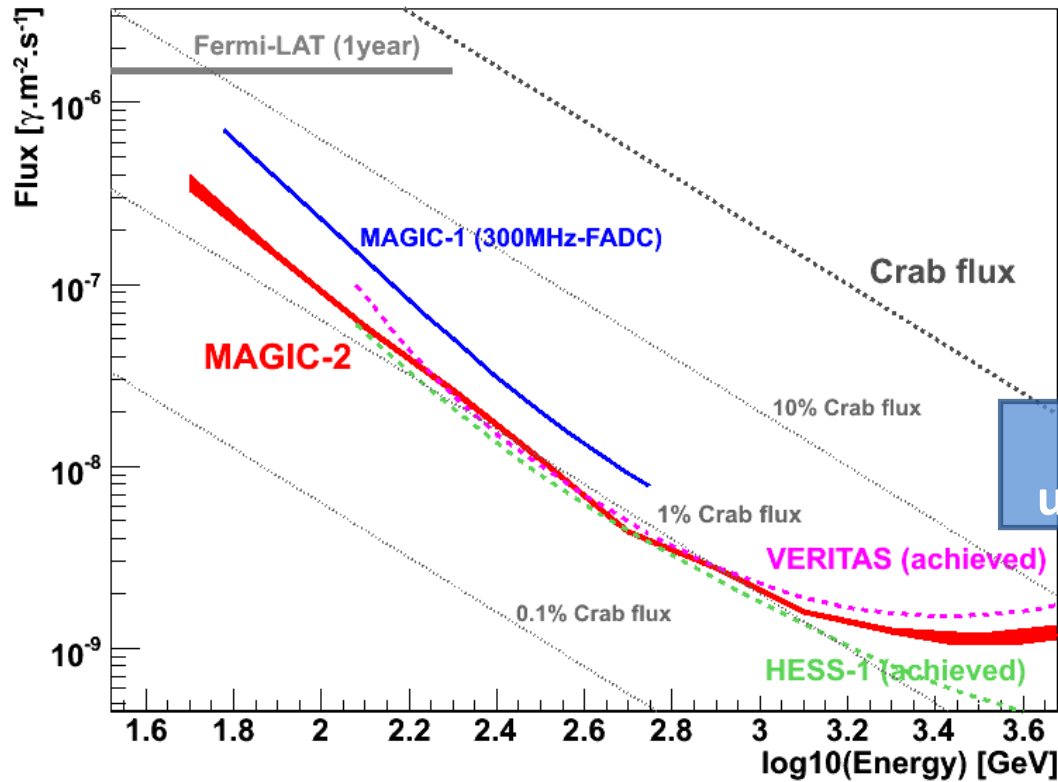


60 cm for
polarimetry

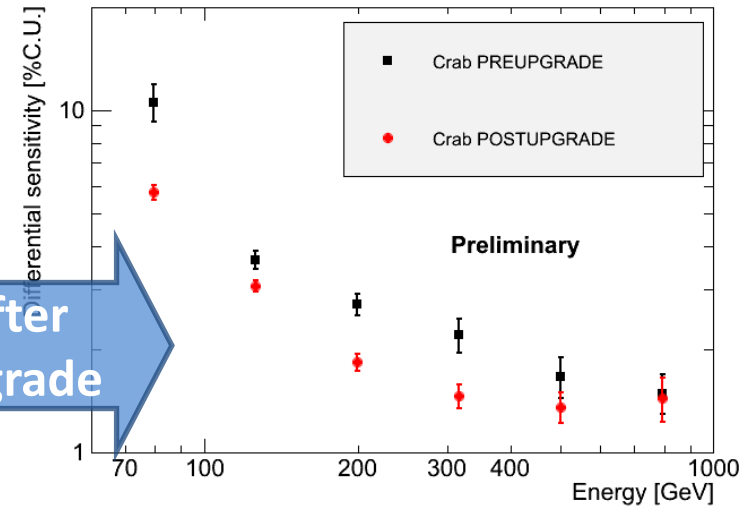
35 cm for
photometry

Goals: provide alerts to MAGIC on flaring blazars to trigger VHE observations, study the long-term optical variability of the sources & provide simultaneous optical LCs to MAGIC

A few words about MAGIC*



After
upgrade



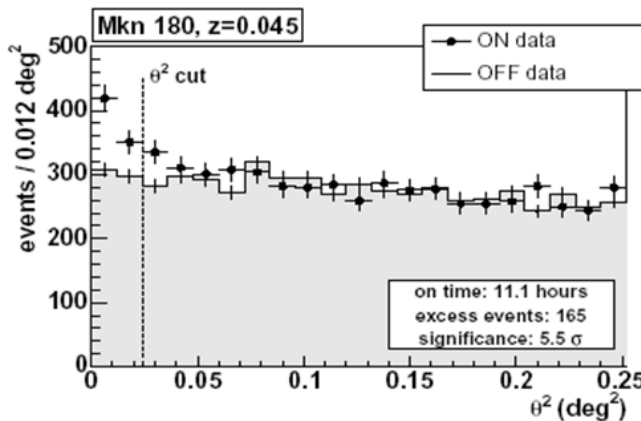
Currently the lowest energy threshold of any IACT
Highest sensitivity @ low energies of any IACT

* More information about MAGIC was shown in the presentation by Elina Lindfors yesterday afternoon

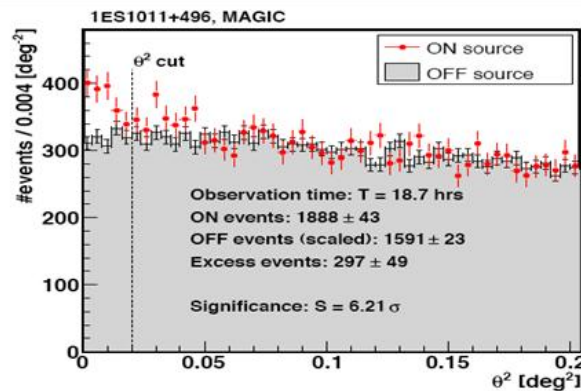
VHE observations from optical ToOs

- MAGIC is the perfect instrument for discovering extra-galactic VHE emitters
 - so far discovered 19 of the 57 known sources
 - 6 of those during ToO observations triggered by optical high states
 - another 3 were made when the sources were also high in optical
- Discoveries resulting from optical triggers have required on average about $\frac{1}{2}$ of the observation time (~ 13.3 h vs 22.6 h) compared to non-optically triggered discoveries

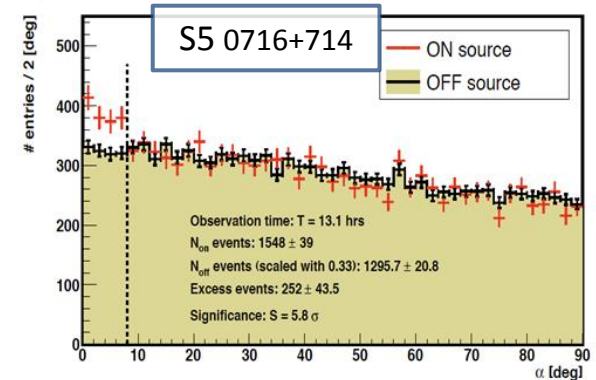
Early success



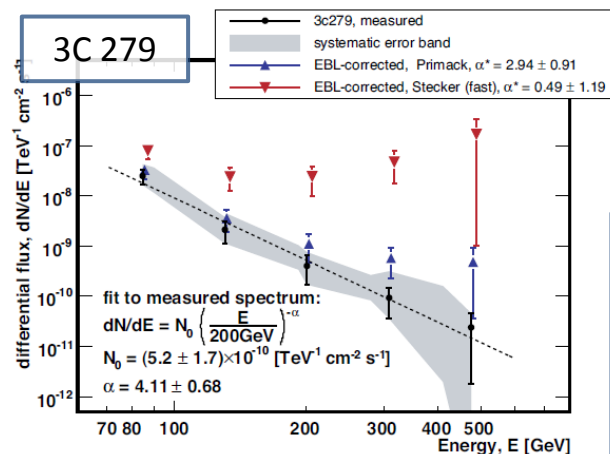
- HBL at $z=0.045$
- Optical outburst in March 2006 triggering MAGIC
- 11% Crab Nebula flux, no var



- HBL/IBL at $z=0.212$
- MAGIC obs betw March-May 2007 after optical trigger
- Optical state during discovery higher than during earlier MAGIC observations



- IBL, $z=0.31$
- Obs in Nov 2007 and April 2008 – triggered by optical high states
- Most signal from April, when optical flux was higher



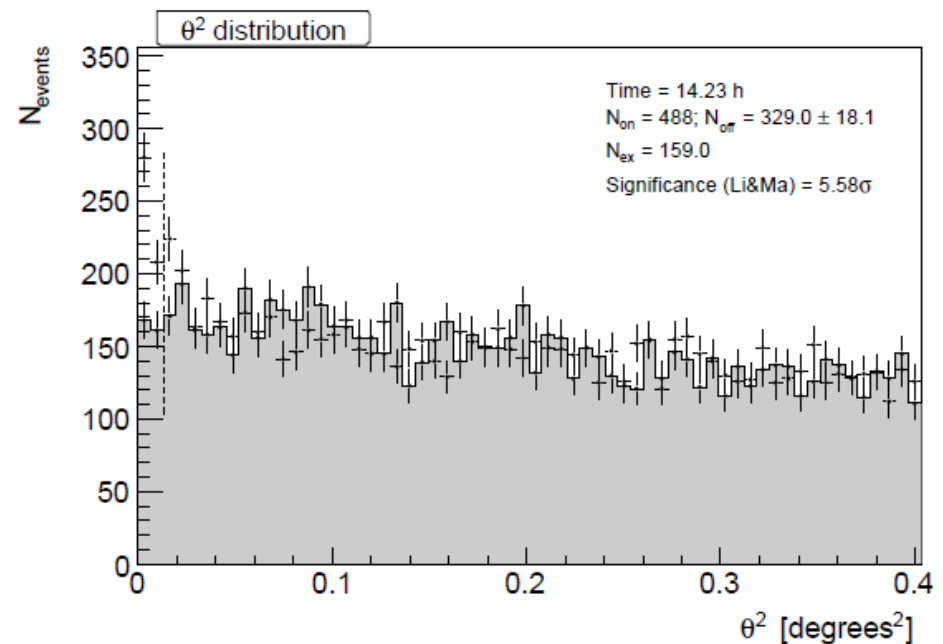
- Discovery of 3C 66A/B triggered by optical high state of the former
- Discoveries of BL Lac and 3C 279 coincided with high optical states

- FSRQ at $z=0.536$ (most distant VHE source until recently)
- MAGIC obs betw Jan-Apr 2006 during optical high state
- Total 10h observed, detection on Feb 23rd
- Constraints on EBL limits

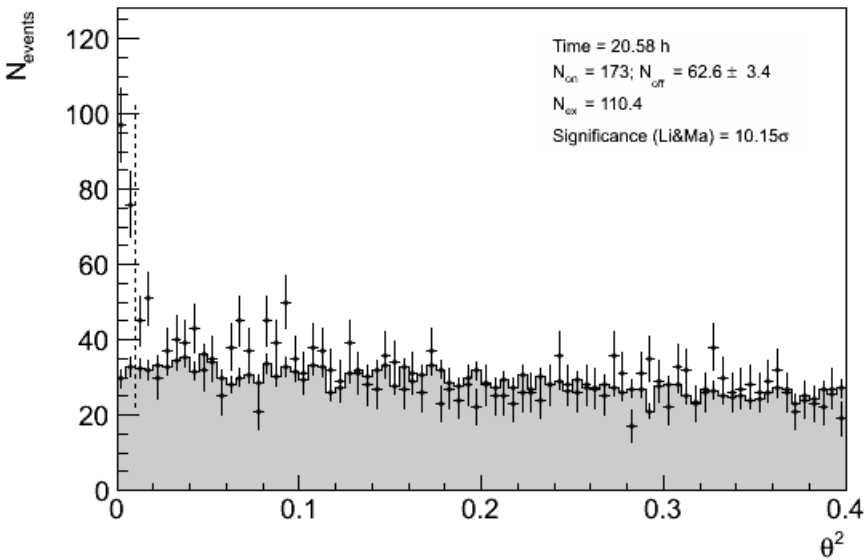
Stereo era

- Since late 2009 MAGIC has been observing in stereo mode
- Until now, MAGIC-stereo has discovered 13 new extra-galactic VHE emitters, 3 of which (B3 2247+381, 1ES 1215+303 and H 1722+119) thanks to optical triggers
 - additionally, the discovery of PKS 1222+216 was made when the source was also high in the optical

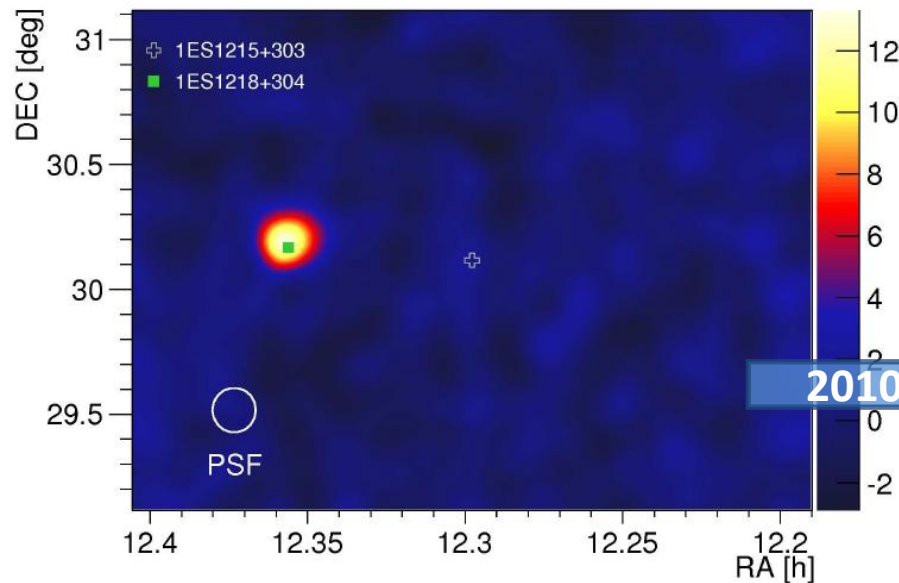
- On top of that several detections of known sources (e.g. 3C 66A, 1ES 0806+524) have been triggered by optical outbursts



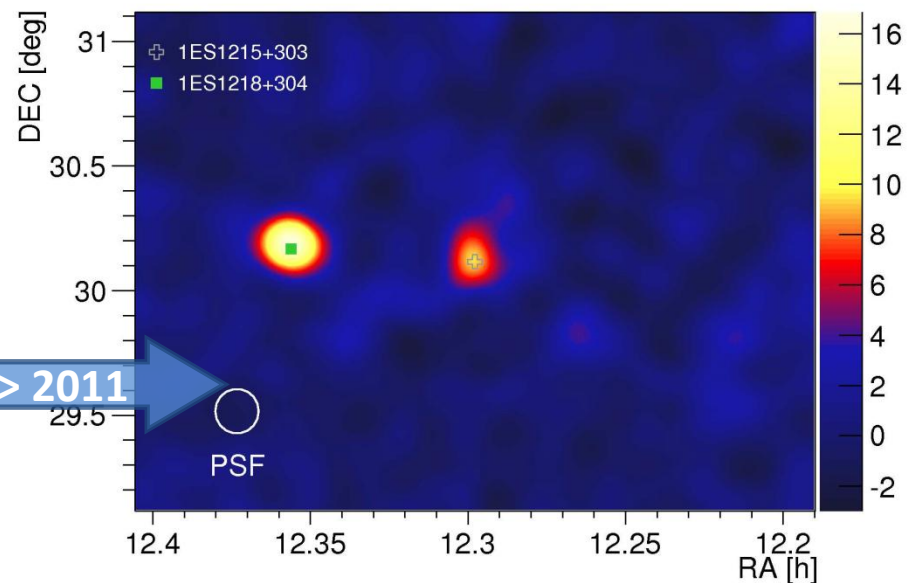
... 1ES 1215+303 (ON 325)



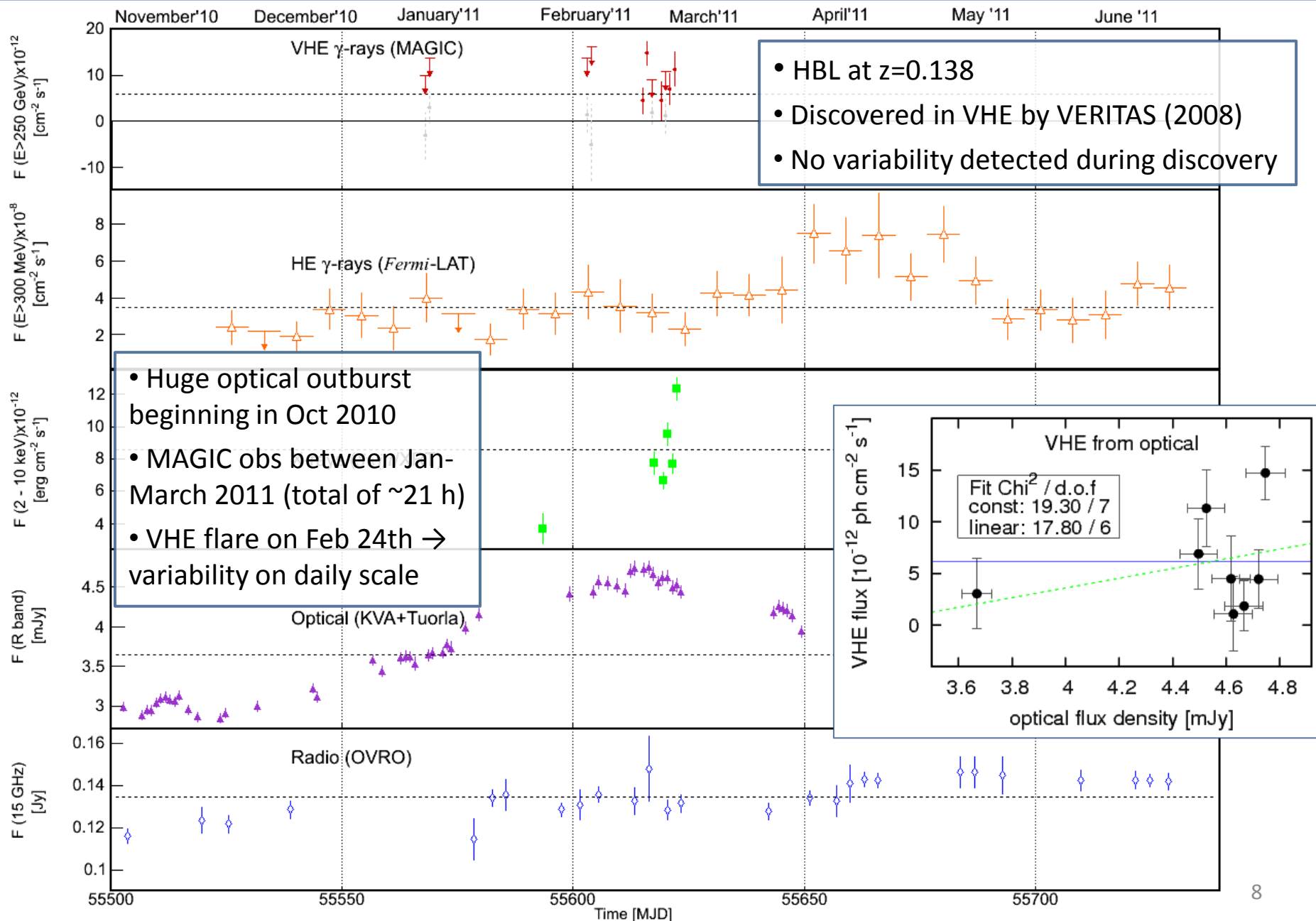
- HBL with $z=0.130$ (0.237 also reported)
- In the same FoV for MAGIC as known VHE emitter 1ES 1218+304
- Previous obs by Whipple and MAGIC resulted in upper limits
- Optical high state in Jan 2011 \rightarrow MAGIC obs in Jan-Feb \rightarrow detection of VHE gamma-rays
- Optical flux clearly higher in 2011 (by $\sim 40\%$) than during previous observations



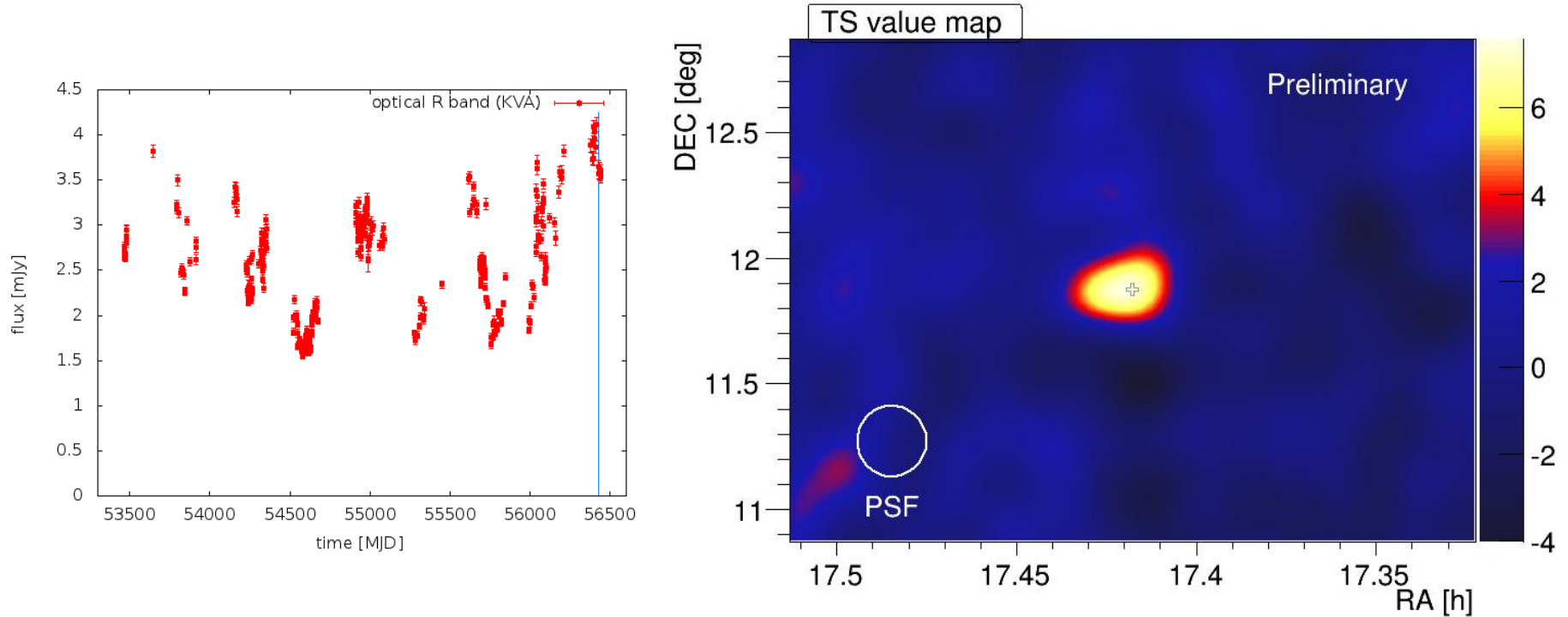
2010 \rightarrow 2011



... 1ES 0806+524



... 1ES 1722+119 (the latest discovery)



- HBL at unknown z
- Included in the Costamante & Ghisellini (2002) list and monitored by Tuorla since 2005
- Strong variability in the optical
- Very active in optical in spring 2013 reaching historical high flux in May → MAGIC ToO request

- MAGIC obs on 5 nights starting May 17th for 11 h → 5σ ($\sim 2\%$ Crab)
- First MWL results show hint of spectral hardening in the Fermi band
- More detailed analysis ongoing

Optical flares and accompanying VHE obs

Name	# flares	Qstate [mJy]	below Qstate	flare cond [mJy]	rise time [days]	decay time [days]	flare duration [days]	t betw flares [days]	duty cycle
1ES_0033+595	3	0.196	14.6	1.71	7.71	11.6	19.31	73.6	0.043
1ES_0120+340	0	0.165	58.4	1.34	-	-	-	-	0
RGB_0136+391	2	1.723	16.2	1.37	3.96	55.95	57.93	-	0.072
RGB_0214+517	0	0.55	20.4	1.33	-	-	-	-	0
3C_66A	10	5.54	23.3	1.69	21.64	18.22	36.22	35.74	0.181
1ES_0229+200	0	0.242	21.1	1.4	-	-	-	-	0
AO_0235+164	3	0.126	14.7	7.2	30.6	4.72	35.32	31.76	0.104
HB89_0317+185	4	0.146	13.6	1.62	6.75	25.23	31.97	20.96	0.199
1ES_0323+022	1	0.293	6.4	1.39	9.97	2.99	12.96	-	0.026
1ES_0414+009	2	0.757	14.8	1.46	19.99	6.97	23.48	37.95	0.124
1ES_0502+675	4	0.588	20.7	1.53	14.24	2.66	16.23	22.99	0.113
1ES_0647+250	15	0.95	8.2	1.56	16.22	21.82	34.19	39.74	0.381
S5_0716+714	12	11.326	17.2	2.18	12.9	11.33	23.15	48.12	0.197
1ES_0806+524	3	1.975	8	1.75	33.08	7.51	38.08	19.73	0.084
OJ_248	1	1.473	33.6	1.41	3.09	10.92	14	-	0.028
OJ_287	18	2.914	20.6	2.33	11.87	14.66	24.25	47.57	0.229
S4_0954+65	3	0.452	17.5	2.21	3.98	2.66	6.64	15.93	0.029
1ES_1011+496	9	2.061	16.6	1.55	25.23	23.94	44.47	45.07	0.253
RGB_1012+424	0	0.188	42.2	1.3	-	-	-	-	0
1ES_1028+511	3	0.46	21.4	1.55	42.83	29.36	57.91	23.97	0.134

- 49 sources with >3 yrs of data with >100 pointings
- Total of 190 optical flares identified (7 objects show no flaring)
- Simultaneous MAGIC data exists for about 1/3 optical flares

Optical flares and accompanying VHE obs

Name	# flares	Qstate	below Qstate	flare cond	rise time	decay time	flare duration	t betw flares	duty cycle
RGB_1117+202	1	0.633	24.2	1.47	52.9	10.01	62.91	-	0.062
Mkn_180	4	1.368	16.7	1.69	34.04	31.73	65.76	32.84	0.135
RGB_1136+676	0	0.271	27.3	1.42	-	-	-	-	0
1ES_1218+304	6	0.808	9.7	1.66	22.31	13.45	31.3	42.26	0.182
ON_231	4	3.725	28	1.65	17.31	22.31	29.71	53.26	0.161
3C_273	1	30.103	32	1.15	-	8.01	8.01	-	0.016
3C_279	3	1.581	35.3	3.65	14.48	27.92	37.58	-	0.089
ON_325	6	3.424	20.5	1.41	19.25	11.31	27.35	18.83	0.151
RGB_1417+257	0	0.44	19.9	1.22	-	-	-	-	0
PG_1424+240	2	7.755	31.6	1.26	12.68	24.45	37.14	-	0.116
1ES_1426+428	1	0.44	31.2	1.25	6.03	4.02	10.04	-	0.01
PKS_1510-089	1	0.923	14.2	4.53	2	2.98	4.98	-	0.005
PG_1553+113	5	10.091	20.5	1.38	32.14	53.63	85.77	-	0.332
B2_1633+38	2	1.407	25.1	1.82	6.97	10.49	17.46	28.84	0.05
Mkn_501	3	5.207	19.6	1.29	4.96	5.67	10.63	-	0.023
RGB_1719+177	1	0.4	28	2.18	32.94	35.95	68.9	-	0.101
HB89_1721+343	1	3.08	26.2	1.12	20.94	43.96	64.9	-	0.091
H_1722+119	11	2.18	19.8	1.48	18.77	14.31	31.24	35.57	0.368
1ES_1741+196	0	0.983	19.7	1.42	-	-	-	-	0
OT_546	3	0.931	19	1.38	32.67	26.19	58.86	-	0.108
1ES_1959+650	4	2.894	17.9	1.88	26.23	18.69	44.92	20.96	0.099
PKS_2155-304	5	12.784	12.9	1.85	14.51	16.71	24.97	-	0.265
B3_2247+381	3	0.531	23.1	1.53	29.57	16.93	46.5	36.44	0.149
BL_Lac	11	3.526	10.6	2.72	18.41	15.08	28.77	58.92	0.195
3C_454.3	7	2.151	13.9	4.3	7.48	20.25	26.66	49.94	0.143
1ES_2344+514	2	0.899	23.2	1.34	9.03	9	18.03	-	0.022

Outlook

- MAGIC the best suited instrument for extra-galactic VHE observations
- Optical monitoring the key for fast and efficient discoveries → enabling to populate the VHE sky for future instruments
- Papers with thorough analysis of the long-term optical monitoring to be published later this year