

Multiwavelength campaigns on the blazar PKS 1510-089 during 2008-2009: the importance of the broad band coverage by the *Swift* satellite

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ABSTRACT

In the last two years, intense gamma-ray activity from the Flat Spectrum Radio Quasar (FSRQ) PKS 1510-089 was detected by the AGILE and *Fermi* satellites. In particular, AGILE detected a rapid flare in March 2008 and an extraordinary activity with several flaring episodes during March 2009, triggering multiwavelength campaigns in which the *Swift* satellite was strongly involved. Moreover, during July-August 2009 an extensive campaign on this object was organized with observations from radio-to-TeV including 18 *Swift* ToO observations. Observations in the optical and UV bands by GASP-WEBT and *Swift*/UVOT seem to indicate the presence of Seyfert-like features in the broad band spectrum of PKS 1510-089, such as the little and big blue bumps. Moreover, the data collected from radio-to-UV on 26 March, simultaneously to a huge gamma-ray flare, seem to show a possible shift from infrared to optical of the synchrotron peak. X-ray observations performed by *Swift*/XRT on mid March 2008 show a harder-when-brighter behaviour of the source spectrum, quite rare in the FSRQs. Instead, during March 2009 the X-ray flux seems not to be correlated with the high optical and gamma-ray activity. The broad band coverage with the *Swift* satellite, thanks to the very quick response during the high activity states and the long term monitoring of the source, allowed us to study in detail these spectral features in optical/UV and X-ray bands together with the multiwavelength observations at other frequencies. We present the results of the analysis of the multiwavelength data of PKS 1510-089 collected during the high gamma-ray activity of March 2008 and March 2009 and the *Swift* data obtained during the July-August 2009 campaign as well as the theoretical implication for the emission mechanisms.

MARCH 2008

During March 2008, after two episodes of medium intensity PKS 1510-089 was not detected for some days in the gamma-ray band and suddenly a rapid gamma-ray flare was observed by AGILE on 18-19 March (Fig. 1), as discussed in detail in D'Ammando et al. (2009a).

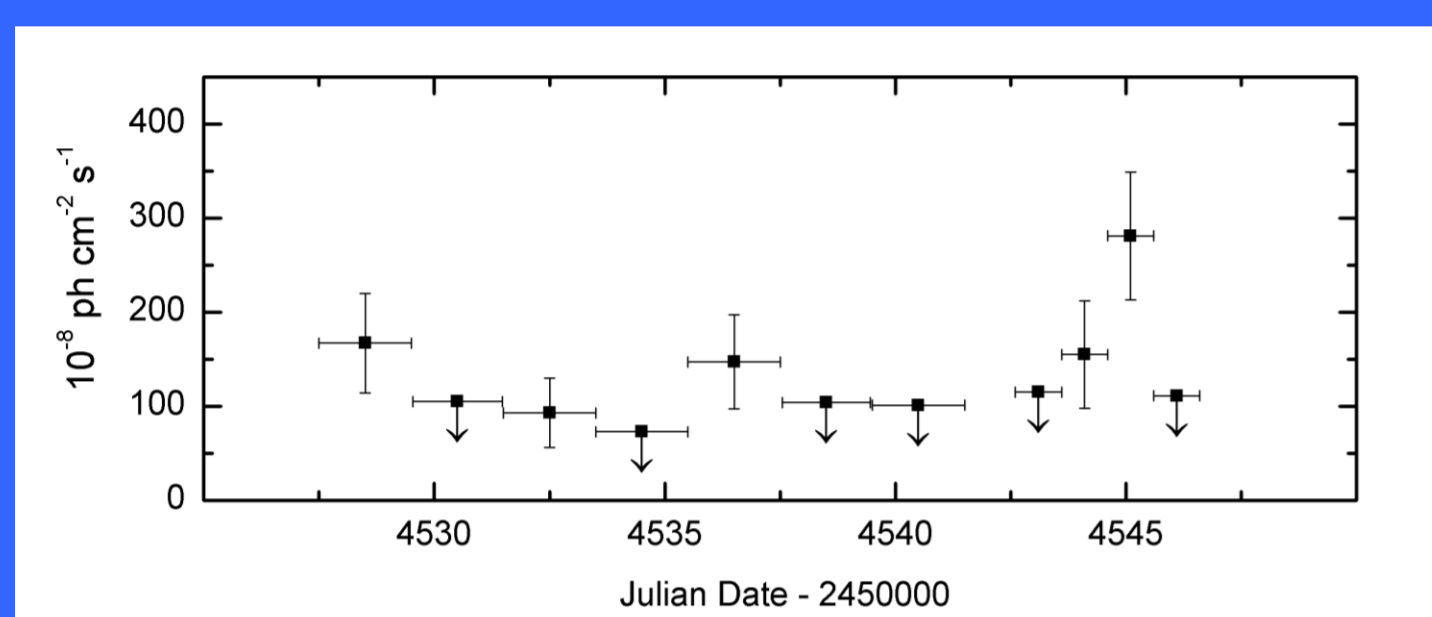


Fig. 1: AGILE gamma-ray light curve between 1 and 21 March 2008 at 1 or 2-day resolution for $E > 100$ MeV. The downward arrows represent 2-sigma upper limits

During the period 1-16 March 2008, AGILE detected an average flux from PKS 1510-089 of $(84 \pm 17) \times 10^{-8}$ photons $\text{cm}^{-2} \text{s}^{-1}$ for $E > 100$ MeV. The average flux between 17 and 21 March was a factor of 2 higher, with a peak level of $(281 \pm 68) \times 10^{-8}$ photons $\text{cm}^{-2} \text{s}^{-1}$ on 19 March 2008.

Moreover, between January and April 2008 the source showed an intense and variable optical activity with several flaring episodes of fast variability detected by GASP-WEBT. Peaks were detected on 15 February, 29 March and 11 April 2008 in the optical band (Fig. 2, upper panel). A significant increase of the flux was observed also at millimetric frequencies in mid April, suggesting that the mechanisms producing the flaring events in the optical and gamma-ray bands also interested the millimetric zone, with a delay.

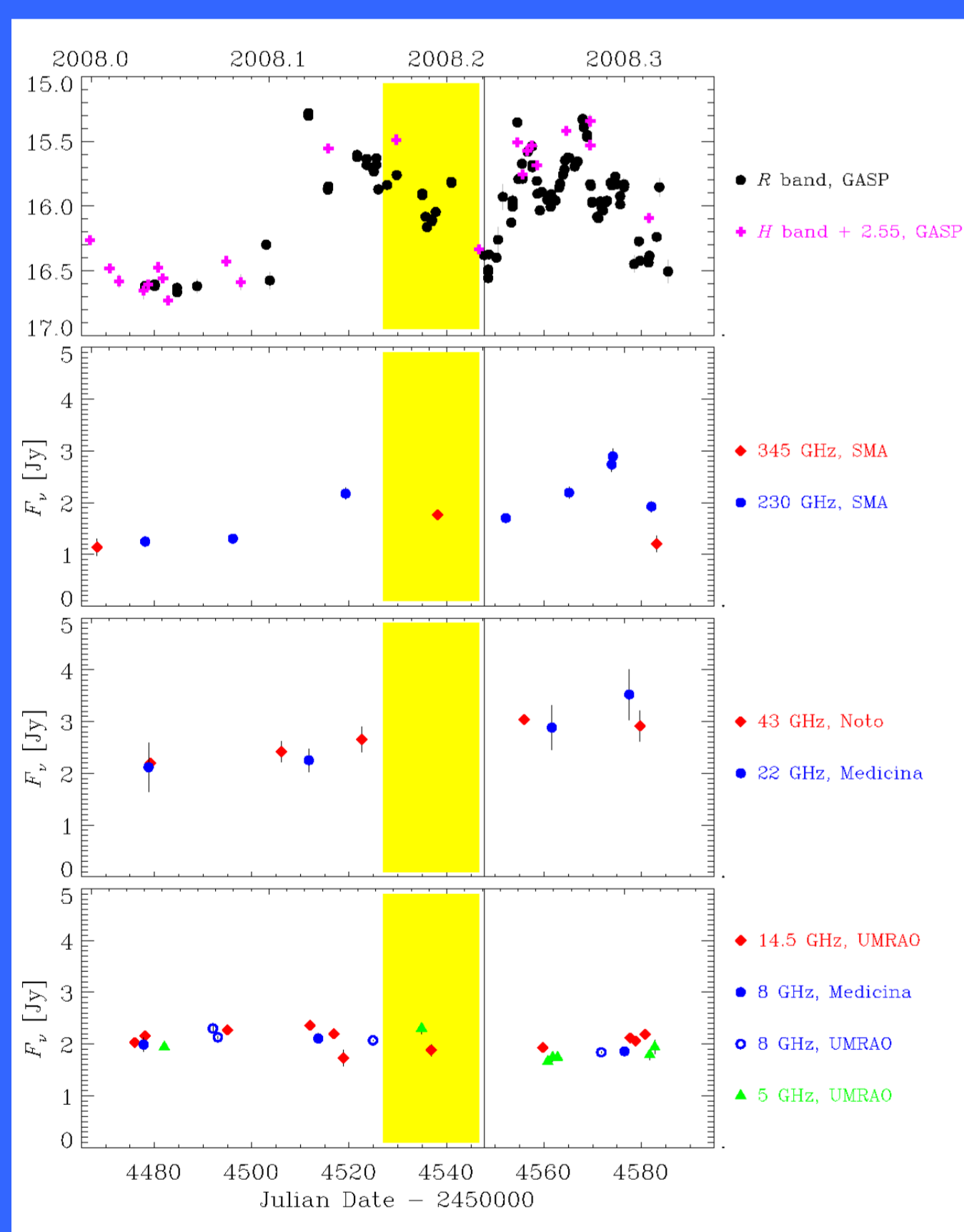


Fig. 2: Optical and radio light curves collected by GASP-WEBT during January-April 2008

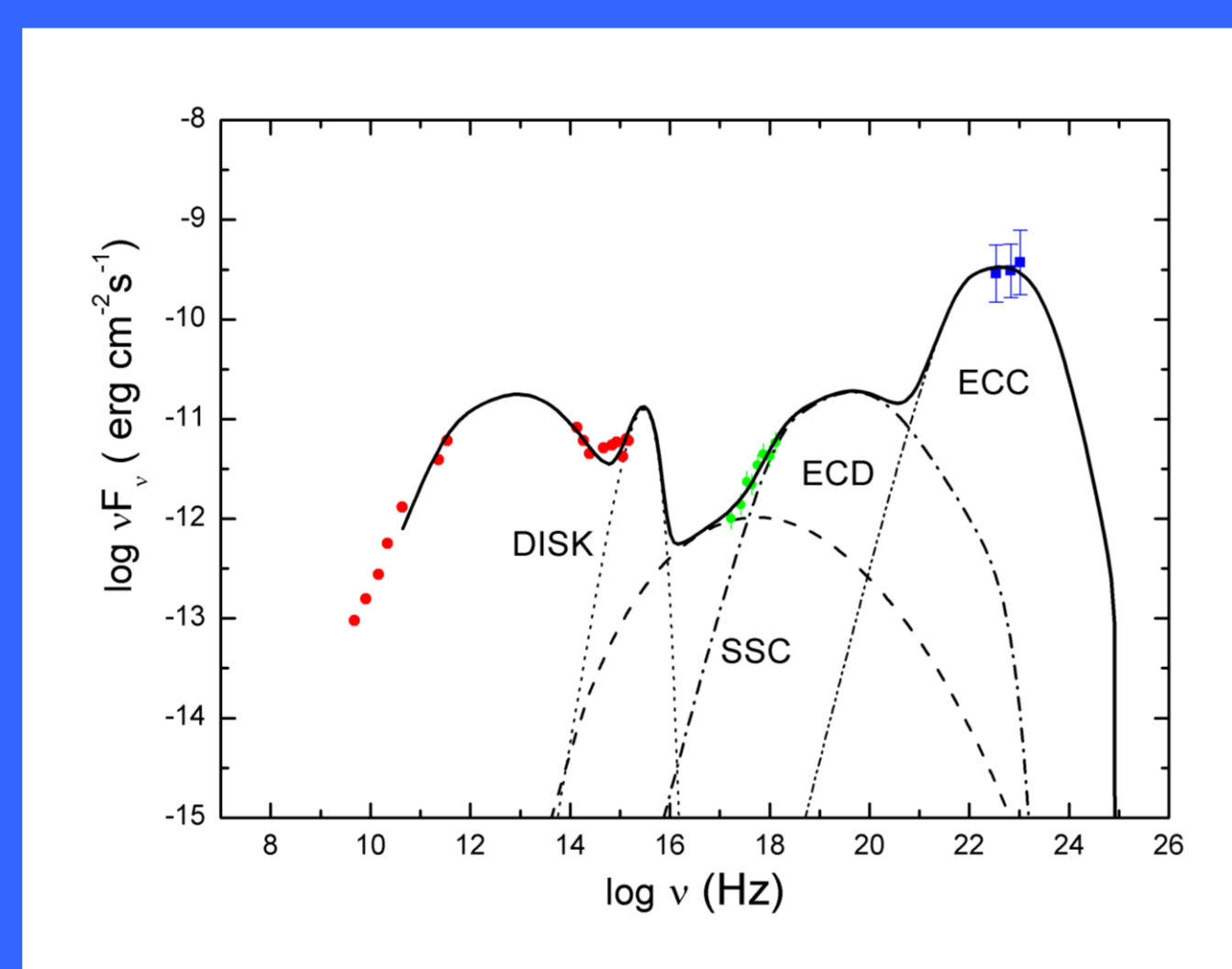


Fig. 3: SED for the AGILE observation of 17-21 March 2008 including radio-to-optical GASP data and UV and X-ray *Swift* data

The gamma-ray flare triggered 3 ToO observations with *Swift* in three consecutive days between 20 and 22 March 2008. The first XRT observation showed a very hard X-ray photon index ($\Gamma = 1.16 \pm 0.16$) with a flux in the 0.3-10 keV band of $(1.22 \pm 0.17) \times 10^{-11}$ erg $\text{cm}^{-2} \text{s}^{-1}$ and a decrease of about 30% between 20 and 21 March.

The *Swift*/XRT observations seem to show a harder-when-brighter behaviour of the spectrum in the X-ray band, confirming a behaviour already observed in this source by Kataoka et al. (2008). This is a trend usually observed in HBL such as Mrk 421 (see e.g. Tramacere et al. 2007) but quite rare in FSRQs such as PKS 1510-089. This harder-when-brighter behaviour is likely due to the different variability of the SSC and EC components, therefore to the change of the contribution of one of the two components with respect to the other. Thus, the X-ray photon index observed on 20 March could be due to the mismatch of the spectral slopes of the SSC and EC components.

The SED for the gamma-ray AGILE observation of 17-21 March 2008 together with the simultaneous data collected in radio and optical bands by GASP-WEBT and UV and X-ray bands by *Swift* is modelled with thermal emission of the disk, SSC model plus the contribution of external Compton scattering of direct disk radiation and reprocessed by the BLR (Fig. 3). Some features in the optical-UV spectrum seem to indicate the presence of Seyfert-like components, such as the little and big blue bumps (see also Fig. 7).

MARCH 2009

PKS 1510-089 showed an extraordinary gamma-ray activity during March 2009, with several flaring episodes (Fig. 4). After a low intensity period in February 2009, the optical activity of the source is also greatly increased in March 2009 with an intense flare (Fig. 5). A similar behaviour was observed by REM with an achromatic variations in near-infrared (Fig. 6) and optical bands.

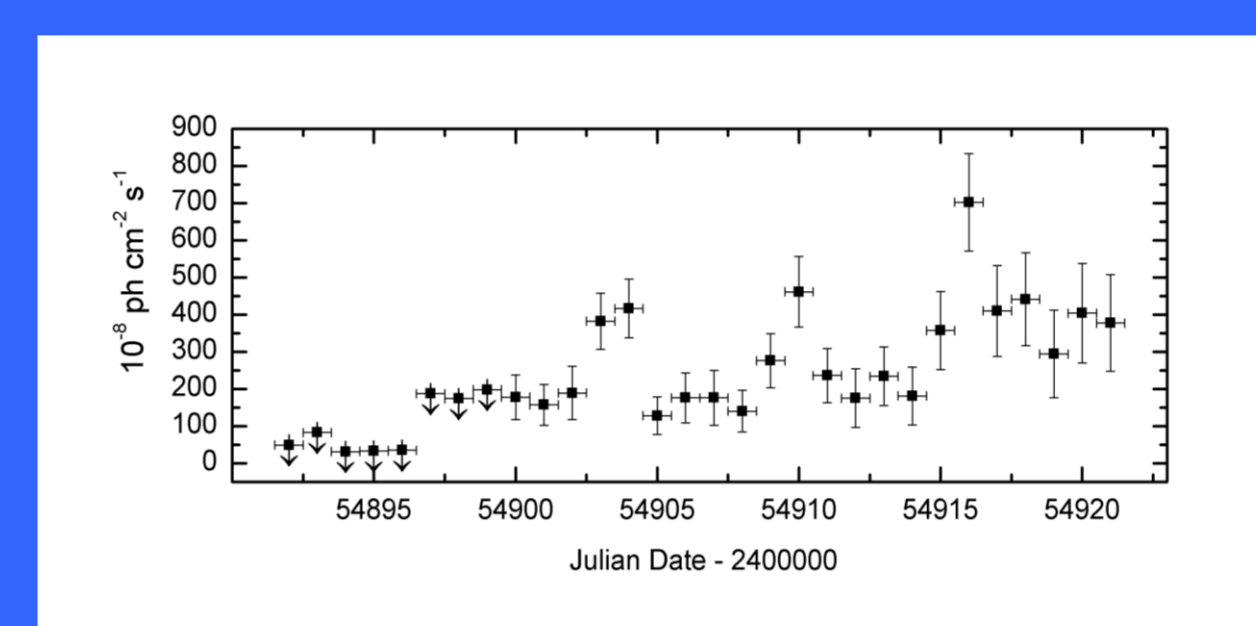


Fig. 4: AGILE gamma-ray light curve between 1 and 30 March 2009 for $E > 100$ MeV. The downward arrows represent 2-sigma upper limits

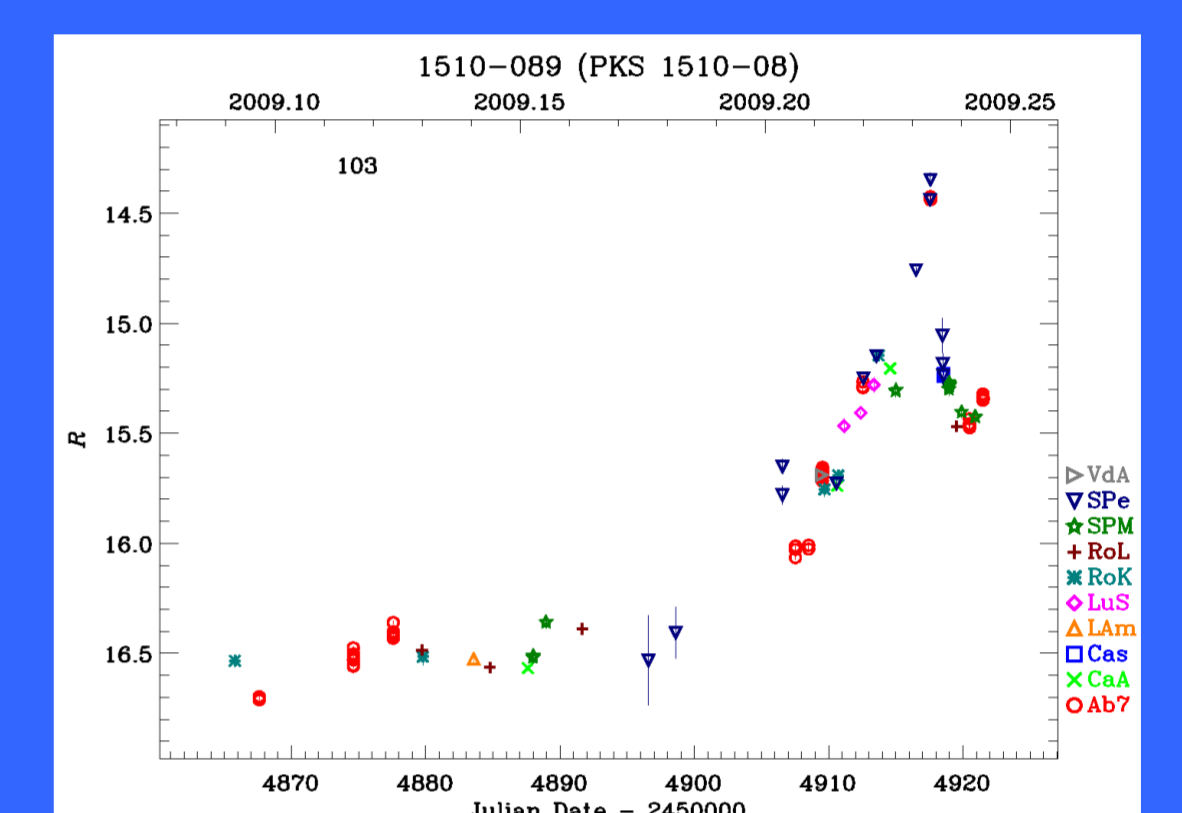


Fig. 5: Optical light curves collected by GASP-WEBT during February-March 2009

During the 14 ToO observations performed in March 2009, *Swift*/XRT observed the source in an intermediate activity state with a 0.3-10 keV flux in the range $(7.5-10.8) \times 10^{-12}$ erg $\text{cm}^{-2} \text{s}^{-1}$. The X-ray flux seems not to be correlated with the high optical and gamma-ray activity. A hard X-ray outburst of this source was detected by *Swift*/BAT on 9 March 2009, with a rise from 15 mCrab to 40 mCrab in 24 hours. On 10 March 2009 the source faded below the BAT sensitivity (Krimm et al. 2009). It is interesting to note that this outburst in the 15-50 keV energy band occurred just at the beginning of the gamma-ray activity observed by AGILE. Taking into account that the dip at the UVW1 frequency it is also found for other blazars with different redshift and could be systematic, the broad band spectrum from radio-to-UV on 25-26 March 2009 (Fig. 7) seems to show a flat spectrum in the optical/UV suggesting an important contribution of the synchrotron emission in this part of the spectrum during the huge flaring episode and therefore a possible shift of the synchrotron peak, usually observed in this source in the infrared band. The result of the MW campaign of March 2009 will be presented in D'Ammando et al. (2009b).

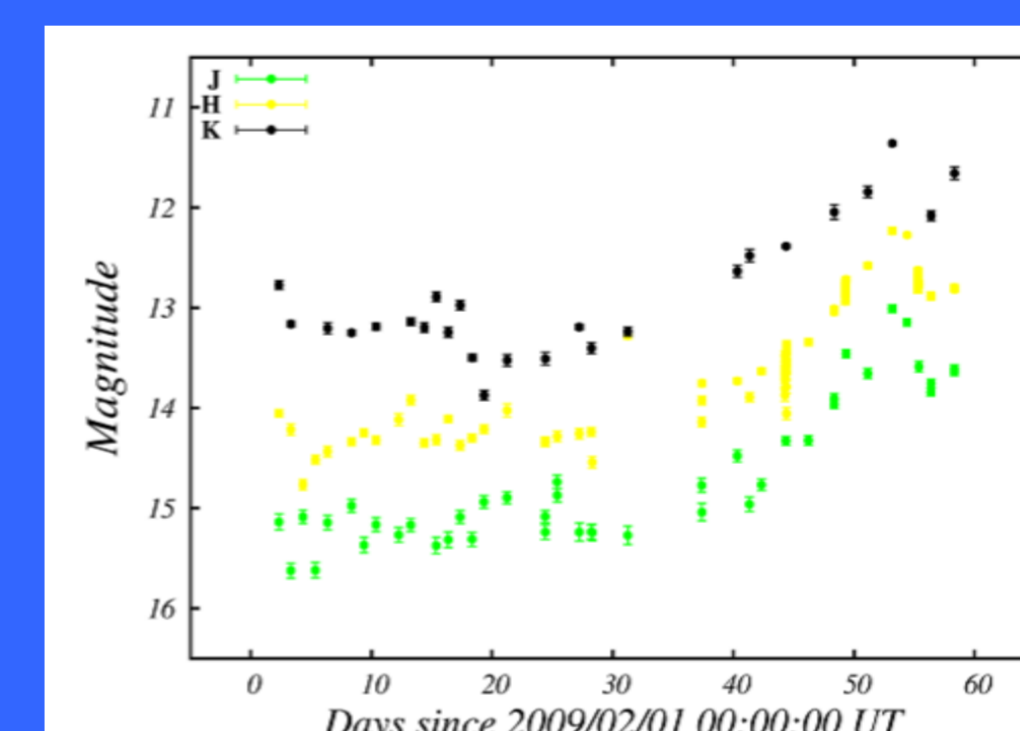


Fig. 6: NIR light curves collected by REM Telescope during February-March 2009

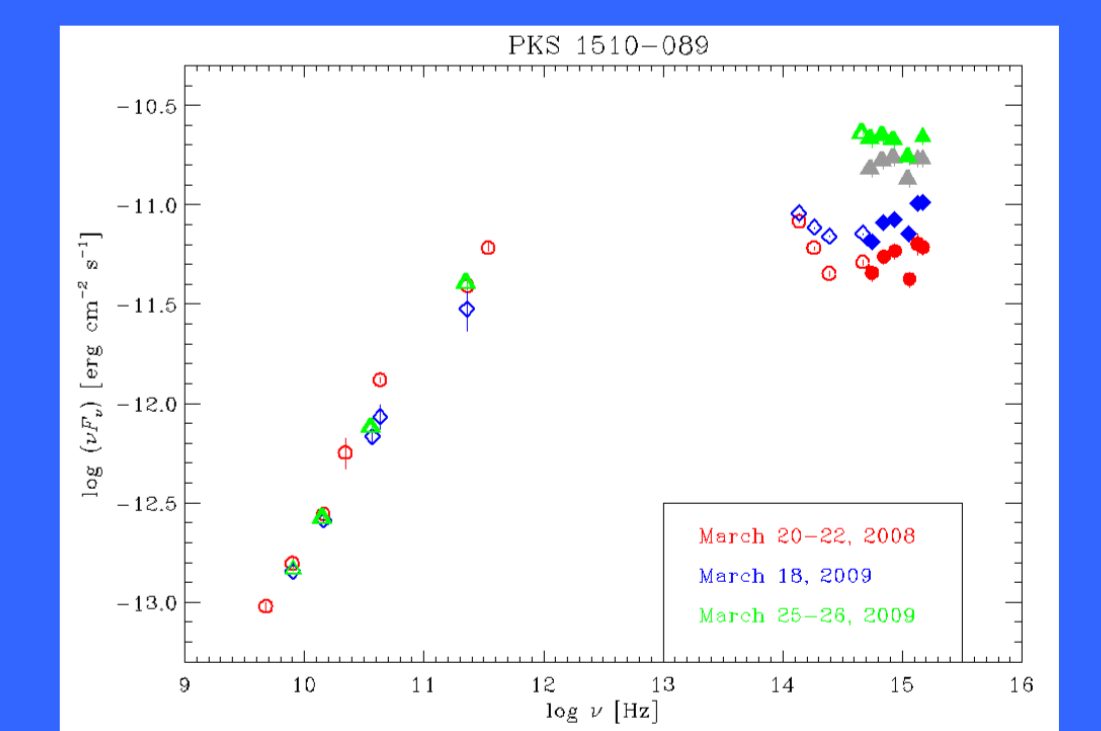


Fig. 7: SED of March 2008 and March 2009 with GASP-WEBT and *Swift*/UVOT data

JULY-AUGUST 2009

During July-August 2009 an extensive multifrequency campaign from radio to TeV on PKS 1510-089 was organized including GASP-WEBT, REM, F-GAMMA Project, *Swift*, RXTE, *Fermi* and H.E.S.S. observations. In particular, the *Swift* satellite with 18 ToO observations allowed a dense monitoring in optical/UV and X-ray bands. Preliminary light curves collected by XRT and UVOT between 21 July and 30 August 2009 are shown in Fig. 8 and Fig. 9.

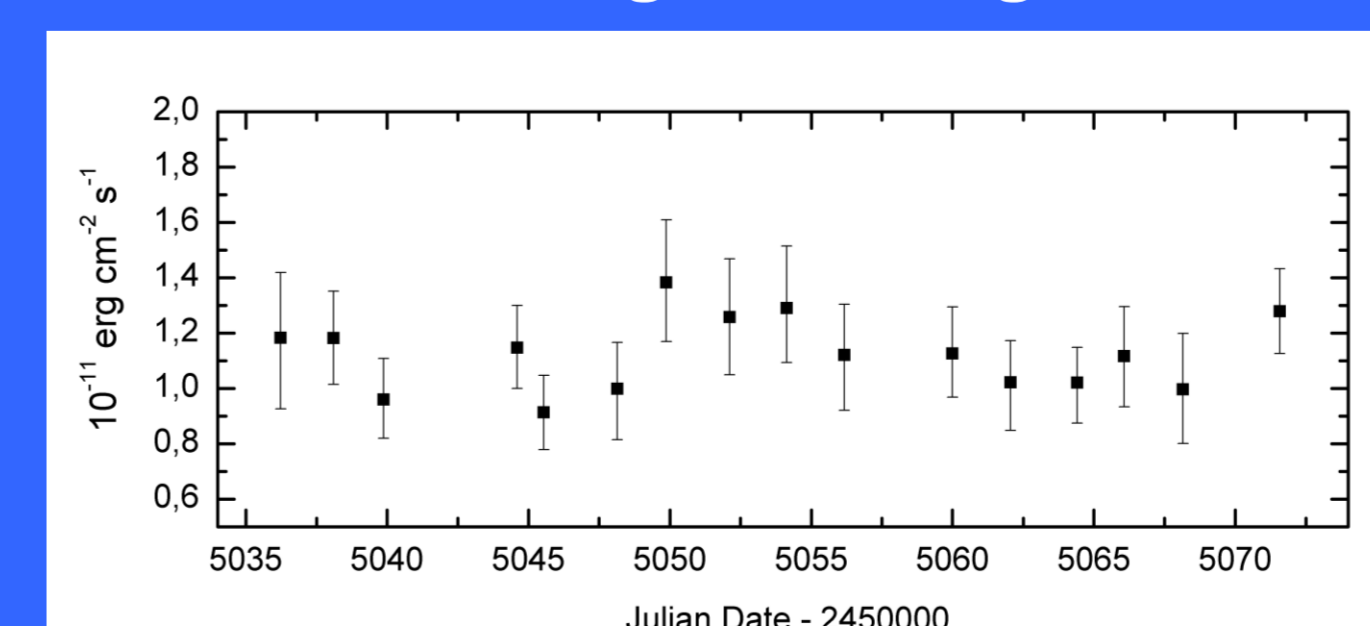


Fig. 8: *Swift*/XRT light curves in the 2.0-10 keV band during July-August 2009

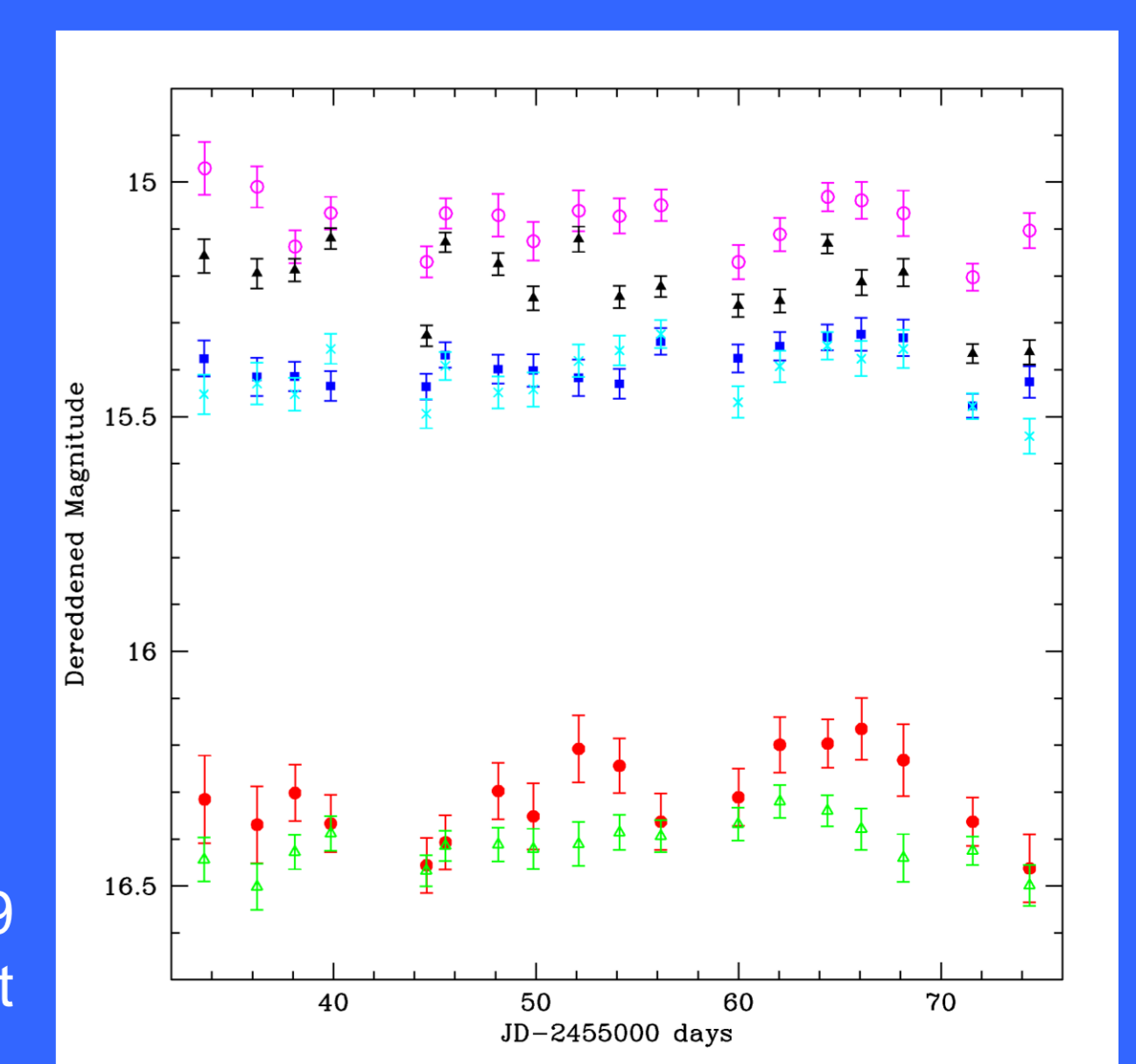


Fig. 9: *Swift*/UVOT light curves in July-August 2009 in filters V (red), B (green), U (dark blue), W1 (light blue), M2 (pink) and W2 (black).