Radio galaxy NGC 1275 MWL paper status report

Saverio Lombardi on behalf of the NGC 1275 team:

Pierre Colin (MAGIC co-analyzer, paper leader)

Dorothée Hildebrand (ex P.I., Fermi data monitoring)

Elina Lindfors (KVA analyzer)

Saverio Lombardi (MAGIC analyzer)
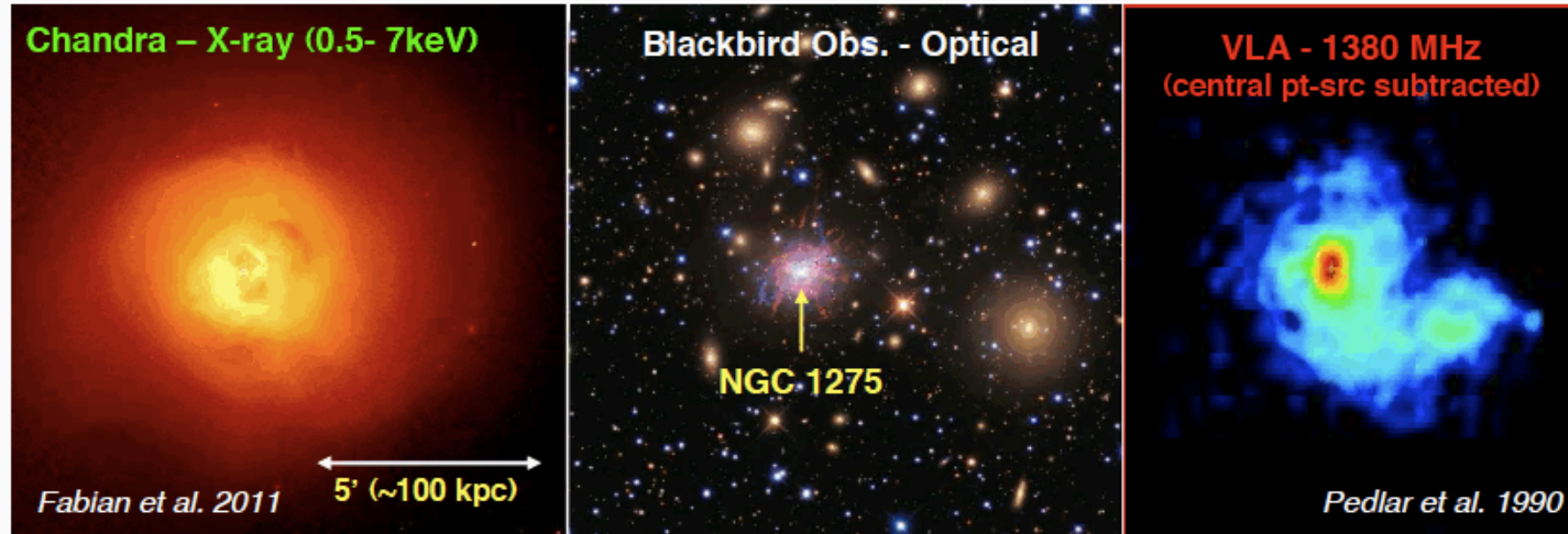
Serena Partini (VLBA analyzer)

Antonio Stamerra (Swift/UVOT analyzer)

Fabrizio Tavecchio (SED model)

**Jun Kataoka & Yosuke Takahashi** (official Fermi analyzers)

Barbara Balmaverde (Chandra analyzer)

MAGIC AGN meeting, Rome, 11-14/02/2013

The Perseus cluster of galaxies

Chandra – X-ray (0.5- 7keV)
Fabian et al. 2011
5' (~100 kpc)

Blackbird Obs. - Optical
NGC 1275

VLA - 1380 MHz
(central pt-src subtracted)
Pedlar et al. 1990

- Brightest galaxy cluster in X-ray
- Typical cool-core Cluster
- Radio mini-halo (electron synchrotron)
- Nearby cluster: Distance = ~73 Mpc (z=0.018)
- NGC 1275: Dominant central galaxy

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NGC 1275 (3C 84): a complex object

Pedlar et al. 1990

VLA 1380 MHz

CORE
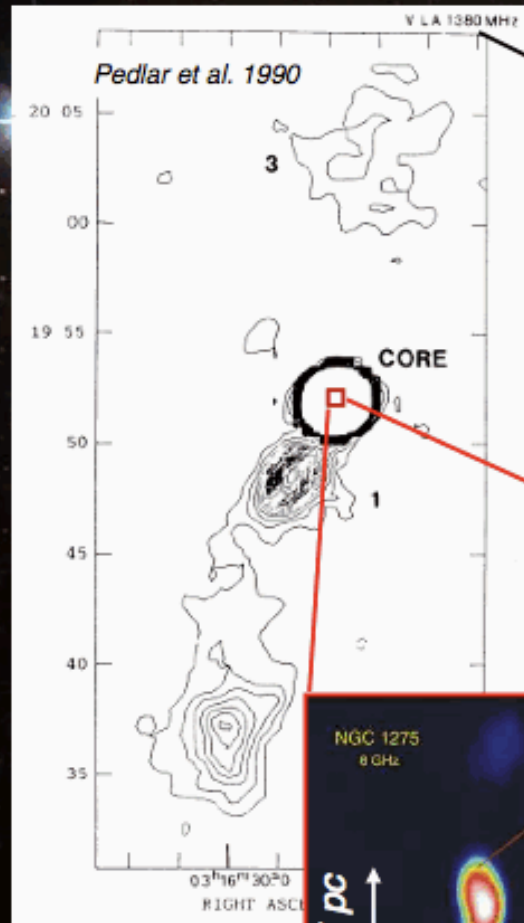
Hubble Space Telescope image
60" (~20 kpc)

NGC 1275
6 GHz

43 GHz

15 mas / 5 pc

sub-pc

http://images.nrao.edu/263

Supermassive Black Hole

Unclear classification:
- **Seyfert 1.5**
- **FR I radio galaxy**
- **BL Lac suggested in 1978**
- **Jet orientation = 30°- 55°**

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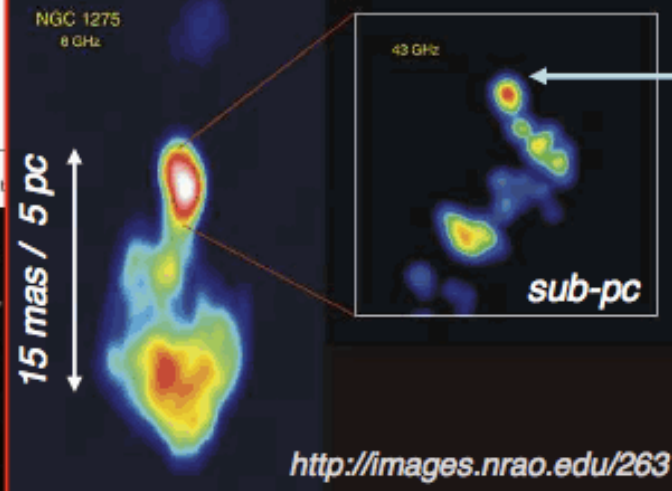
Historic of MAGIC Observations

- April 2008: First proposal for Perseus cluster / NGC 1275
  (PI: Elsaesser, Pfrommer, Zandanel)
- Automn 2008: Mono observation
- **May 2009: proposal for cycle-5 (PI: Hildebrand, Zandanel)**
- Sep. 2009: Mono data UL paper on arXiv
- **Oct. 2009: First Stereo Data**
- March 2010: IC 310 detection ATEL
- Sep. 2010: IC 310 discovery letter on arXiv

6 months

- **Oct. 2010: NGC 1275 Detection ATEL**
- **Feb. 2011: End of Cycle-6 observation**
- **Dec. 2011: NGC 1275 discovery letter on arXiv**

10 months

- **July 2012 : New results shown at Gamma 2012:**
  - Detection in cycle 5
  - Hint of variability in cycle 5
  - MWL light curve: MAGIC – Fermi – KVA - MOJAVE

Dead-line 4 months (no way)

- **August 2012 : Pierre & Saverio take the lead of the paper**
- **xxx 2013 : Publication of The MWL NGC 1275 paper**

MAGIC results: READY!

Analyzers: Saverio Lombardi and Pierre Colin
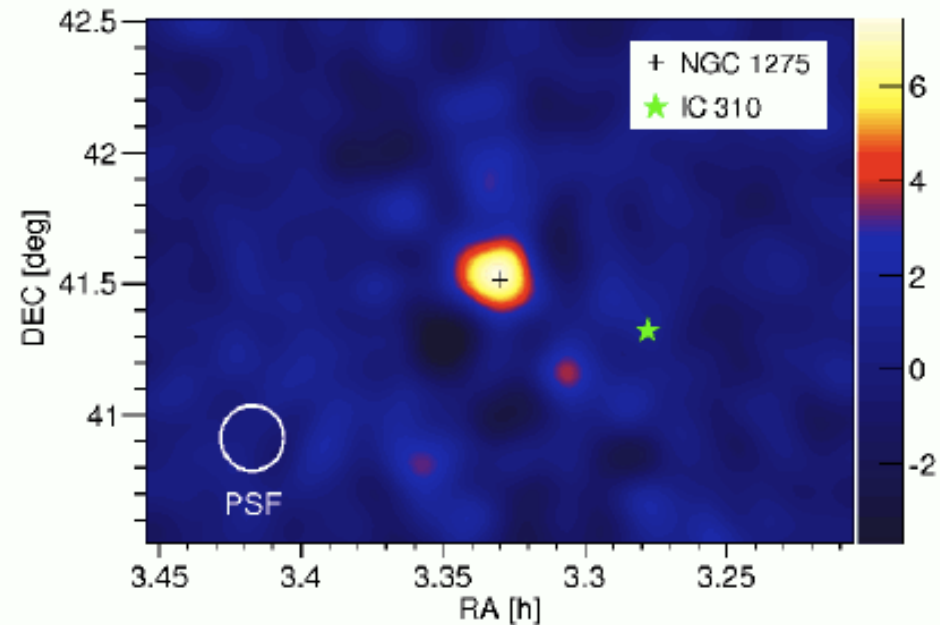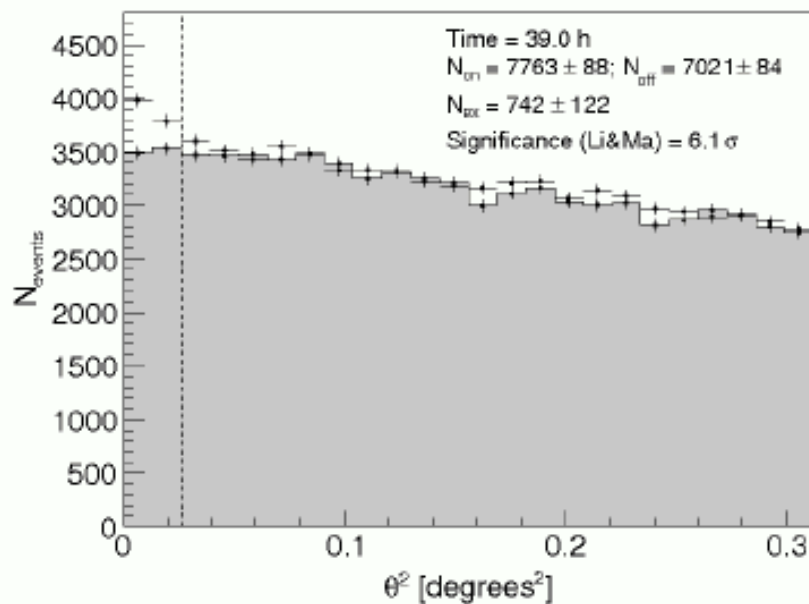
- Re-analysis of Cycle 5 data: Oct. 2009 – Feb. 2010 (39h)
- Clear detection in Cycle 5 at low energy (E_{th} = 100 GeV)
- Required new MC data because of "soft" stereo trigger

MAGIC results: READY!

Analyzers: Saverio Lombardi and Pierre Colin
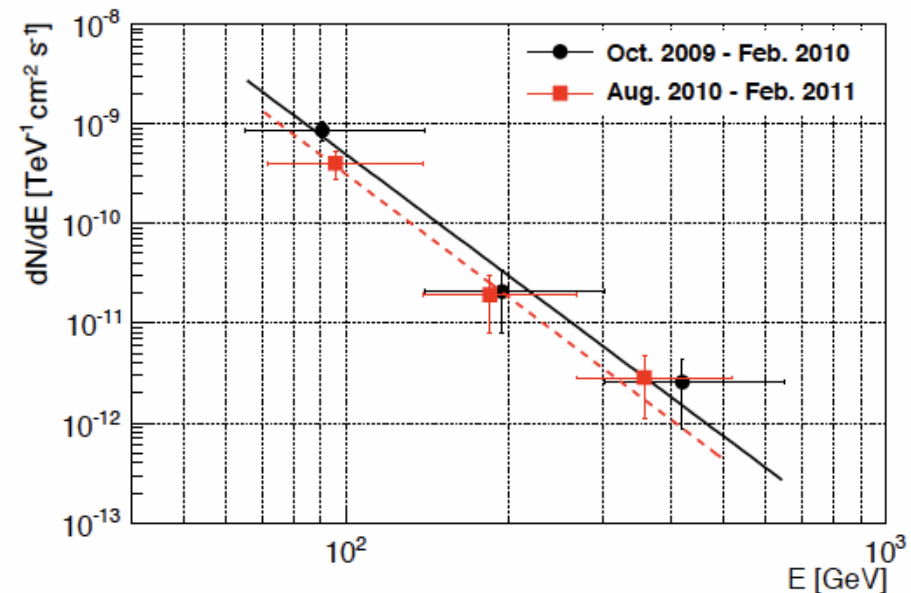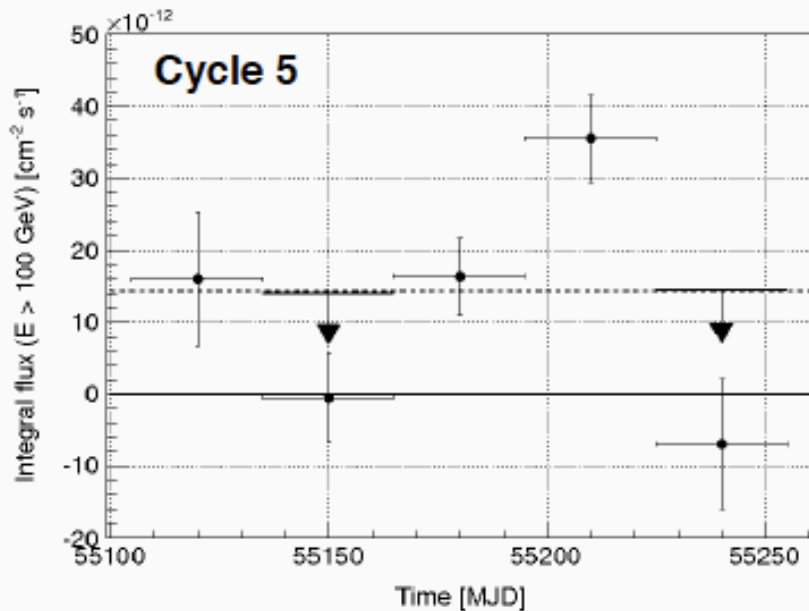
- Hint of variability: Constant fit χ^2/d.o.f. = 23.8 / 4
  - Proba=8.86 $\cdot 10^{-5}$ (3.7 sigma)
- Same spectrum than cycle 6 (discovery paper)

Paper: MAGIC section already drafted

Fermi-LAT results: READY!

Analyzers: Jun Kataoka and Yosuke Takahashi (Dorothée Hildebrand, monitoring)
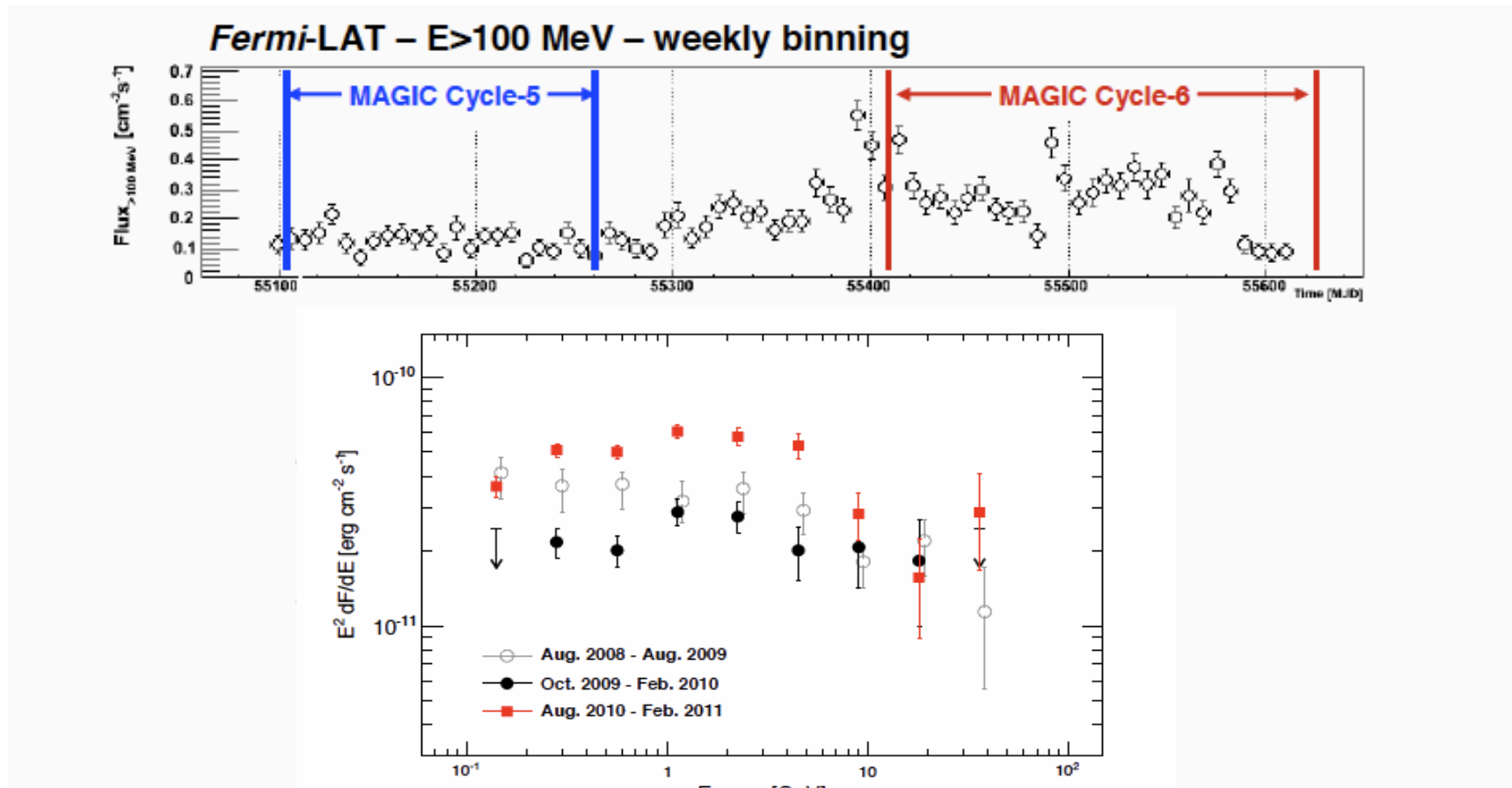
Paper: *Fermi*-LAT section already drafted

Chandra results: 2006 results

Analyzers: Has been : Swen Wilbert (not correct ???)
           Now   : Barbara Balmaverde (since September 2012)

- 7 Chandra observations during MAGIC **cycle-5**
- Total exposure time: ~450 ks
- Difficult analysis:
    - Large offset (>3 arcmin)
    - Strong pileup

The measurement of Balmaverde et al. (2006) will be considered for the paper

Paper: Chandra section already drafted

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KVA-NOT results: READY!

Analyzer: Elina Lindfors

KVA – R-band – Core flux (Host galaxy subtracted)

Flux density [Jy]

MAGIC Cycle-5

MAGIC Cycle-6

Time [MJD]
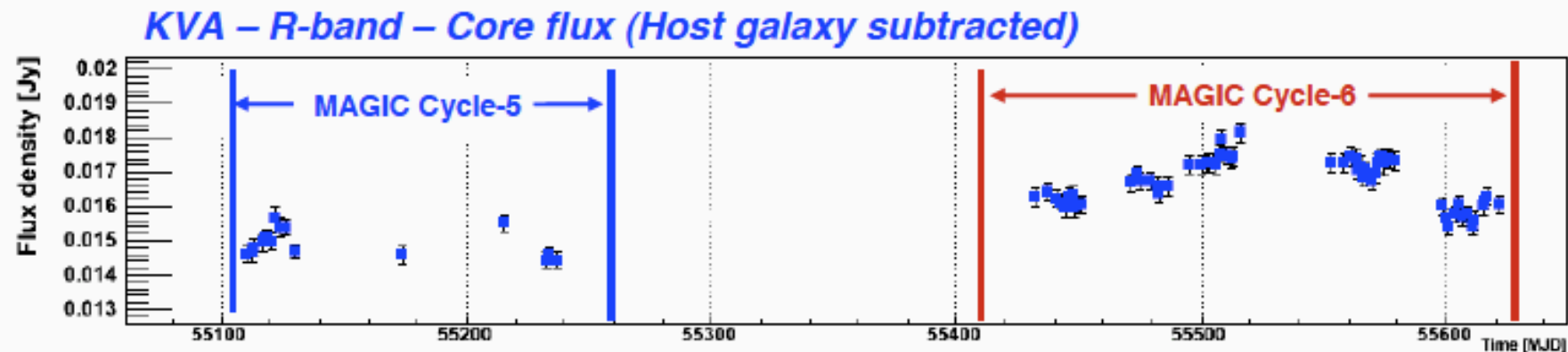
- Core flux (aperture = 5")
- Host galaxy contribution estimated with **NOT**: *3.87 ± 0.4 mJy*
- Mean flux during **cycle-5** = *14.92 mJy*
- Mean flux during **cycle-6** = *16.68 mJy*

Paper: KVA-NOT section already drafted

VLBA results: READY!

Analyzer: Serena Partini
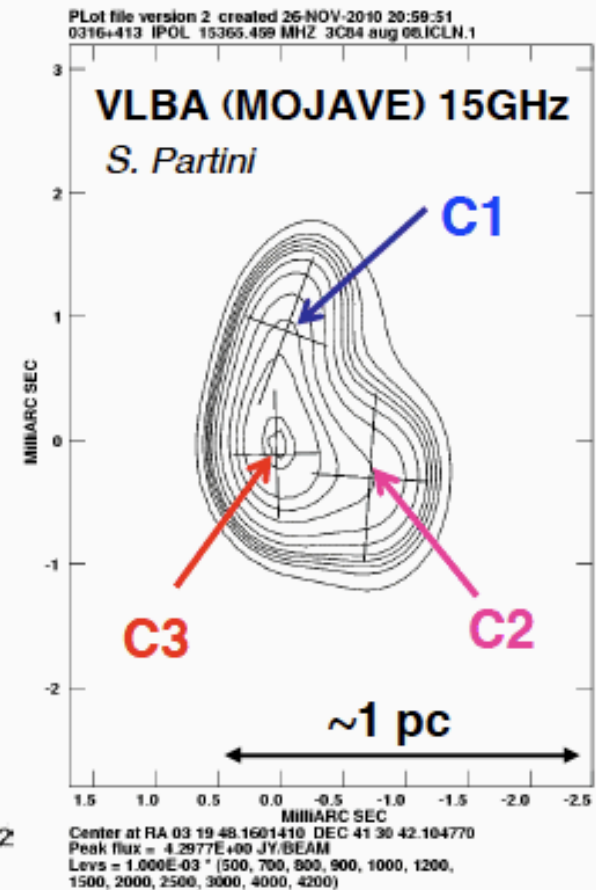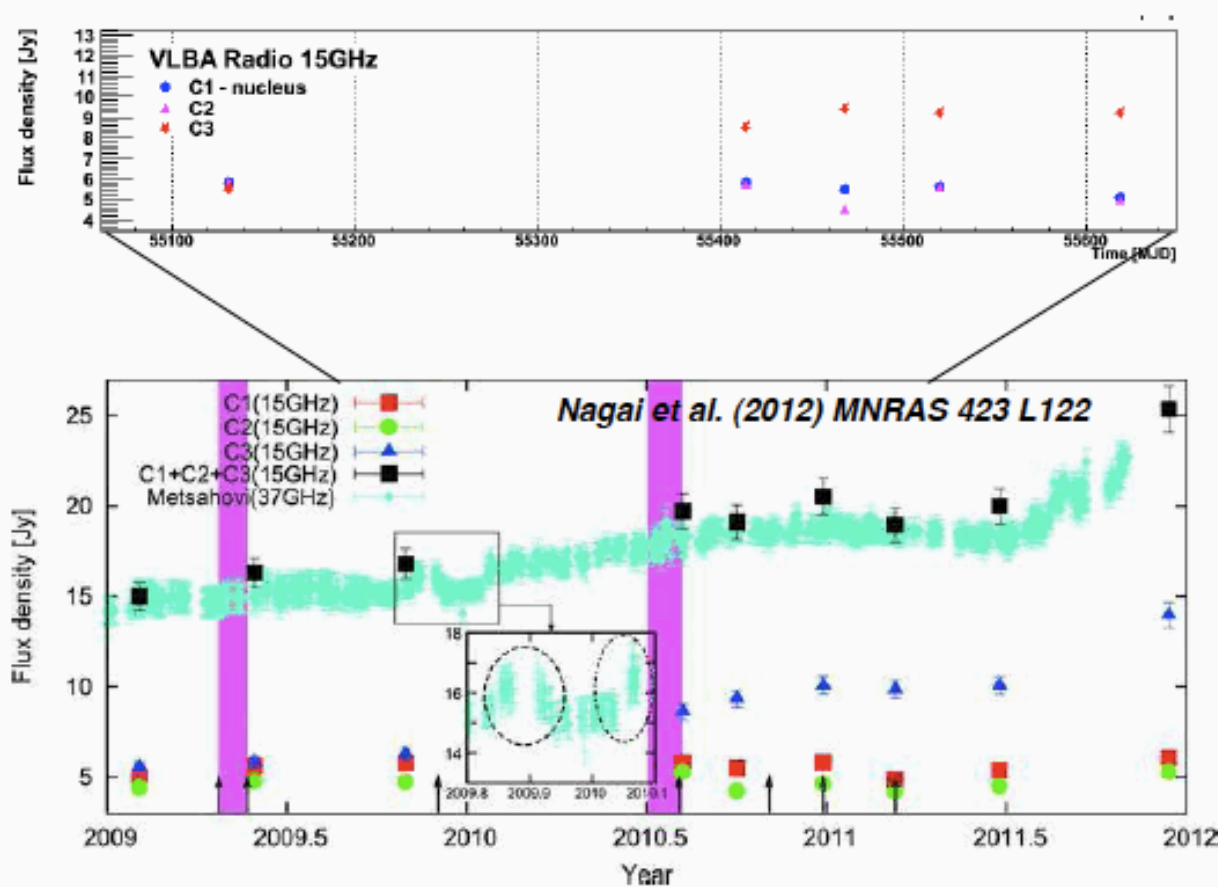
Paper: VLBA section already drafted

Planck/UVOT results: published

Giommi, P., et al. 2012, A&A 541, 160

J0319+4130 – NGC 1275

Planck
29.08.2010 – 04.09.2010
(within cycle-6)

Swift-UVOT
09.08.2010
(ObsID 31770010)

NGC1275 SED from Giommi et al. 2012 (arXiv:1108.1114)
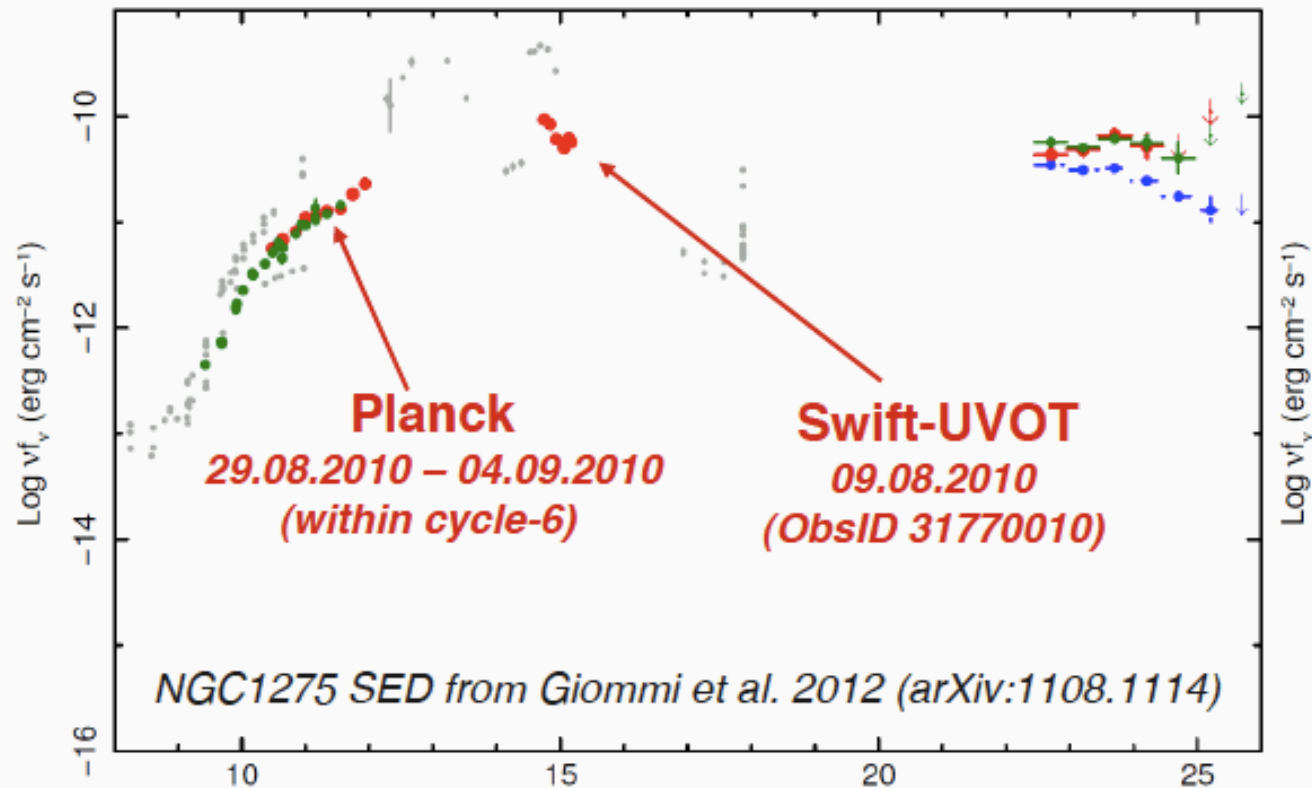
Paper: Other MWL data section already drafted

Correlation gamma - optical
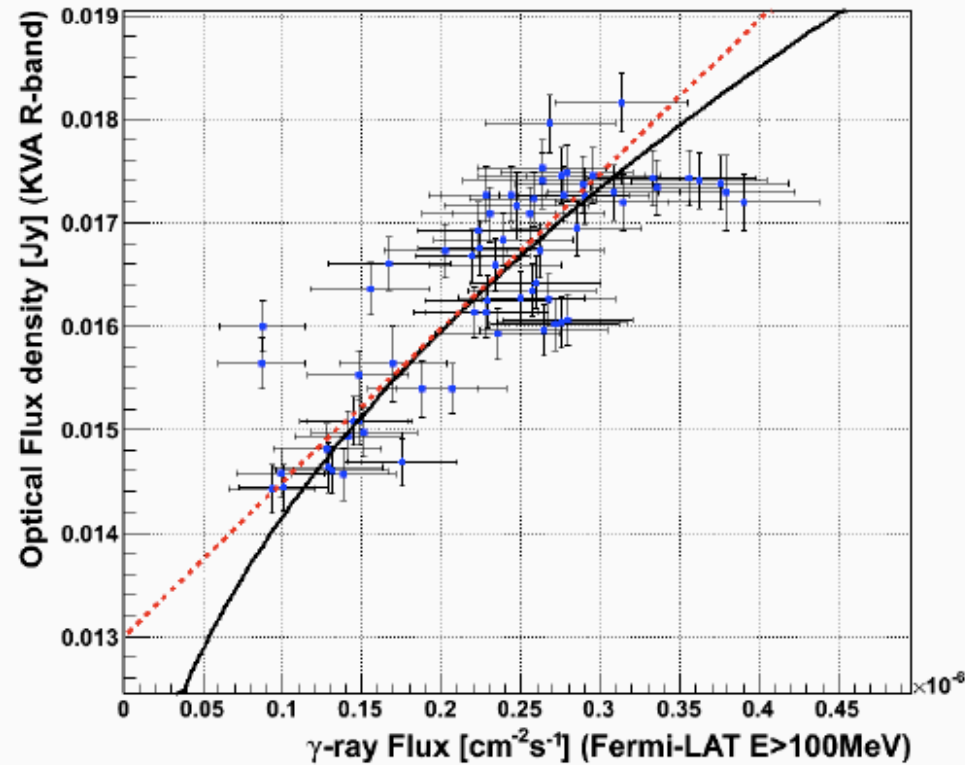
Correlation	Base line	Variable (C-5)	Variable (C-6)
Linear	12.97 mJy	1.95 mJy	3.71 mJy
Quadratic	9.81 mJy	5.11 mJy	6.87 mJy

HE SED results

Fig. 8. NGC 1275 spectral energy distribution in γ-ray band measured with MAGIC and *Fermi*-LAT together with fit functions of the data. Upper and lower panels correspond to the periods Oct. 2009 – Feb. 2010 and Aug. 2010 – Feb. 2011 respectively.

Table 3. NGC 1275 γ-ray SED fit parameters for:

a power law: $dF/dE = f_0(\frac{E}{GeV})^\Gamma$

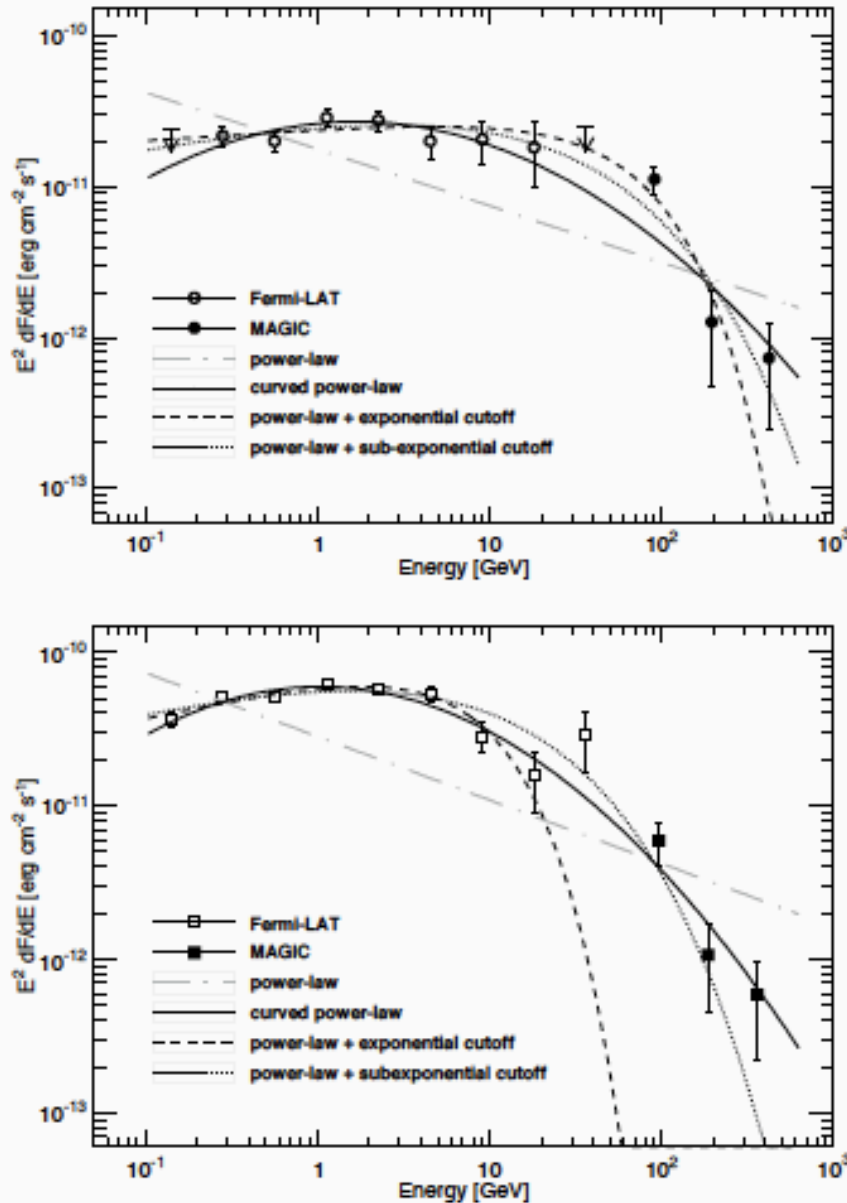| Epoch	$f_0{}^a$	$-\Gamma$	χ^2/dof	Proba.
camp. 1	178±12	2.38±0.03	57.4/8	1.5e-9
camp. 2	282±10	2.41±0.02	317/10	3.e-62

a curved power-law: $dF/dE = f_0(\frac{E}{GeV})^{-2-\beta log(E/E_p)}$

Epoch	$f_0{}^a$	β	$E_p{}^b$	χ^2/dof	Proba.
camp. 1	262±18	0.26±0.04	2.8±1.5	12.3/7	0.09
camp. 2	595±21	0.31±0.03	1.1±0.2	13.4/9	0.15

a power law with exponential cutoff: $\frac{dF}{dE} = f_0(\frac{E}{GeV})^\Gamma e^{-E/E_c}$

Epoch	$f_0{}^a$	$-\Gamma$	$E_c{}^c$	χ^2/dof	Proba.
camp. 1	239±16	1.93±0.06	67±12	8.6/7	0.28
camp. 2	659±40	1.75±0.05	7.3±1.6	26.5/9	1.7e-03

a power law with a sub-exp. cutoff: $\frac{dF}{dE} = f_0(\frac{E}{GeV})^\Gamma e^{-\sqrt{E/E_c}}$

Epoch	$f_0{}^a$	$-\Gamma$	$E_c{}^c$	χ^2/dof	Proba.
camp. 1	321±27	1.77±0.08	13.1±4.2	9.4/7	0.22
camp. 2	860±81	1.72±0.05	5.0±1.6	19.3/9	0.22

[a] Normalization flux at 1 GeV in 10^{-13} erg cm^{-2} s^{-1}
[b] Peak energy in GeV
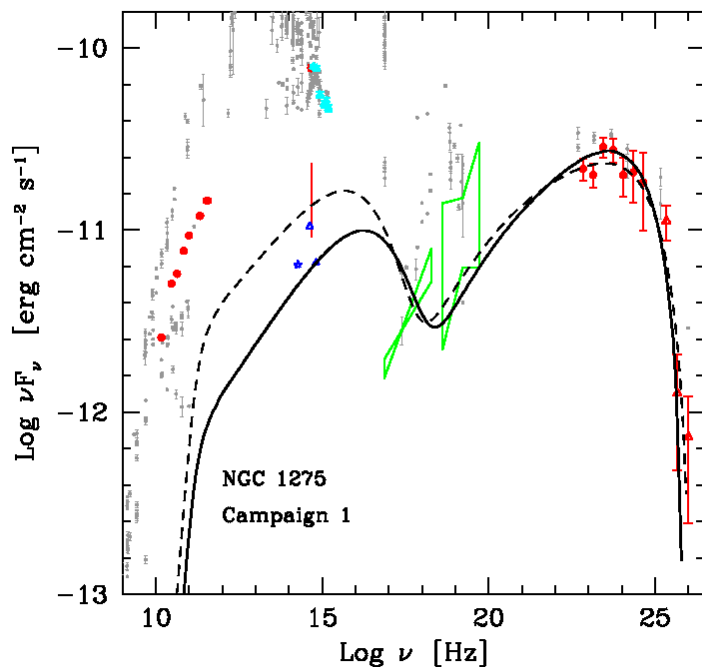[c] Cutoff energy in GeV

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SED results

Fig. 9. NGC 1275 spectral energy distribution for the epoch of camp. 1 (Oct. 2009 - Feb. 2010). Red symbols show nearly simultaneous data from MOJAVE, Planck, KVA, *Fermi*/LAT and MAGIC. Green bow-ties in the X-ray band report the *Chandra* and *Swift*/BAT from Balmaverde et al. (2006) and Ajello et al. (2009), respectively. Blue symbols report optical-IR measurement by *HST* from Chiaberge et al. (1999) (triangles) and Baldi et al. (2010) (star). Cyan points show *Swift*/UVOT data (SHOULD BE IN RED?) (corrected for the contribution of the host galaxy). Gray points show data from NED. The solid and dashed lines report the SSC models for $\delta = 2$ and $\delta = 4$ respectively.
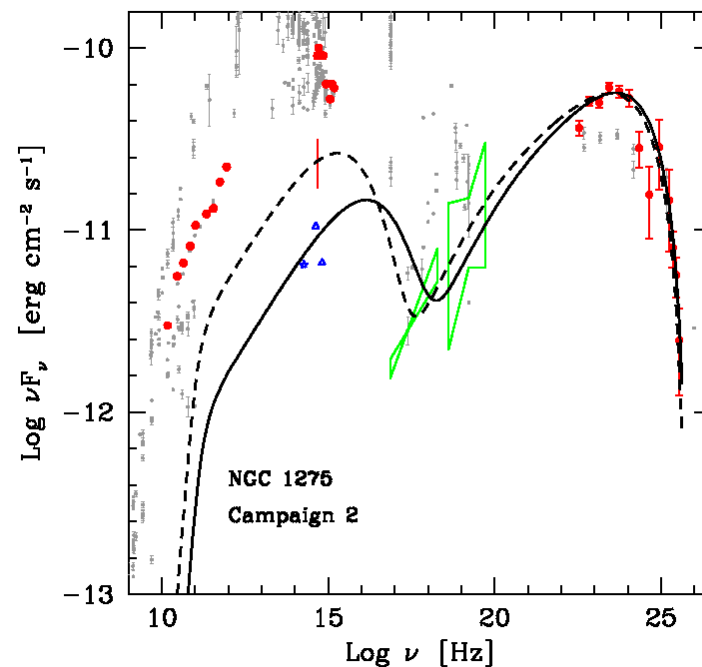
Fig. 10. NGC 1275 spectral energy distribution for the epoch of camp 2 (Aug. 2010 - Feb. 2011). Symbols as in Fig. 9. *Swift*/UVOT data in red are from Giommi et al. (2012).

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SED results

	B	K	R	$\gamma_{\min}$	γ_{c}	n	Γ	θ_{v}	δ	P_{j}
	[G]	$[10^5 \mathrm{~cm}^{-3}]$	$[10^{16} \mathrm{~cm}]$					[deg]		$[\mathrm{erg~s}^{-1}]$
Campaign 1	0.03	2.4	8.2	100	2.45×10^5	2.55	3.2	14	4	1.2×10^{44}
	0.1	4.7	4.1	50	2.9×10^5	2.45	2	30	2	1.1×10^{44}
Campaign 2	0.03	1.05	8.2	100	1.2×10^5	2.4	3.2	14	4	1.2×10^{44}
	0.1	4.3	4.1	70	2.4×10^5	2.4	2	30	2	7.7×10^{43}

Table 4. Parameters for the models reported in Figs. 9-10. For both epochs we show the parameters for two different choices of the Doppler factor, $\delta = 2$ and 4. From the first column the Table reports the magnetic field B, the particle density K, the source radius R, the minimum electron Lorentz factor, $\gamma_{\min}$, the cut-off Lorentz factor γ_{c}, the electron slope n, the bulk Lorentz factor Γ, the viewing angle θ_{v} and the Doppler factor. The last column shows the jet power, calculated with the parameters estimated with the emission models and an assumed composition of one cold proton per relativistic electron.

Status

Paper:
o Introduction: Done
o Observation and data analysis: Done
o Interpretations: Done
o Discussion: spread ideas to be developed
o Conclusion: not yet finished

Publication plan:
o submission to internal referee: end 02/2013 ?
o submission to review: end 03/2013 ?