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# AGILE detection of intense $\gamma$-ray activity from the blazar PKS 0537–441 in October 2008

G. Pucella[1], F. D'Ammando[1,2,3], P. Romano[3], A. Treves[4], E. Pian[5,6], S. Vercellone[3], V. Vittorini[1], G. Piano[1,2], D. Impiombato[4,7], D. Fugazza[8], F. Verrecchia[9], H. A. Krimm[10], I. Donnarumma[1], M. Tavani[1,2], A. Bulgarelli[11], A. W. Chen[12], A. Giuliani[12], F. Longo[13], L. Pacciani[1], A. Argan[1], G. Barbiellini[13], F. Boffelli[14,15], P. Caraveo[12], P. W. Cattaneo[14], V. Cocco[1], E. Costa[1], E. Del Monte[1], G. De Paris[1], G. Di Cocco[11], Y. Evangelista[1], M. Feroci[1], M. Fiorini[12], T. Froysland[2], F. Fuschino[11], M. Galli[16], F. Gianotti[11], C. Labanti[11], I. Lapshov[1], F. Lazzarotto[1], P. Lipari[17], M. Marisaldi[11], S. Mereghetti[12], E. Morelli[11], A. Morselli[18], A. Pellizzoni[19], F. Perotti[12], P. Picozza[2,18], M. Pilia[4,19], M. Prest[15], M. Rapisarda[20], A. Rappoldi[14], S. Sabatini[1], P. Soffitta[1], E. Striani[2,18], M. Trifoglio[11], A. Trois[1], E. Vallazza[4], A. Zambra[12], D. Zanello[17], M. Perri[9], C. Pittori[9], P. Santolamazza[9], P. Giommi[9], L. A. Antonelli[9], S. Colafrancesco[9], and L. Salotti[21]

*(Affiliations can be found after the references)*

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## ABSTRACT

*Context.* We report the detection by the AGILE satellite of intense $\gamma$-ray activity from the source 1AGL J0538−4424, associated with the low-energy-peaked BL Lac PKS 0537−441, during a target of opportunity (ToO) observation performed on 2008 October 10–17, triggered by a *Fermi*-LAT alert, together with REM and *Swift* observations.

*Aims.* The quasi-simultaneous near-infrared, optical, UV, X-ray, and $\gamma$-ray coverage allowed us to investigate the behaviour of the source in different energy bands and study the spectral energy distribution and a theoretical model that can describe the $\gamma$-ray state observed in mid-October.

*Methods.* AGILE observed the source with its two co-aligned imagers: the Gamma-Ray Imaging Detector (GRID) and the hard X-ray imager (SuperAGILE), sensitive in the 30 MeV−30 GeV and 18−60 keV ranges, respectively. During the AGILE observation, the source was monitored simultaneously in the UV and X-ray bands by the *Swift* satellite through 6 ToO observations carried out between 2008 October 8 and 17. Moreover, the source was observed in the near-infrared and optical bands by the REM telescope on 2008 October 7, 8, and 9.

*Results.* During 2008 October 10–17, AGILE-GRID detected $\gamma$-ray emission from PKS 0537–441 at a significance level of 5.3-$\sigma$ with an average flux of $(42 \pm 11) \times 10^{-8}$ photons cm$^{-2}$ s$^{-1}$ for energies higher than 100 MeV. A significant increase in the $\gamma$-ray activity was detected between the first and the second halves of the observing period. REM and *Swift*/XRT detected the source in near-infrared/optical and X-rays during a relatively low and intermediate activity state, respectively, with no signs of evident variability in the different observations. However, *Swift*/UVOT detected an increase between the first and the second parts of the observing period, smaller than in the $\gamma$-rays.

*Conclusions.* The average $\gamma$-ray flux of PKS 0537−441 detected by AGILE is close to the average flux observed for this source by the EGRET and *Fermi*-LAT instruments, with an increase of a factor 3 throughout the observation period up to a flux level slightly lower than the highest flux observed by *Fermi*-LAT during the first 11 months of operation. The spectral energy distribution of PKS 0537−441 in mid-October 2008 seems to require two synchrotron self-Compton components to be modelled, to account for both the near-infrared/optical bump and the X-ray data, together with the information on the $\gamma$-ray flux level observed by AGILE. An alternative model based on the external Compton radiation, which requires an accretion disk with a relatively high luminosity, is also proposed.

**Key words.** gamma rays: general – BL Lacertae objects: individual: PKS 0537−441 – radiation mechanisms: non-thermal

## 1. Introduction

PKS 0537−441 is one of the best studied blazars of the southern hemisphere. The source is strongly variable at all wavelengths. The overall spectrum in different intensity states has been discussed in detail by Pian et al. (2002). Recently, this source was the target of simultaneous long-term optical and near-infrared monitoring with the Rapid Eye Mounting (REM) telescope and UV and X-ray monitoring with the *Swift* satellite between 2004 December and 2005 November (Dolcini et al. 2005; Pian et al. 2007). This systematic monitoring in the optical and near-infrared showed an excursion in all bands of ~5 mag.

According to its spectral energy distribution (SED) the source belongs to the low-energy-peaked BL Lac (LBL) or low-synchrotron-peaked (LSP; see Abdo et al. 2010) class. BL Lacs usually exhibit featureless spectra, although weak emission lines are sometimes seen during quiescent periods in some objects. Instead, a prominent emission feature at 5304 Å, likely associated to the Mg II $\lambda 2798$ line, was observed in the optical spectrum of PKS 0537−441, which indicates a redshift of 0.894 (Peterson et al. 1976; Stickel et al. 1993). Furthermore strong, broad emission lines of Ly$\alpha$ and C IV were observed by *Hubble Space Telescope* and, on the basis of their measured central wavelengths, Pian et al. (2002) derived $z = 0.896 \pm 0.001$. The detection of these broad emission lines suggests a mistaken classification of this object as BL Lac. At this redshift the inferred properties of PKS 0537–441 places it among the most luminous blazars.

PKS 0537−441 was detected in the $\gamma$-ray band by the EGRET telescope onboard the *Compton Gamma-Ray Observatory* (Hartman et al. 1999). Using this instrument, variability up to a factor 3 was found with a time scale of several years (Pian et al. 2002). More than ten years after the EGRET *era* this blazar appears also in the First AGILE-GRID Catalog of High Confidence Gamma-Ray Sources (Pittori et al. 2009) and in the First Catalog of Active Galactic Nuclei detected by the *Fermi*-Large Area Telescope (LAT) (Abdo et al. 2010), confirming its $\gamma$-ray activity over timescales of at least two decades. In particular, between 2008 September 15 and October 3, *Fermi*-LAT detected an increase of the $\gamma$-ray activity from the source (Tosti 2008) and this alert triggered multiwavelength observations by REM, *Swift* and AGILE observatories.

In this paper, we present the analysis of the AGILE data obtained during a ToO on PKS 0537−441 between 2008 October 10 and 17. In the same period the source was monitored in optical/UV and X-rays bands by *Swift* through 6 ToOs, performed between 2008 October 8 and 17. Moreover, the source was observed in near-infrared and optical bands by the REM telescope on October 7, 8, and 9 immediately before the AGILE observation. Throughout this paper, the quoted uncertainties are given at the 1-$\sigma$ significance level, unless otherwise stated.

## 2. AGILE data

### 2.1. AGILE observations

AGILE (*Astrorivelatore Gamma a Immagini LEggero*) is an Italian Space Agency (ASI) mission devoted to high-energy astrophysics studies. The AGILE scientific Instrument (Tavani et al. 2008, 2009) is very compact and combines four active detectors that provide broad-band coverage from hard X-rays to $\gamma$-rays: a silicon tracker sensitive in the 30 MeV−30 GeV energy band (ST; Prest et al. 2003; Barbiellini et al. 2001); a co-aligned coded-mask X-ray imager sensitive in the 18−60 keV energy band (SuperAGILE; Feroci et al. 2007; Costa et al. 2001); a non-imaging cesium iodide mini-calorimeter placed below the ST and sensitive in the 0.3−100 MeV energy band (MCAL; Labanti et al. 2009); and a segmented anti-coincidence system (ACS; Perotti et al. 2006). The combination of silicon tracker, mini-calorimeter, and anti-coincidence system forms the Gamma-Ray Imaging Detector (GRID).

In October 2008, during a dedicated satellite repointing on the source, the AGILE satellite devoted one week to observing the blazar PKS 0537−441 between 2008 October 10 11:50 UT and October 17 10:16 UT. SuperAGILE observed PKS 0537−441 for a total onsource net exposure time of about 308 ks.

### 2.2. Data analysis and results

Level–1 AGILE-GRID data were analysed using the AGILE Standard Analysis Pipeline. After the alignment of all data times to Terrestrial Time (TT), an ad-hoc implementation of the Kalman Filter technique was used to achieve track identification and event direction reconstruction. Subsequently, the data were filtered and a quality flag was assigned to each GRID event. We selected only events flagged as confirmed $\gamma$-ray events, while all events collected during the South Atlantic Anomaly were rejected. We also rejected all $\gamma$-ray events with reconstructed directions that formed angles with the satellite-Earth vector smaller than 80°, and this reduced the $\gamma$-ray Earth Albedo contamination by excluding regions within ~10° from the Earth limb.

Counts, exposure, and Galactic-background $\gamma$-ray maps, the last based on the diffuse emission model developed for AGILE (Giuliani et al. 2004), were created with a binsize of 0.25°×0.25° for photons of energies higher than 100 MeV.

During the observation of PKS 0537−441 an unidentified source at ~2° from the blazar showed weak activity in $\gamma$-rays. Thus, in order to separate the contributions of the two sources, the $\gamma$-ray flux of PKS 0537–441 was derived with the ALIKEMULTI2 task of the AGILE Scientific Analysis Pipeline, which allows multi-source maximum likelihood analysis considering two or more sources simultaneously.

During the period 2008 October 10–17, PKS 0537−441 was detected by AGILE-GRID at a significant level of 5.3-$\sigma$. The AGILE 95% maximum likelihood contour level barycentre of the source is $l = 249.78°$, $b = -31.23°$. The distance between this position and the PKS 0537−441 radio position ($l = 250.08°$, $b = -31.09°$) is 0.29°. The overall AGILE error circle, also taking systematic errors into account, has a radius $r = 0.35°$. The average $\gamma$-ray flux above 100 MeV during the entire observation period is $F_{E>100\ \mathrm{MeV}} = (42 \pm 11) \times 10^{-8}$ photons cm$^{-2}$ s$^{-1}$. To investigate the possible variation in $\gamma$-ray activity during the AGILE observation, we divided the whole period into two intervals of equal length: P1 (2008-10-10 11:50 UT – 2008-10-13 23:03 UT) and P2 (2008-10-13 23:03 UT – 2008-10-17 10:16 UT). During the interval P1 the source was marginally detected at a significance level of 2.5-$\sigma$, with an average flux of $F_{E>100\ \mathrm{MeV}} = (24 \pm 13) \times 10^{-8}$ photons cm$^{-2}$ s$^{-1}$, corresponding to a 2-$\sigma$ upper limit of $54 \times 10^{-8}$ photons cm$^{-2}$ s$^{-1}$ (95% confidence level). During the interval P2, however, the source was detected at a significance level of 5.7-$\sigma$, with an average flux of $F_{E>100\ \mathrm{MeV}} = (72 \pm 19) \times 10^{-8}$ photons cm$^{-2}$ s$^{-1}$, showing a clear rise of activity of the source in the second half of the observing period.

SuperAGILE observed PKS 0537−441 during 2008 October 10–17 for a total onsource net exposure time of 308 ks. The source was not detected (above 5-$\sigma$) by the SuperAGILE iterative removal of sources (IROS) algorithm, which was applied to the image in the 20−60 keV energy range. A 3-$\sigma$ upper limit of 6 mCrab was derived from the observed count rate by a study of the background fluctuations at the position of the source and a simulation of the source and background contributions with IROS.

## 3. *Swift* observations

The NASA *Swift* $\gamma$-ray Burst Mission (Gehrels et al. 2004) data on PKS 0537−441 were collected as a ToO observing campaign carried out between 2008 October 8 and 17 for a total onsource exposure of about 12 ks. All the observations were performed using all three onboard experiments: the X-ray Telescope (XRT; Burrows et al. 2005, 0.2−10 keV), the UV and Optical Telescope (UVOT; Roming et al. 2005, 170−600 nm), and the coded-mask Burst Alert Telescope (BAT; Barthelmy et al. 2005, 15−150 keV). The hard X-ray flux of this source is below the sensitivity of the BAT instrument for this short exposure. A 3-$\sigma$ upper limit of 1.2 mCrab in the 15−50 keV energy range was derived over the whole observing period.

### 3.1. *Swift*/XRT

The XRT data were processed with standard procedures (`xrtpipeline` v0.12.4), filtering, and screening criteria by using the `Heasoft` package (v.6.8). The source count rate was low during the whole campaign (mean count rate <0.5 counts s$^{-1}$), so we only considered photon counting (PC) data and further

**Table 1.** *Swift*/XRT observations and results of the spectral fits.

| Start time (UT) (yyyy-mm-dd hh:mm:ss) | End time (UT) (yyyy-mm-dd hh:mm:ss) | Exposure$^{a}$ (s) | Flux (0.3–10 keV)$^{b}$ (erg cm$^{-2}$ s$^{-1}$) | $\Gamma$ | $\chi^2_{\rm red}$ (d.o.f.) |
|---|---|---|---|---|---|
| 2008-10-08 00:03:19 | 2008-10-09 13:01:56 | 6850 | $7.52^{+0.73}_{-0.77} \times 10^{-12}$ | $1.64^{+0.07}_{-0.07}$ | 1.134 (45) |
| 2008-10-10 14:32:25 | 2008-10-17 00:48:56 | 4868 | $8.09^{+0.91}_{-0.90} \times 10^{-12}$ | $1.61^{+0.08}_{-0.08}$ | 1.010 (35) |
| 2008-10-08 00:03:19 | 2008-10-17 00:48:56 | 11 718 | $7.70^{+0.56}_{-0.55} \times 10^{-12}$ | $1.62^{+0.05}_{-0.05}$ | 1.246 (79) |

**Notes.** $^{(a)}$ The exposure time is spread over several snapshots (single continuous pointings at the target) during each observation. $^{(b)}$ Unabsorbed flux.

selected XRT event grades 0–12. Pile-up correction was not required. Source events were extracted from a circular region (radius of 20 pixels; 1 pixel ∼2.″36), while background events were extracted from an annular region centred on the source and with radii of 55 and 95 pixels. Ancillary response files were generated with `xrtmkarf`, and they account for different extraction regions, vignetting and PSF corrections. We used the spectral redistribution matrices v011 in the calibration database maintained by HEASARC.

A mean spectrum was extracted from the combined observations and was fit with `XSPEC` (v11.3.2) by adopting an absorbed power-law model with free photon index $\Gamma$ and using the photoelectric absorption model `tbabs` (Wilms 2000) with a neutral hydrogen column fixed to its Galactic value ($2.91 \times 10^{20}$ cm$^{-2}$; Murphy et al. 1996), consistently with Pian et al. (2007).

We also extracted spectra for two different subperiods, one before and one during the AGILE observation, and performed fits adopting the same model described above. No evidence of variability is detected in the X-ray during the *Swift*/XRT observations. Data were rebinned to have at least 20 counts per energy bin to allow the $\chi^2$ minimization. The fit results are reported in Table 1.

### 3.2. Swift/UVOT

During the six *Swift* pointings, the UVOT (Poole et al. 2008) instrument observed PKS 0537−441 in the $v$, $b$, $u$, and the $uvw1$, $uvm2$, and $uvw2$ photometric bands. The `uvotsource` tool was used to extract counts, correct for coincidence losses, apply background substraction, and calculate the source flux. We applied a standard 5 arcsec radius source aperture, and a 20 arcsec background region. The source fluxes were dereddened using the interstellar extinction curve in Fitzpatrick (1999). The magnitudes in the different filters are reported in Table 2.

## 4. REM observations

Since 2004 PKS 0537−441 was observed routinely by the REM robotic telescope (Zerbi et al. 2001; Covino et al. 2004). The REM telescope hosts two instruments: REMIR for near-IR (Conconi et al. 2004) and ROSS for the optical (Tosti et al. 2004), used to obtain nearly simultaneous data.

Observations in the VRIJHK bands from 2004 December to 2007 July are reported in Dolcini et al. (2005) and in Pian et al. (2007), while the 2007 November – 2008 February data appear in Impiombato et al. (2008). The entire set of data from 2004 to 2009 will be published in a forthcoming paper (Impiombato et al. 2010), where details on calibration and analysis procedure can be found.

After the alert on the high $\gamma$-ray state of PKS 0537-441 detected by *Fermi*-LAT (Tosti 2008), REM observed the source on three consecutive days, the first occurring on 2008 October 7. The results for all the bands are reported in Table 3. No significant variability is shown during the three nights. The state of the source was relatively low. In fact the overall 2004–2009 light curve in $V$-band ranges between 13.3 and 16.7 (see Impiombato et al. 2010, for more details).

**Table 2.** *Swift*/UVOT observations and magnitudes.

| Start Time (UT) | MJD | Filter | Mag$^{a}$ |
|---|---|---|---|
| 2008-10-08 01:39:50 | 54 747.0693 | $v$ | 15.73 ± 0.08 |
| 2008-10-08 01:35:45 | 54 747.0665 | $b$ | 16.10 ± 0.05 |
| 2008-10-08 01:34:54 | 54 747.0659 | $u$ | 15.37 ± 0.05 |
| 2008-10-08 01:33:16 | 54 747.0648 | $uvw1$ | 15.47 ± 0.06 |
| 2008-10-08 22:29:23 | 54 747.9371 | $v$ | 15.75 ± 0.05 |
| 2008-10-08 22:21:57 | 54 747.9319 | $b$ | 16.19 ± 0.04 |
| 2008-10-08 22:20:26 | 54 747.9308 | $u$ | 15.48 ± 0.04 |
| 2008-10-08 22:17:27 | 54 747.9288 | $uvw1$ | 15.50 ± 0.05 |
| 2008-10-09 04:56:34 | 54 748.2059 | $v$ | 15.74 ± 0.06 |
| 2008-10-09 04:50:50 | 54 748.2020 | $b$ | 16.30 ± 0.04 |
| 2008-10-09 04:49:38 | 54 748.2011 | $u$ | 15.50 ± 0.04 |
| 2008-10-09 04:47:20 | 54 748.1995 | $uvw1$ | 15.60 ± 0.05 |
| 2008-10-09 04:52:02 | 54 748.2028 | $uvw2$ | 15.74 ± 0.05 |
| 2008-10-10 14:40:22 | 54 749.6114 | $v$ | 15.74 ± 0.07 |
| 2008-10-10 14:35:25 | 54 749.6079 | $b$ | 16.28 ± 0.05 |
| 2008-10-10 14:34:24 | 54 749.6072 | $u$ | 15.52 ± 0.05 |
| 2008-10-10 14:32:26 | 54 749.6059 | $uvw1$ | 15.60 ± 0.06 |
| 2008-10-10 14:41:23 | 54 749.6121 | $uvm2$ | 15.49 ± 0.06 |
| 2008-10-10 14:36:28 | 54 749.6087 | $uvw2$ | 15.66 ± 0.05 |
| 2008-10-11 00:20:38 | 54 750.0143 | $v$ | 15.82 ± 0.10 |
| 2008-10-11 00:17:48 | 54 750.0124 | $b$ | 16.26 ± 0.07 |
| 2008-10-11 00:17:12 | 54 750.0119 | $u$ | 15.48 ± 0.06 |
| 2008-10-11 00:16:04 | 54 750.0112 | $uvw1$ | 15.75 ± 0.08 |
| 2008-10-11 00:21:14 | 54 750.0147 | $uvm2$ | 15.58 ± 0.08 |
| 2008-10-12 19:39:26 | 54 751.8191 | $b$ | 16.41 ± 0.05 |
| 2008-10-12 21:16:02 | 54 751.8861 | $b$ | 16.44 ± 0.05 |
| 2008-10-12 19:38:25 | 54 751.8183 | $u$ | 15.74 ± 0.05 |
| 2008-10-12 21:14:56 | 54 751.8854 | $u$ | 15.60 ± 0.05 |
| 2008-10-12 19:36:26 | 54 751.8170 | $uvw1$ | 15.77 ± 0.06 |
| 2008-10-12 21:12:48 | 54 751.8839 | $uvw1$ | 15.76 ± 0.06 |
| 2008-10-12 19:40:29 | 54 751.8198 | $uvw2$ | 15.87 ± 0.05 |
| 2008-10-12 21:17:10 | 54 751.8869 | $uvw2$ | 15.88 ± 0.05 |
| 2008-10-17 00:47:24 | 54 756.0329 | $b$ | 15.89 ± 0.03 |
| 2008-10-17 00:45:47 | 54 756.0318 | $u$ | 15.17 ± 0.03 |
| 2008-10-17 00:42:39 | 54 756.0296 | $uvw1$ | 15.19 ± 0.04 |

**Notes.** $^{(a)}$ Magnitudes are corrected for Galactic extinction.

## 5. Discussion

PKS 0537−441 was detected for the first time in the $\gamma$-ray band by EGRET in 1991 (Michelson et al. 1992). Subsequently it was observed in several different states (Treves et al. 1993; Hartman et al. 1999; Pian et al. 2002) with an integrated flux

**Table 3.** REM observations and magnitudes.

| Start Time (UT) | MJD | Filter | Mag |
|---|---|---|---|
| 2008-10-07 06:50:16 | 54 746.28491 | *v* | 16.063 ± 0.085 |
| 2008-10-07 06:55:44 | 54 746.28871 | *R* | 15.362 ± 0.011 |
| 2008-10-07 07:01:10 | 54 746.29248 | *I* | 14.779 ± 0.028 |
| 2008-10-07 06:51:31 | 54 746.28578 | *J* | 13.773 ± 0.047 |
| 2008-10-07 06:56:58 | 54 746.28956 | *H* | 12.984 ± 0.041 |
| 2008-10-07 07:02:25 | 54 746.29334 | *K* | 12.418 ± 0.024 |
| 2008-10-08 06:50:09 | 54 747.28483 | *v* | 15.989 ± 0.086 |
| 2008-10-08 06:55:35 | 54 747.28861 | *R* | 15.337 ± 0.028 |
| 2008-10-08 07:01:02 | 54 747.29239 | *I* | 14.698 ± 0.026 |
| 2008-10-08 06:51:23 | 54 747.28568 | *J* | 13.543 ± 0.041 |
| 2008-10-08 06:56:50 | 54 747.28947 | *H* | 12.844 ± 0.041 |
| 2008-10-08 07:02:16 | 54 747.29324 | K | 12.367 ± 0.024 |
| 2008-10-09 05:30:48 | 54 748.22973 | *v* | 15.908 ± 0.090 |
| 2008-10-09 05:36:17 | 54 748.23353 | *R* | 15.201 ± 0.030 |
| 2008-10-09 05:41:43 | 54 748.23731 | *I* | 14.734 ± 0.030 |
| 2008-10-09 05:32:02 | 54 748.23058 | *J* | 13.651 ± 0.041 |
| 2008-10-09 05:37:31 | 54 748.23439 | *H* | 12.857 ± 0.040 |
| 2008-10-09 05:42:58 | 54 748.23817 | *K* | 12.367 ± 0.024 |

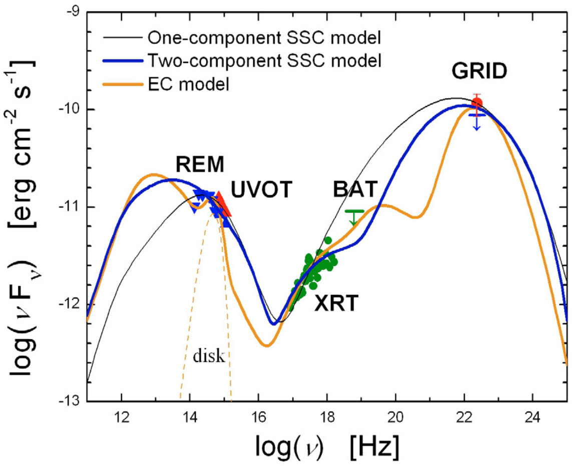

**Fig. 1.** The SED of PKS 0537−441, including near-infrared and optical REM data, UV, soft X-ray and hard X-ray *Swift* data, and $\gamma$-ray AGILE data. Blue symbols refer to the period 2008 October 7–13, red symbols refer to the period 2008 October 13–17. The *Swift*/XRT and *Swift*/BAT data (in green) are averaged over the whole observing period. For *Swift*/UVOT are represented the data collected in the *u, b, uvw1* filters, with the data of the first period averaged over all the available observations. The black, blue and orange lines represent the one-component SSC, two-component SSC, and EC model, respectively. The dashed orange line represents the emission from the disk in the EC model.

above 100 MeV between $(16.5\pm4.5)$ and $(91.1\pm14.6)\times10^{-8}$ photons cm$^{-2}$ s$^{-1}$. The average flux over all the EGRET observations was $(25.3 \pm 3.1) \times 10^{-8}$ photons cm$^{-2}$ s$^{-1}$. However, the peak of the $\gamma$-ray emission was observed by EGRET in January 1995 at $(200\pm50)\times10^{-8}$ photons cm$^{-2}$ s$^{-1}$ (Pian et al. 2002), considering a temporal binning of 2 days.

During its first eleven months of observations (2008 August – 2009 July) *Fermi*-LAT observed an average flux of $F_{E>100\ \mathrm{MeV}} = (37.77 \pm 1.06) \times 10^{-8}$ photons cm$^{-2}$ s$^{-1}$ (Abdo et al. 2010). This blazar is included also in the First AGILE-GRID Catalog of High Confidence Gamma-Ray Sources with an average flux of $F_{E>100\ \mathrm{MeV}} = (42 \pm 10) \times 10^{-8}$ photons cm$^{-2}$ s$^{-1}$ (Pittori et al. 2009), confirming, also in the period 2007 July–2008 June, the average flux level of the source observed by *Fermi*-LAT.

Since 2008 September 15, *Fermi*-LAT observed an increase in the $\gamma$-ray flux of the source. On October 3 the flux almost reached the maximum observed by EGRET in the several viewing periods. A similar level of activity was also detected by *Fermi*-LAT on 2008 July 8 (Bastieri 2009) and AGILE on 2010 mid-February (Lucarelli et al. 2010).

AGILE observed $\gamma$-ray activity from PKS 0537−441 between 2008 October 10 and 17. A multi-source maximum likelihood analysis (which also takes into account the weak emission coming from an unidentified source at ~2° from the blazar) yields a source flux of $F_{E>100\ \mathrm{MeV}} = (42 \pm 11) \times 10^{-8}$ photons cm$^{-2}$ s$^{-1}$ for photon energies above 100 MeV. This is a factor of five lower than the maximum flux detected by EGRET but comparable to the averaged flux detected by *Fermi*-LAT during the first eleven months of observations and practically coincident with the average flux detected by AGILE in the first year of operation. An increase by a factor of three between the first and the second halves of the observing period was observed, with a $\gamma$-ray flux value rising to $(72\pm19)\times10^{-8}$ photons cm$^{-2}$ s$^{-1}$. This flux is a factor of three lower than the maximum flux observed by EGRET.

During 2004–2005 the source was intensively monitored by REM and *Swift* and these long-term observations showed that the optical *V*-band and X-ray light curves are highly correlated, even if the *V*-band varies with much higher amplitude: an optical flux variation of a factor of 60 was observed between 2004 December and 2005 February, whereas in the X-ray band *Swift*/XRT observed a variation only of a factor 2.

The average flux observed by *Swift* during 2008 October obtained by combining the 6 ToO observations, $F(0.3{-}10\ \mathrm{keV}) = (7.7 \pm 0.6) \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$, seems to indicate an intermediate activity state of the source, with respect to the range of flux detected during the observations carried out by *Swift* in 2005, $(3.9{-}14.9) \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$. No significant variability in X-rays is noted between the different observations.

During the period October 10–17 the source was also observed in the 2–10 keV energy band by the All Sky Monitor (ASM) onboard the *Rossi X-ray Timing Explorer* (RXTE), and on October 13 there is a 3-$\sigma$ detection with a flux of the order of $2 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$, which, while considering the low significance of the detection and the relative high uncertainties, could be a hint of the increase in activity of the source in X-rays, also observed in the $\gamma$-ray band. Moreover, the fluxes observed by *Swift*/UVOT in *u*, *b*, *uvw*1 bands increased by about 0.5 mag between the observations in October 12 and 17, possibly indicating a rise in the activity of PKS 0537−441.

The SED for the AGILE, *Swift*, and REM data of 2008 mid-October is shown in Fig. 1. Our modelling of the spectrum starts with an assumed electron distribution in the form of a broken power-law

$$n_{\mathrm{e}}(\gamma) = \frac{K\,\gamma_{\mathrm{b}}^{-1}}{(\gamma/\gamma_{\mathrm{b}})^{\zeta_1} + (\gamma/\gamma_{\mathrm{b}})^{\zeta_2}} \tag{1}$$

where $\zeta_1$ and $\zeta_2$ are the spectral indices before and after the break Lorentz factor $\gamma_{\mathrm{b}}$. These electrons emit a primary synchrotron spectrum, and a second contribution is then produced by inverse Compton as the primary synchrotron photons scatter off the same electron population. If we assume that the broad optical/UV peak is due to synchrotron emission from a population of high-energy electrons in a random magnetic field $B$, then the synchrotron self-Compton (SSC) emission can account for the strong $\gamma$-ray flux observed by GRID.

In this case, SSC contribution by a second population of low-energy electrons is required to account for the stable and moderate emission in X-rays, so we adopt a two-component SSC model. For the first component the parameters are: $\gamma_{\rm b} = 500$; $\gamma_{\rm min} = 100$; $\zeta_1 = 2$; $\zeta_2 = 5$; $K = 70\,{\rm cm}^{-3}$ and $B = 1.0\,{\rm G}$. For the second one, $\gamma_{\rm b} = 6500$; $\gamma_{\rm min} = 3000$; $\zeta_1 = 2$; $\zeta_2 = 5$; $K = 20\,{\rm cm}^{-3}$ and $B = 0.15\,{\rm G}$. In this way, the total jet power is $L_{\rm j} = 5 \times 10^{45}\,{\rm erg\,cm^{-2}s^{-1}}$ (see Celotti & Ghisellini 2008).

A standard one-component SSC model can only marginally reproduce the optical bump and the X-ray spectrum simultaneously. Moreover, the very strong jet power involved in such a model, up to $L_{\rm j} = 9 \times 10^{45}\,{\rm erg\,s^{-1}}$, is consistent with the Blandford-Znajek (1977) mechanism of power extraction from a rotating black hole (BH) only for BH masses higher than $2 \times 10^9\ M_\odot$. For this model the parameters are $\gamma_{\rm b} = 6500$; $\gamma_{\rm min} = 230$; $\zeta_1 = 2$; $\zeta_2 = 5$; $K = 10\,{\rm cm}^{-3}$ and $B = 0.2\,{\rm G}$.

We also propose an alternative model where the optical bump comes from the accretion disk emission, with a subsequent significant contribution in the high-energy bump of the external Compton (EC) scattering of both direct-disk radiation and photons reprocessed by the broad line region. In this case remarkable disk power of $L_{\rm d} \sim 3 \times 10^{46}\,{\rm erg\,s^{-1}}$ would be required with the following jet parameters: $\gamma_{\rm b} = 400$; $\gamma_{\rm min} = 100$; $\zeta_1 = 2$; $\zeta_2 = 5$ $K = 70\,{\rm cm}^{-3}$, and $B = 1.6\,{\rm G}$. In all models the emission region is assumed to have radius $R = 2.3 \times 10^{16}$ cm and to move with bulk Lorentz factor $\Gamma = 15$ at an angle $\sim 2°$ with respect to the observer. BL Lacs are usually associated with low photon-density ambients; however, past observations of broad emission lines in the optical/UV spectrum of this object (Pian et al. 2002) suggest that, at least during significant activity states, the EC contribution could be important for the radiation emission in the high-energy part of the spectrum. Only the long-term monitoring in $\gamma$-rays by the AGILE and *Fermi* satellites, together with suitable multifrequency coverage, can firmly conclude on the EC contribution in this object and on the real nature of this peculiar blazar.

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[1] INAF/IASF–Roma, via del Fosso del Cavaliere 100, 00133 Roma, Italy
e-mail: `gianluca.pucella@iasf-roma.inaf.it`
[2] Dip. di Fisica, Univ. "Tor Vergata", via della Ricerca Scientifica 1, 00133 Roma, Italy
[3] INAF/IASF–Palermo, via U. La Malfa 153, 90146 Palermo, Italy
[4] Dip. di Fisica, Univ. dell'Insubria, via Valleggio 11, 22100 Como, Italy
[5] INAF – Osservatorio Astronomico di Trieste, via G. B. Tiepolo 11, 34143 Trieste, Italy
[6] Scuola Normale Superiore, Piazza dei Cavalieri 7, 56126, Pisa
[7] Dip. di Fisica, Univ. di Perugia, via B. Bonfigli, 06126 Perugia, Italy
[8] INAF – Osservatorio Astronomico di Brera, via E. Bianchi 46, 23807 Merate (LC), Italy
[9] ASI–ASDC, via G. Galilei, 00044 Frascati (Roma), Italy
[10] NASA/Goddard Space Flight Center, Greenbelt, MD 20771, USA
[11] INAF/IASF–Bologna, via Gobetti 101, 40129 Bologna, Italy
[12] INAF/IASF–Milano, via E. Bassini 15, 20133 Milano, Italy
[13] Dip. di Fisica and INFN Trieste, via Valerio 2, 34127 Trieste, Italy
[14] INFN–Pavia, via Bassi 6, 27100 Pavia, Italy
[15] Dip. di Fisica Nucleare e Teorica, Univ. di Pavia, via Bassi 6, 27100 Pavia, Italy
[16] ENEA, via Martiri di Monte Sole 4, 40129 Bologna, Italy
[17] INFN–Roma "La Sapienza", Piazzale A. Moro 2, 00185 Roma, Italy
[18] INFN–Roma "Tor Vergata", via della Ricerca Scientifica 1, 00133 Roma, Italy
[19] INAF–OA Cagliari, loc. Poggio dei Pini, strada 54, 09012 Capoterra, Italy
[20] ENEA–Frascati, via E. Fermi 45, 00044 Frascati (Roma), Italy
[21] ASI, via le Liegi 26, 00198 Roma, Italy