FACT - the First G-APD Cherenkov Telescope

Blazar Variability - Insights from Long-Term Monitoring

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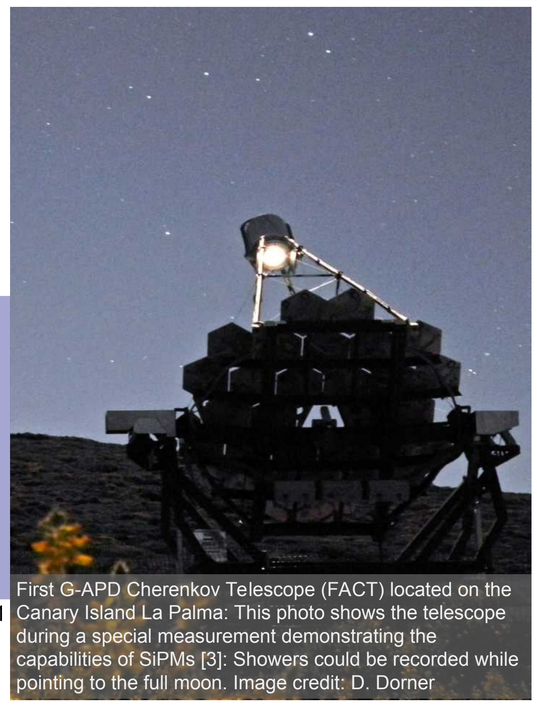
First G-APD Cherenkov Telescope [1,2]

- Operation since October 2011 @ Observatorio Roque de los Muchachos, La Palma, Spain (2200 m a.s.l.)
- Imaging Atmospheric Cherenkov Telescope (IACT)
- Camera with silicon photosensor (SiPM, aka G-APDs*)
  - 4.5° field of view (FoV)
  - 1440 pixels (0.11° FoV each)
- 9.5 m² mirror surface
- Robotic operation
- Quick-Look Analysis (QLA):
  - Low latency results
  - 20-minute and nightly binning
  - **105 flare alerts** since March 2014
  - **Results publicly available:** **http://www.fact-project.org/monitoring**

*: G-APD: Geiger-mode Avalanche Photo-Diode

Data Sample:	**14800 h**
Mrk 501:	3018 h
Mrk 421:	3219 h
Crab Nebula:	2386 h
1ES 2344+51.4:	1975 h
1ES 1959+650:	2235 h
1H0323+341:	1179 h
PKS 0736+01	151 h

status 7.6.2021

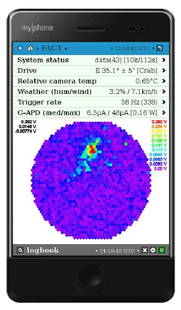


First G-APD Cherenkov Telescope (FACT) located on the Canary Island La Palma: This photo shows the telescope during a special measurement demonstrating the capabilities of SiPMs [3]: Showers could be recorded while pointing to the full moon. Image credit: D. Dorner

Unbiased Long-Term Monitoring

- Source sample: bright TeV blazars
- Strategy: observe small sample of sources as much as possible
  → **Unbiased monitoring: 14800 h of physics data**
- SiPMs – Ideal for Monitoring:
  - Robust and stable, excellent performance [2]
  - No aging effect due to bright light
    → Observations during strong moon [left]
  - Remote and automatic operation [right]
    http://www.fact-project.org/smartfact
    → Stable, consistent data taking
    → High data taking efficiency

→ **Maximizing duty cycle, minimizing gaps, denser sampling**

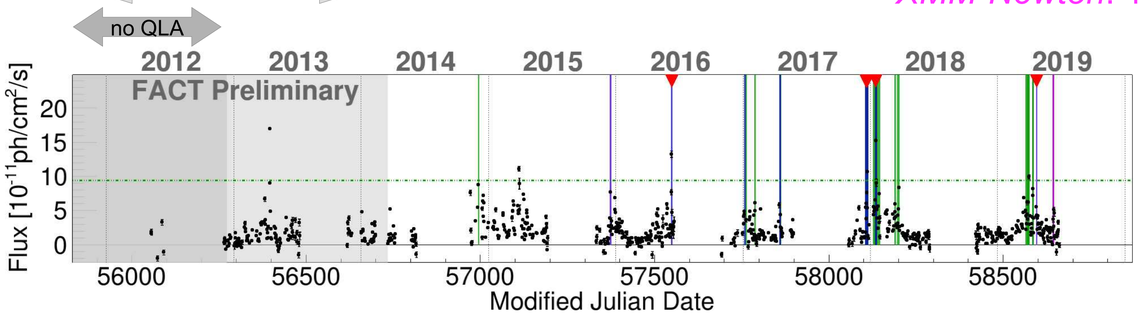


Mrk 421

Physics data: **3192 hours**

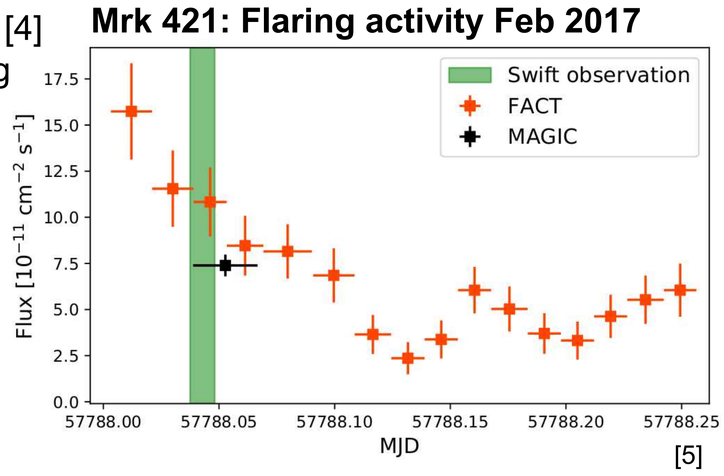
Alerts: **48**

MoU & MWL partners: 29 *Swift*-XRT: 10
ATel: 5 *INTEGRAL*: 3
XMM-Newton: 1



- 5.5 years multi-wavelength (MWL) study [4]
  - Radio emission reproduced convolving GeV variations by delayed response
  - TeV-X-ray correlation
- MWL campaign including NuSTAR [5]
  - Flaring activity with intra-night variability Feb 2017 [right]
- Bright flares Apr 2013, June 2016 [6], Dec 2017 / Jan 2018 [7]
- X-ray ToOs (*INTEGRAL*, *XMM-Newton*) activated: Dec 2019, Jun 2019 [7,8,9]

Mrk 421: Flaring activity Feb 2017



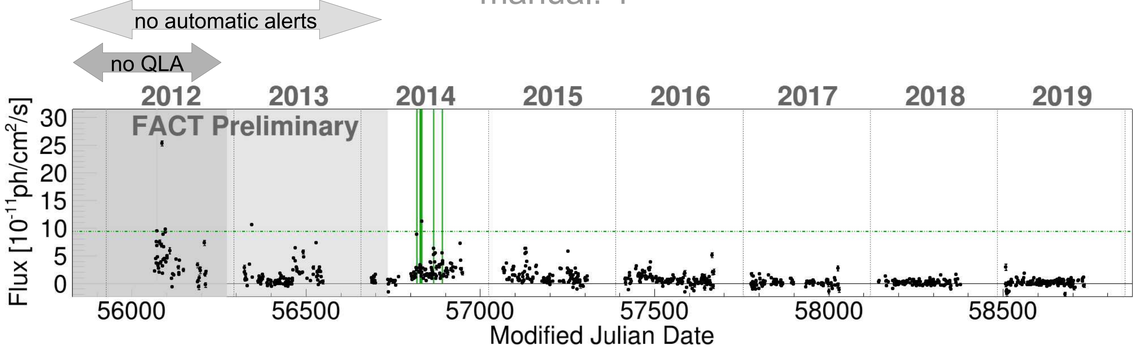
[5]

Mrk 501

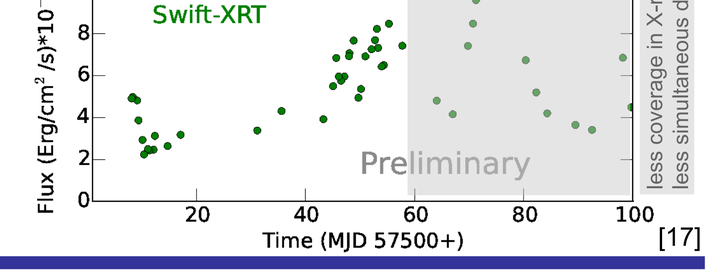
Physics data: **2993 hours**

Alerts: **6**

MoU & MWL partners: 6
manual: 1



- Bright flare June 2012 showing extreme behaviour [10]
- Flaring activity June 2014 → Alert
  → H.E.S.S. constraints on LIV [11, 12]
- Study of temporal and spectral behaviour in gamma rays [13]
  - TeV range: log-normal flux distribution
    - Flare night [14]
    - Nightly binning [right, 15]
  - GeV range: no log-normal flux distribution



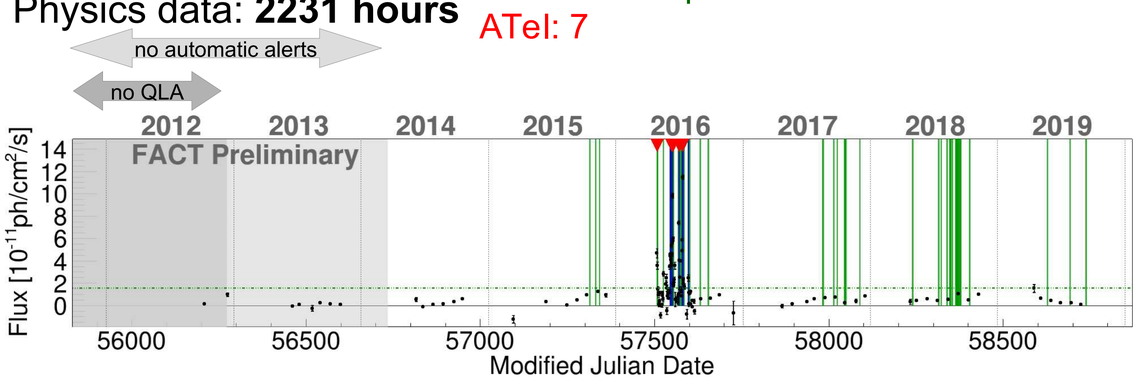
[15]

1ES 1959+650

Physics data: **2231 hours**

Alerts: **74**

MoU & MWL partners: 62 *Swift*-XRT: 7
ATel: 7



- 2012-2014: low state, brightening in 2015
- Series of bright outbursts in 2016 [16]
- **Densest daily light curve measured so far by an IACT**
- X-ray monitoring and ToOs [17]
- Correlation study with
  - X-rays [right, 18]
  - Neutrinos [19]
- Bright outburst in 2016 cannot be explained by simple one-zone SSC model [18]

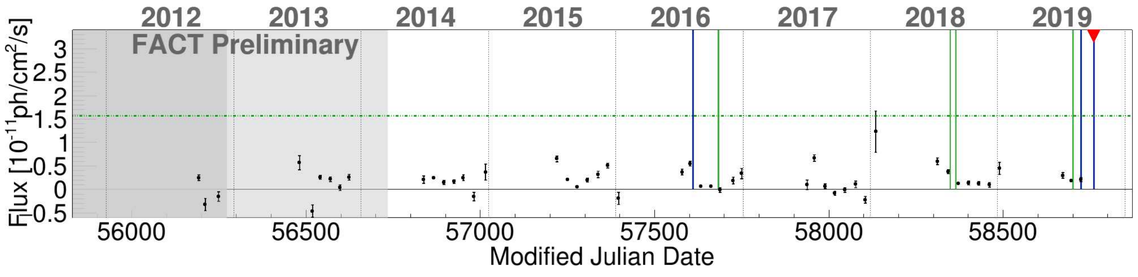
[17]

1ES 2344+51.4

Physics data: **1975 hours**

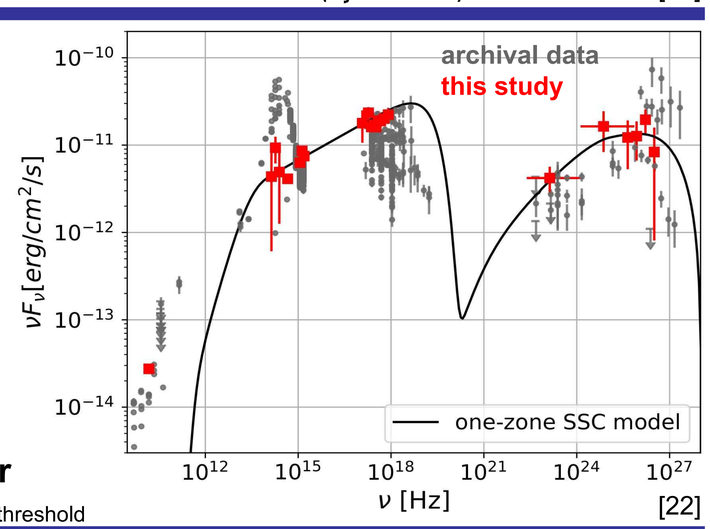
Alerts: **11**

MoU & MWL partners: 7 *Swift*-XRT: 3
ATel: 1



- Overall average flux: $1.6 \cdot 10^{-12}$ erg/s/cm²
- Outbursts of 0.5-1CU* in
  - Aug 2016 [20]
  - Aug, Sep 2018
  - Aug, Oct 2019 [21]
- Multi-wavelength campaign triggered in 2016 [22, right]
  - Follow-up by MAGIC, *Swift*-XRT, ...
  - Hard TeV spectrum
  - Extreme behaviour during outburst
  - Source as **intermittent extreme blazar**

*: CU: Crab Unit, i.e. integral flux of the Crab Nebula above energy threshold



[22]

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