The FACT TeV Monitoring program

Axel Arbet-Engels, ETH Zürich
for the FACT collaboration

Cochem, Germany
September 2018

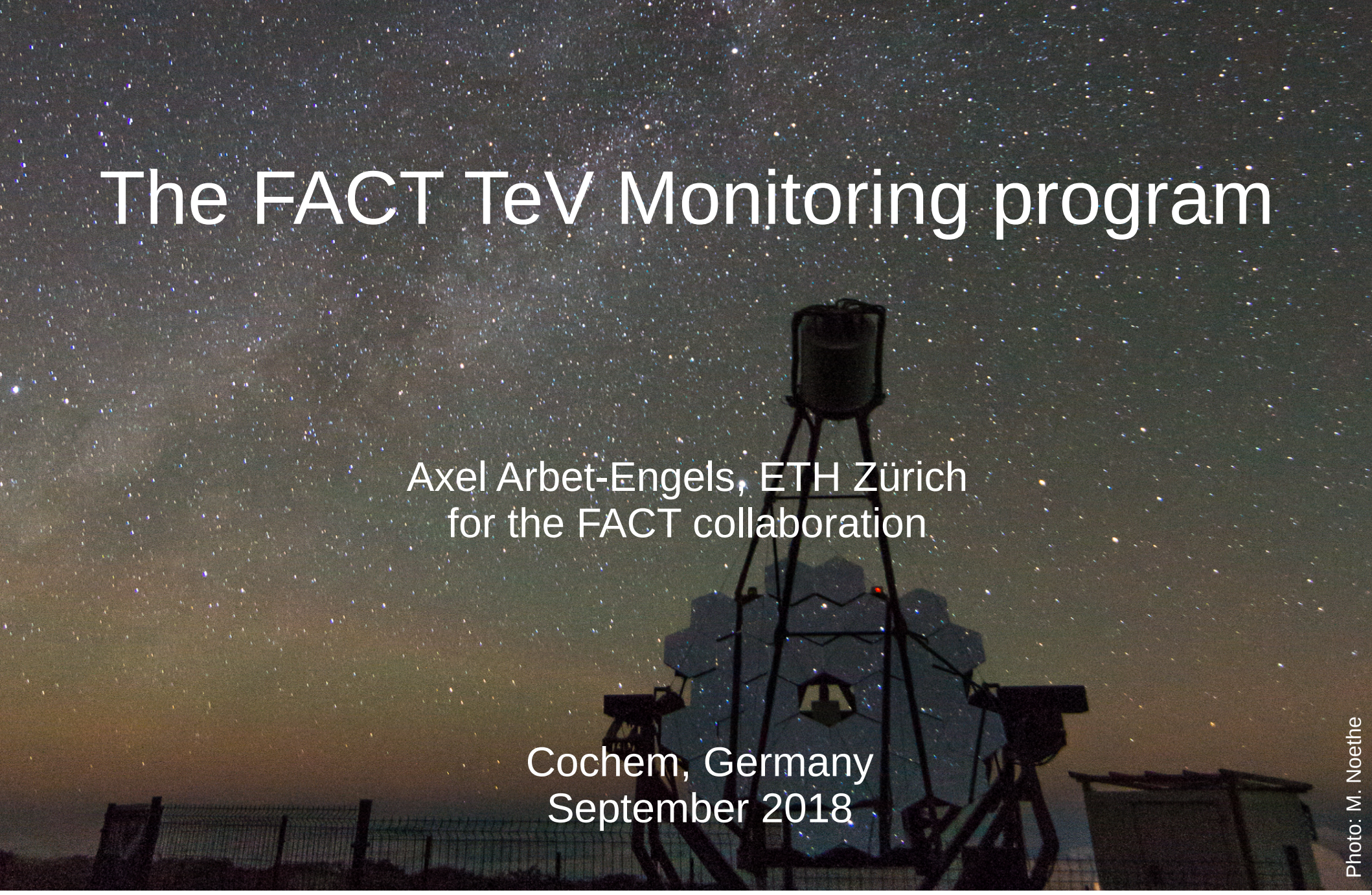
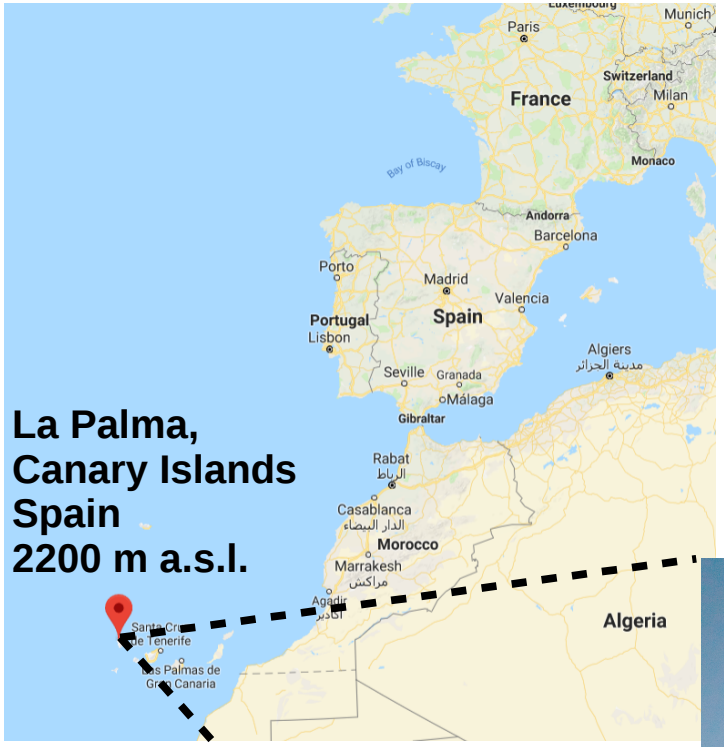


Photo: M. Noethe

ETH zürich ISDC DATA CENTRE FOR ASTROPHYSICS Julius-Maximilians-UNIVERSITÄT WÜRZBURG technische universität dortmund

FACT
First G-APD Cherenkov Telescope

FACT – First G-APD Cherenkov Telescope

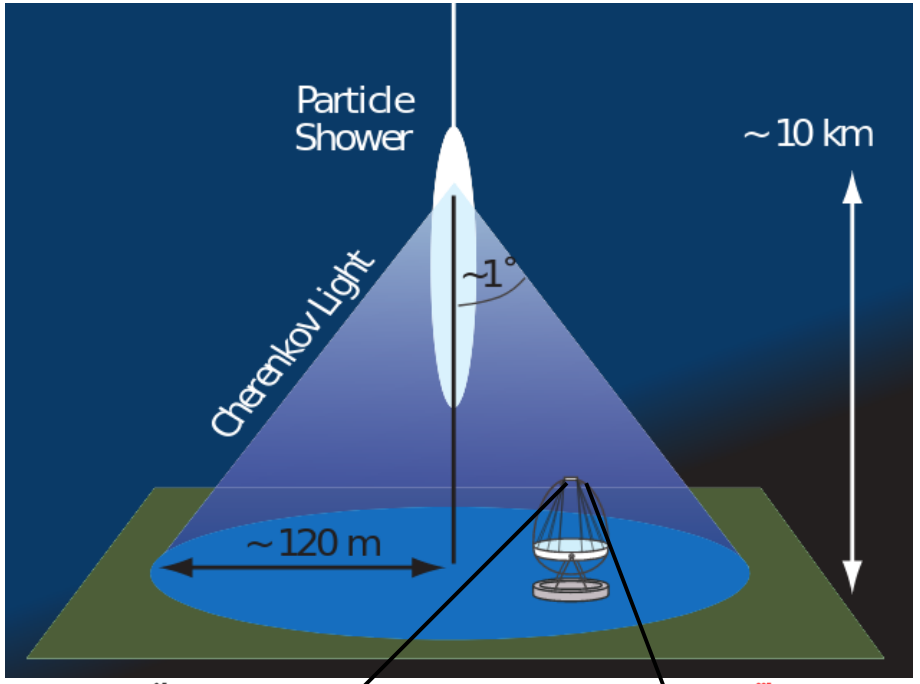


- Measuring photons at ~TeV energies
- First light in October 2011, remote operations since July 2012
- Robotic since December 2017
- 9.5 m² mirror area, 4.5° FoV
- Pioneering silicon photomultiplier camera (G-APDs)

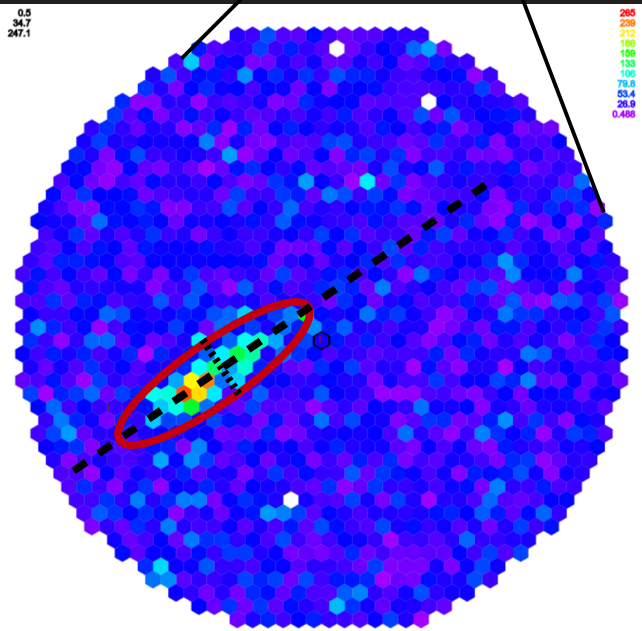
Reference paper: H. Anderhub et al. JINST 8 (2013) P06008
Performance paper: A. Biland et al. JINST 9 (2014) P10012

Photo: M. Noethe

The Imaging Air Cherenkov Technique



de Naurois, M., & Mazin, D. 2015, Comptes Rendus Physique, 16, 610

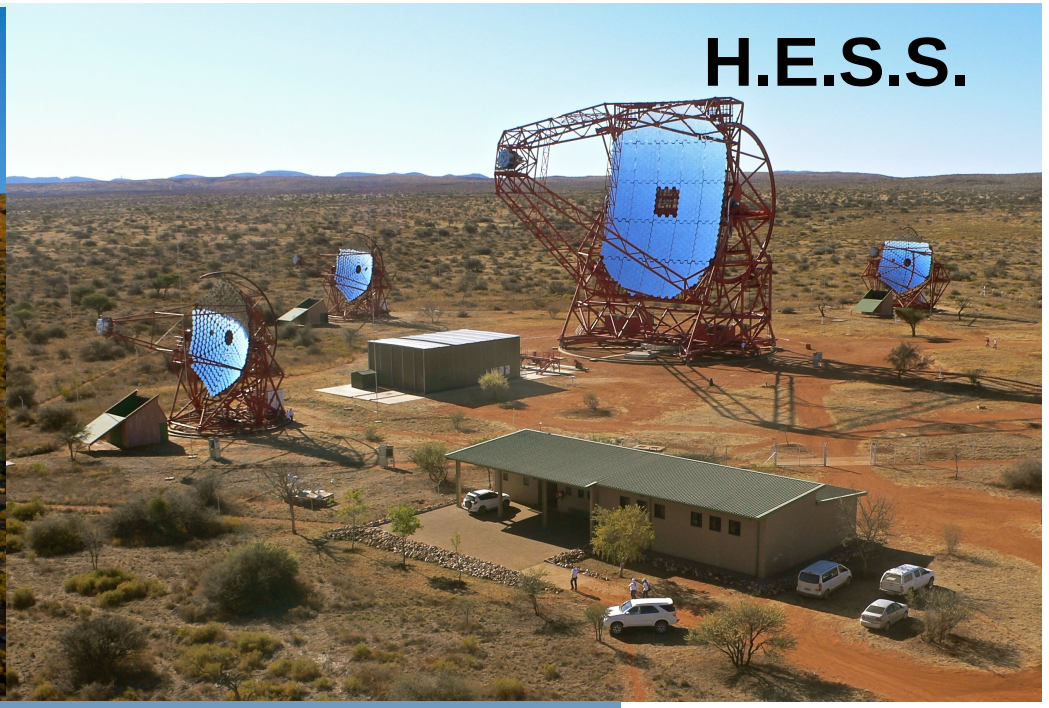


~TeV Gamma rays enter the atmosphere and produce a shower of particles

Secondary particles generate Cherenkov radiation

- Very fast Cherenkov flash: ~few ns
- Images contain around ~100 Cherenkov photons
- Each image is parametrized to reject hadronic cosmic rays and reconstruct the direction, energy

The Imaging Air Cherenkov Technique



Study of bright TeV Blazars

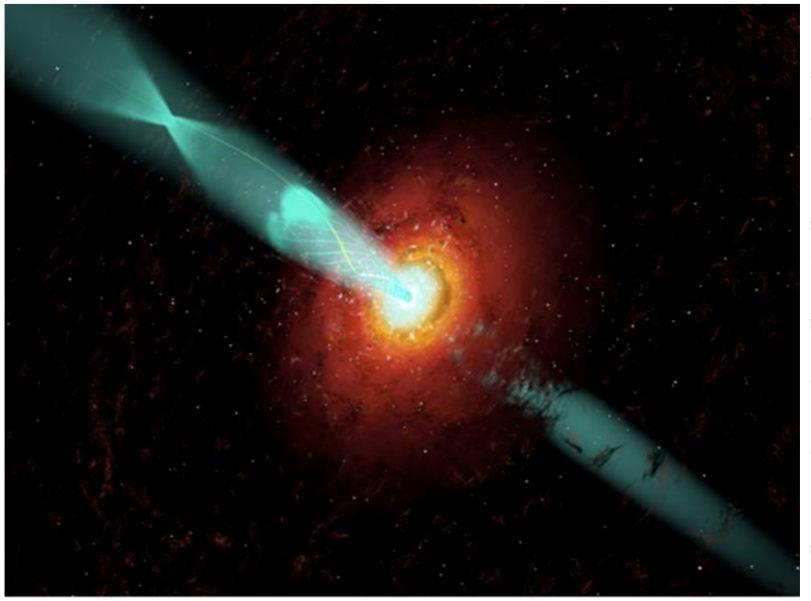
Leptonic or hadronic scenario?

How to explain their extreme flux variabilities?

How do X-Ray and VHE emission correlate?

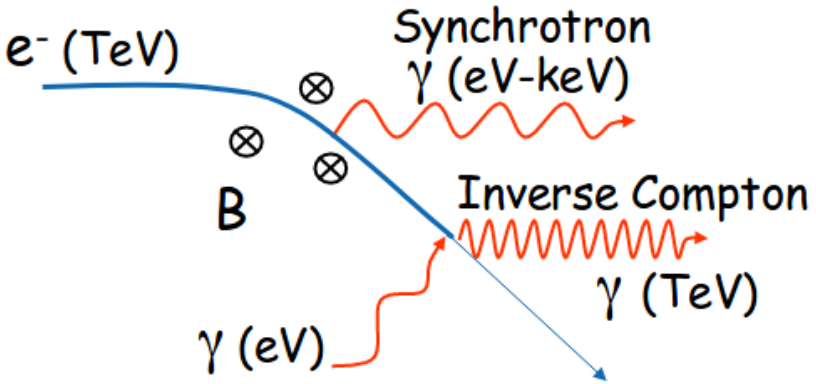
Where are these photons emitted?

…



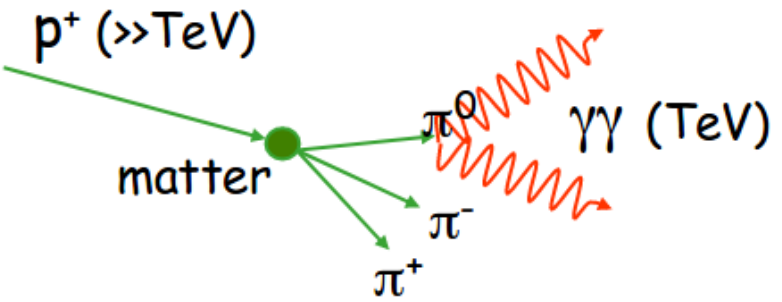
Credits: Marscher et al., Wolfgang Steffen, NRAO/AUI/NSF

Leptonic scenario:



?

Hadronic scenario:



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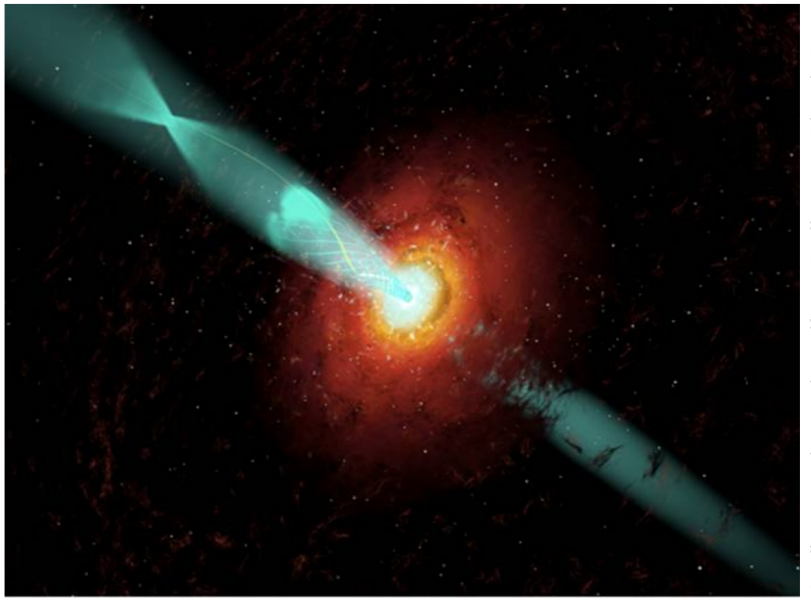

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→ **Homogeneous and dense observations are crucial to better understand the emission mechanisms**

Unbiased monitoring of TeV Blazars

Photo: José Luis Lemus

- **SiPM** camera is **robust and stable**
  → Minimize gaps: SiPMs do not degrade when exposed to bright moon light

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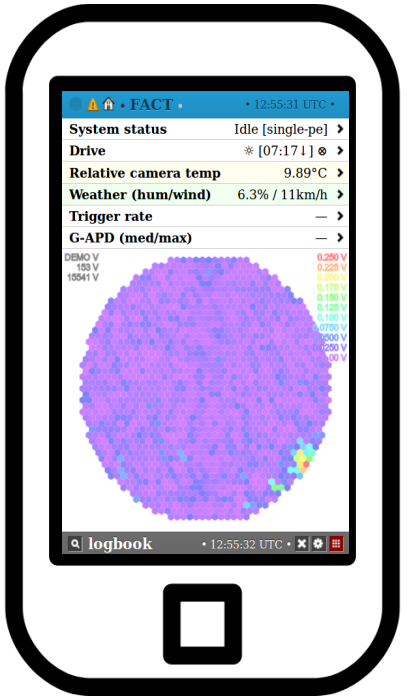
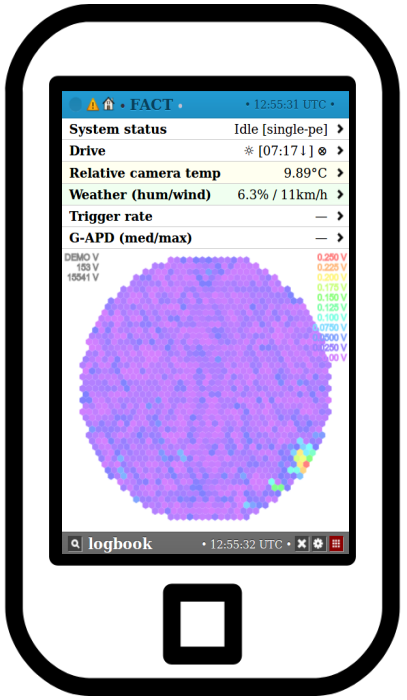


Unbiased monitoring of TeV Blazars



Since ~end 2017:
→ shifter on-call mode

Unbiased monitoring of TeV Blazars

Photo: José Luis Lemus

- **SiPM** camera is **robust and stable**
  → Minimize gaps: SiPMs do not degrade when exposed to bright moon light

- **Remote & Robotic** operations

→ Increased duty cycle
→ **Ideal monitoring instrument**

Unbiased monitoring of TeV Blazars

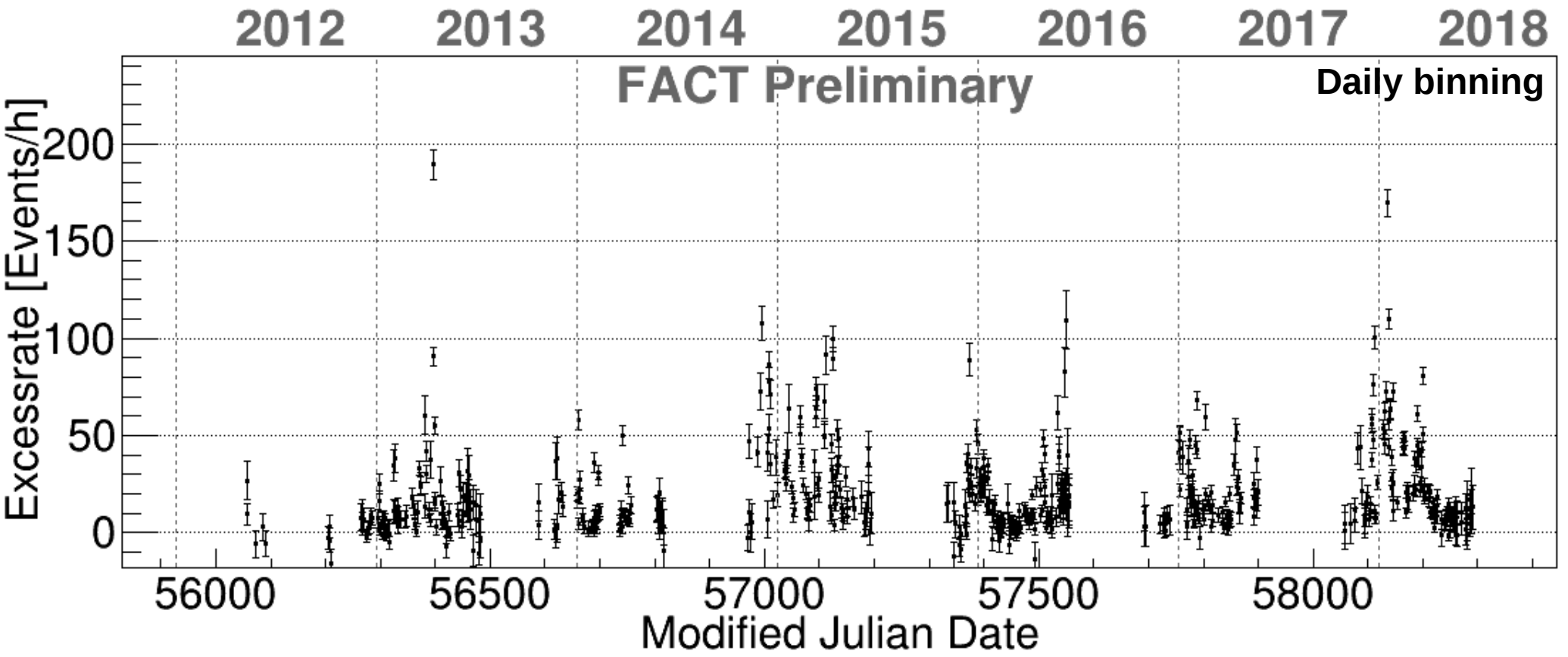
Photo: José Luis Lemus

- **SiPM** camera is **robust and stable**
  → Minimize gaps: SiPMs do not degrade when exposed to bright moon light
- **Remote & Robotic** operations

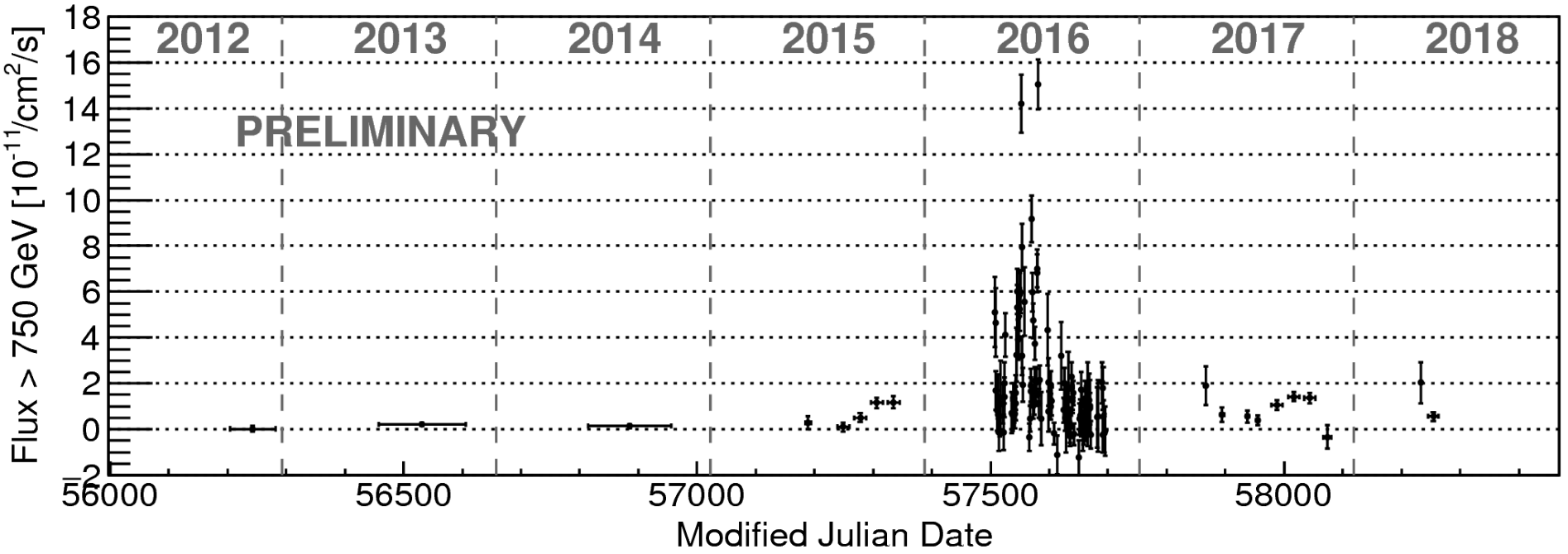
  → Increased duty cycle
  → **Ideal monitoring instrument**
- Focusing on a small sample of Blazars
  → **Unbiased**

Blazar Name	Total observing time
Mrk 421	~2500 hrs
Mrk 501	~2500 hrs
1ES 1959+650	~1700 hrs
1ES 2344+514	~1500 hrs

Mrk 421 (z~0.03) – 6+ years light curve



1ES 1959+950 (z~0.05) – 6+ years light curve



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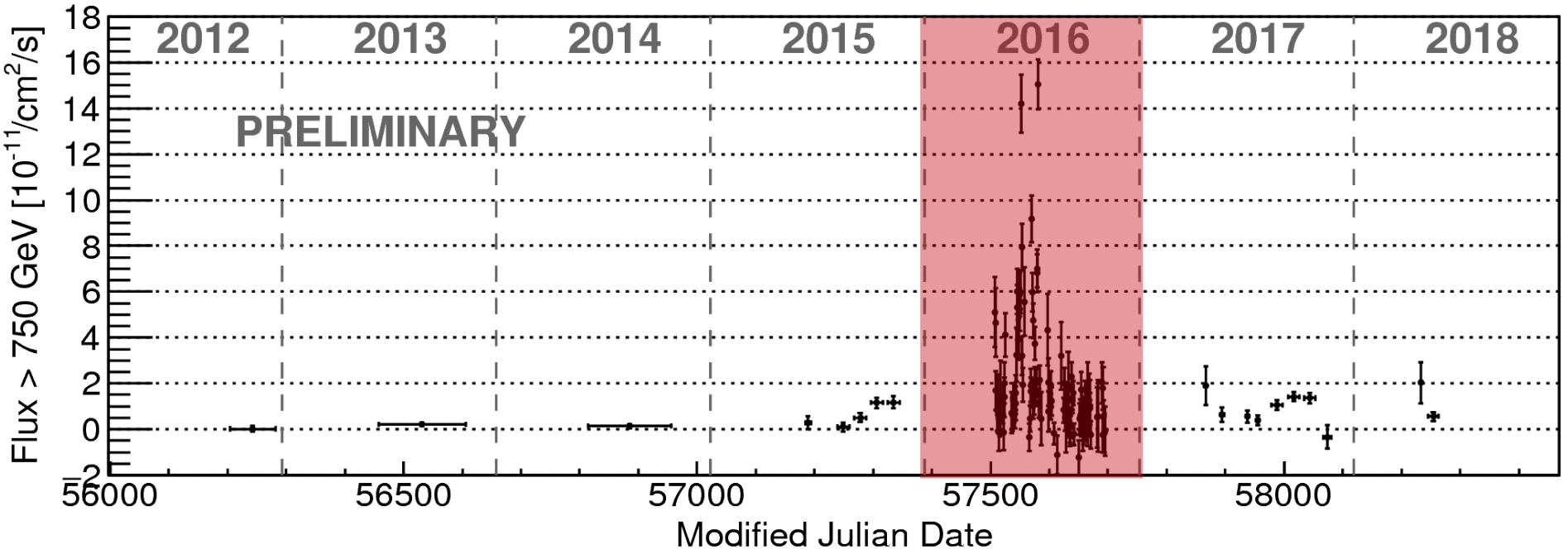
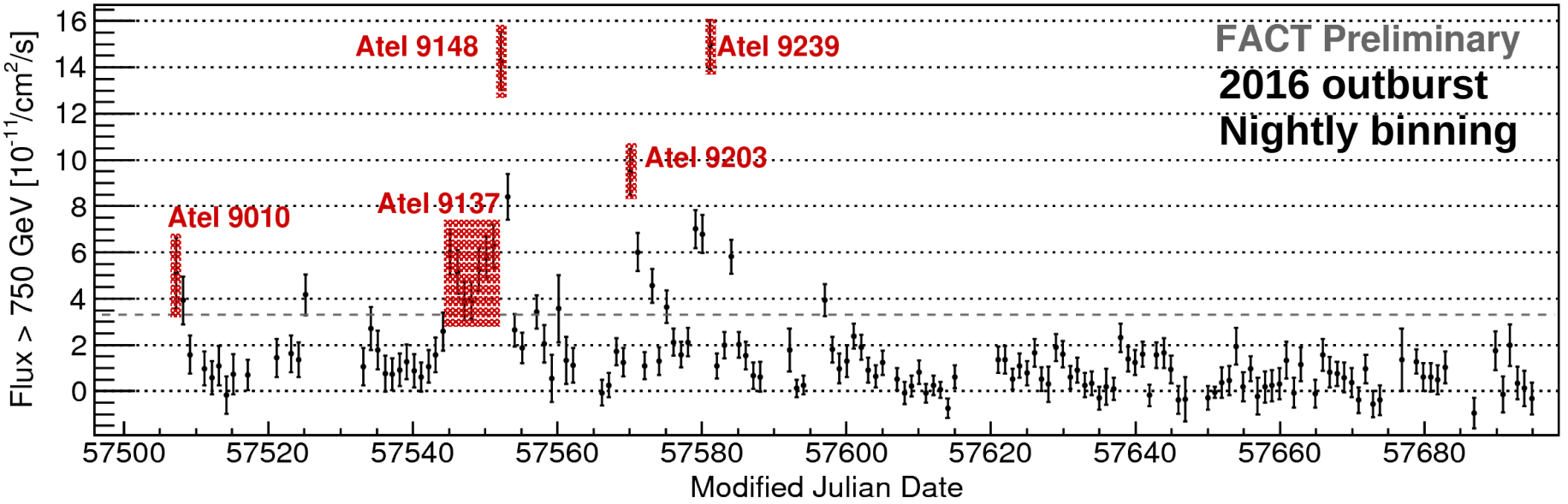


→ Unprecedented dense and homogeneous light curve in 2016
→ Excellent coverage during exceptionally high state

1ES 1959+950 (z~0.05) 2016 outburst



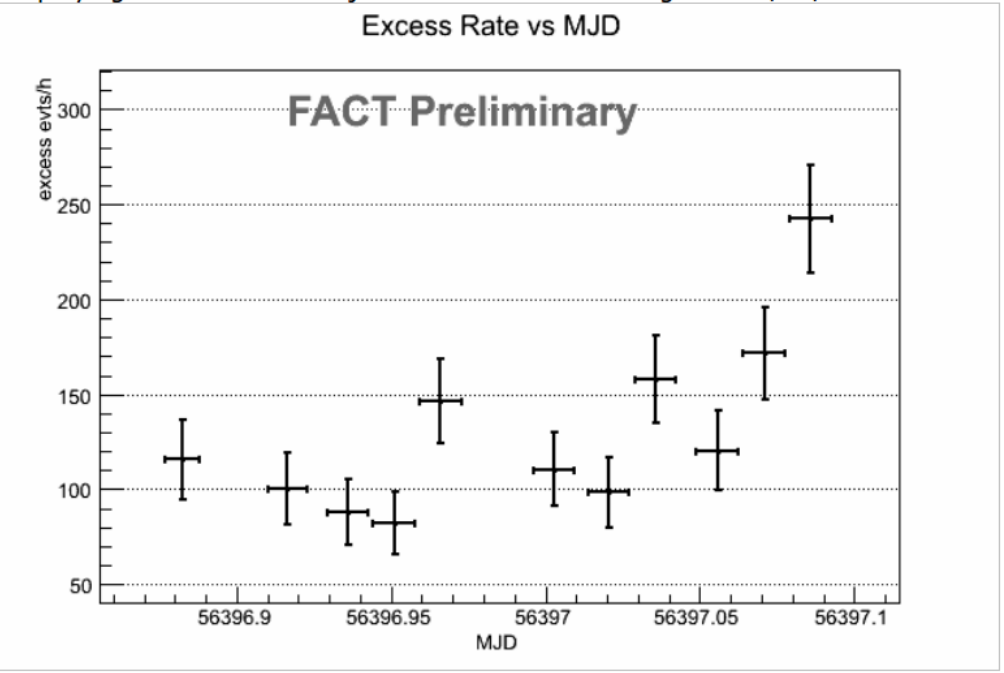
~daily monitoring during almost 4 months!

Quick Look Analysis

FACT Quick Look Analysis

Select date 2013 04 14 source Mrk 421
Select time binning 20min and range night Reset

Displaying 'excess rate vs mjd' for Mrk 421 for the night 2013/04/14.



https://fact-project.org/monitoring/

More informations: Dorner, D., Ahnen, M. L., Bergmann, M., et al. 2015, ArXiv e-prints[arXiv:1502.02582]

Public fast analysis to detect rapid flux enhancement

→ Sending alerts to the community

→ Triggering Multi-wavelength observations
with X-ray satellites and other Cherenkov Telescopes

Since March 2014
- → 88 flare alerts sent
- → 9 Astronomers Telegrams
- → 2 GCN circulars

Target-of-Opportunity program

Long-Term Monitoring

FACT (since 2012)
- daily VHE observations
- provides detailed variability information
- provides flare alerts

Trigger criterium:
VHE FACT rate > 70 evts/hour

Swift (since 2014)
- weekly scheduled (~1ks)
- monitoring of the low-E emission
- test for orphan flares & time lags
- public data

MWL ToO Program

Upon FACT trigger:

***Swift*/ XRT**
~20ks total
5 x 2 ks / day, then
10 x 1 ks / 2nd day follow-up

***XMM-Newton*/ EPIC**
~100 ks total
1 x 80 ks, then
4 x 5 ks / day follow-up

***INTEGRAL* / JEM-X / IBIS**
~500 ks total
1 x 500 ks
(~200 ks / revolution)

Time-Resolved SEDs

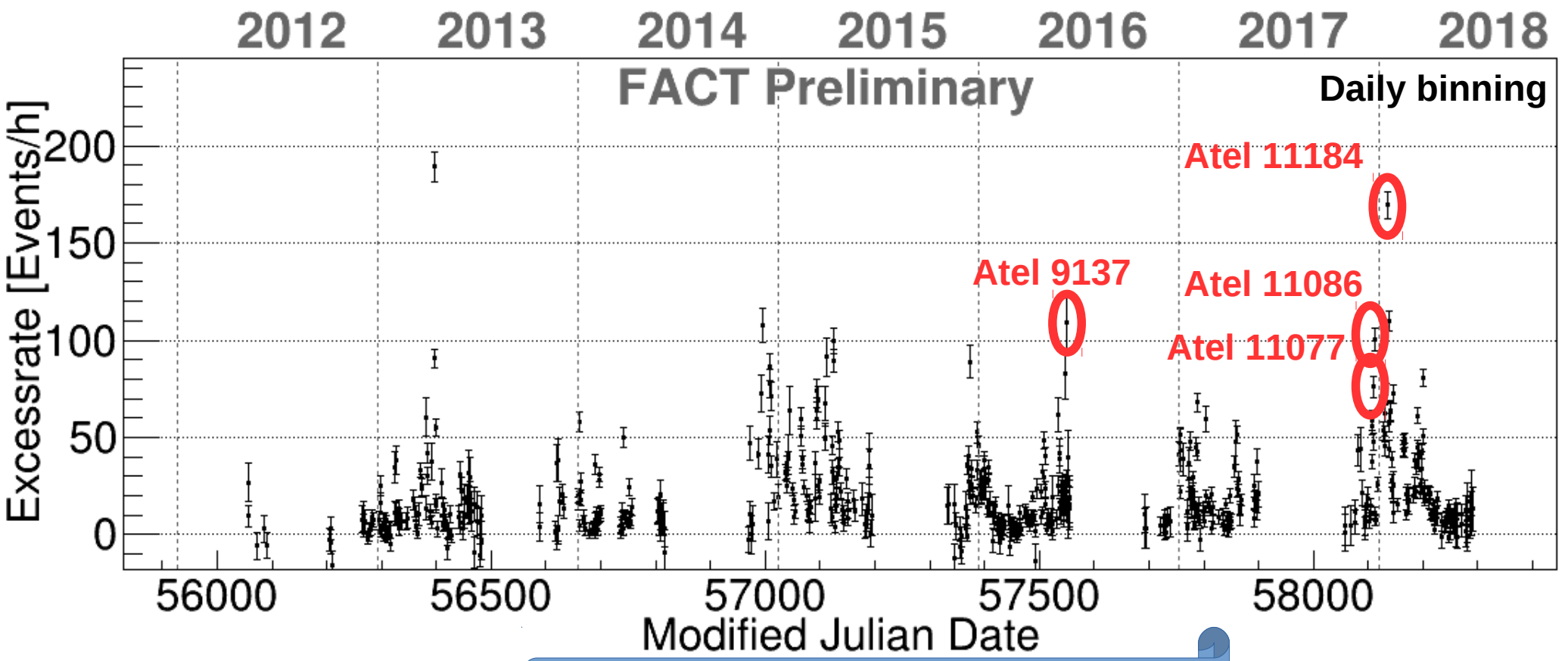
Include *Fermi*/ LAT data

Apply time-resolved jet emission modes
(e.g. Spanier & Weidinger 2012)

Provide contraints on jet emission models

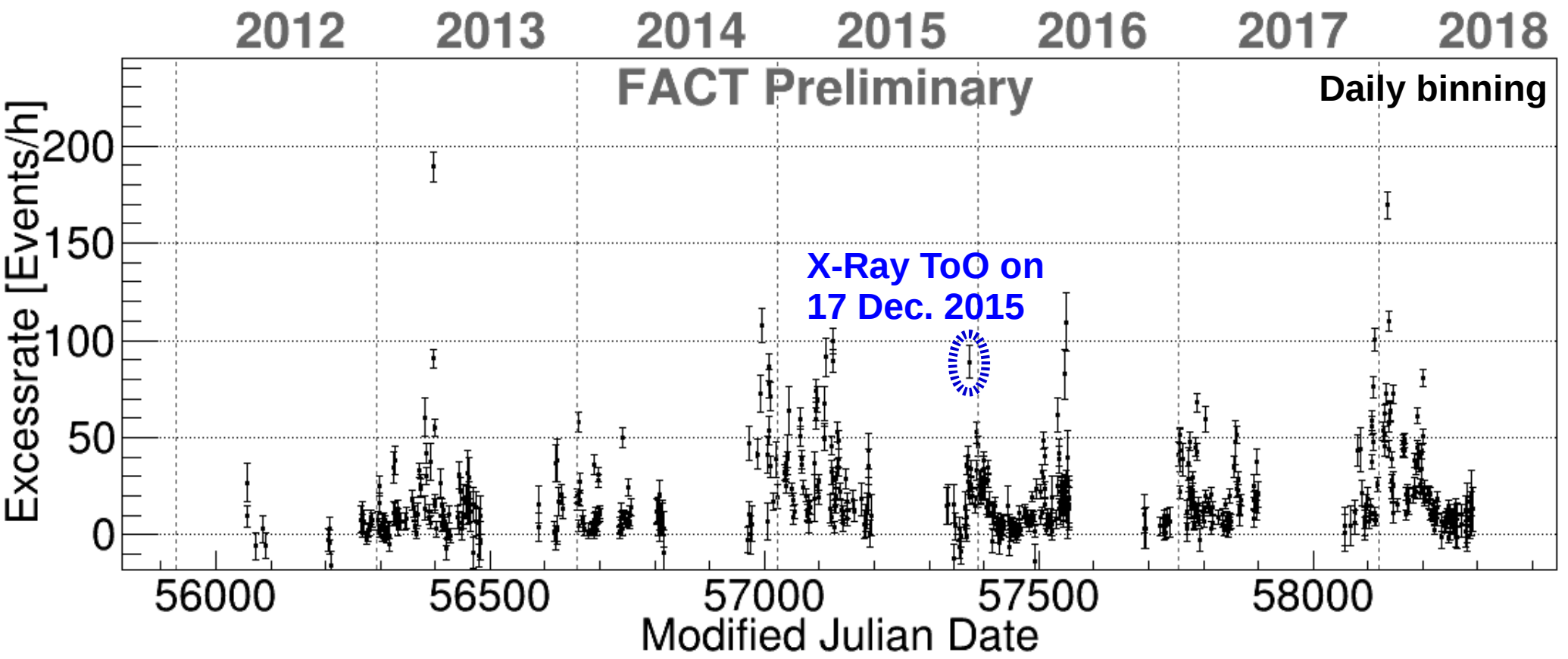
Slide courtesy: A. Kreikenbohm

Mrk 421 – long-term light curve

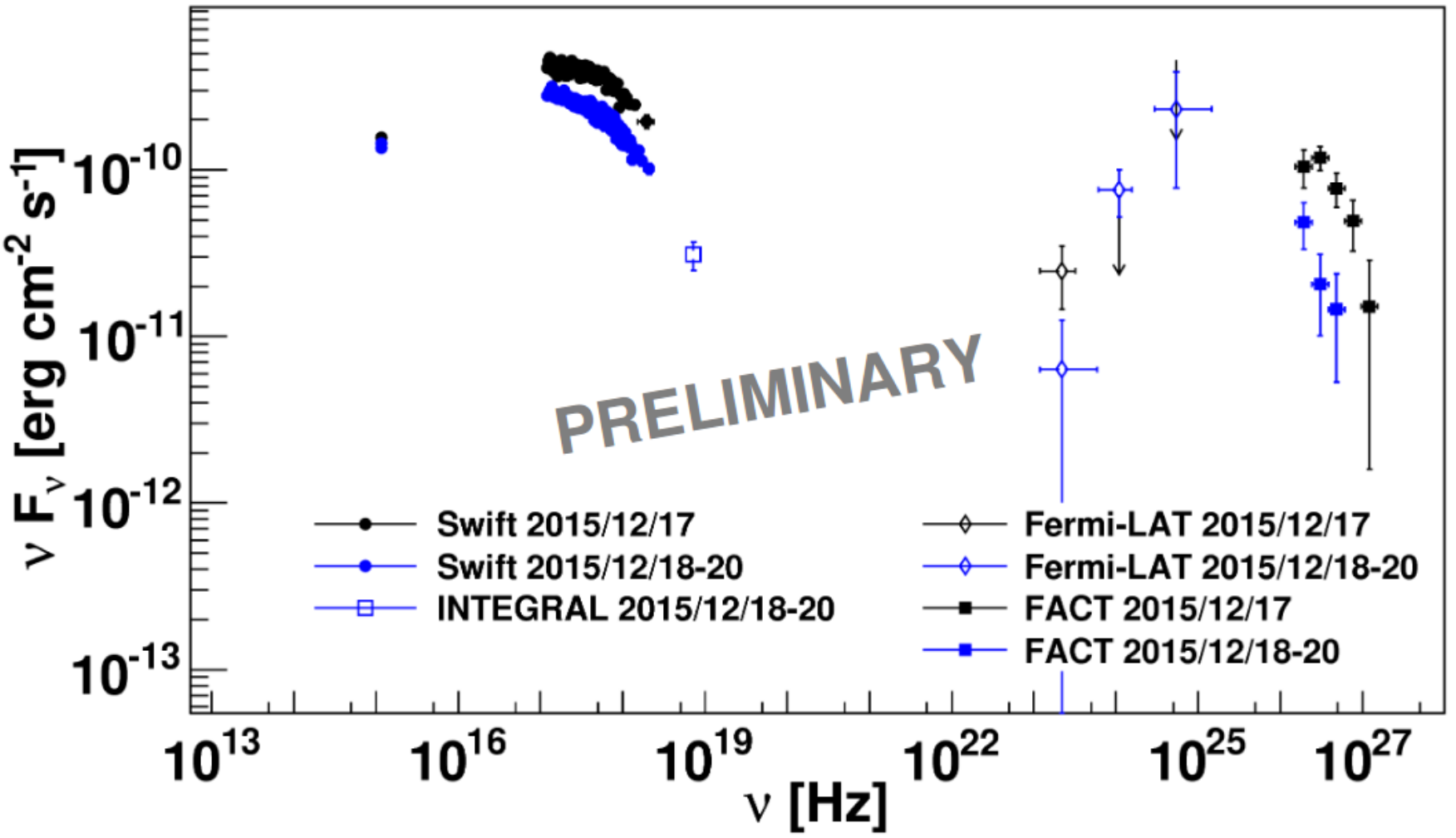


→ 4 Astronomers Telegrams (Atel)
→ 21 flare alerts sent

Mrk 421 – long-term light curve



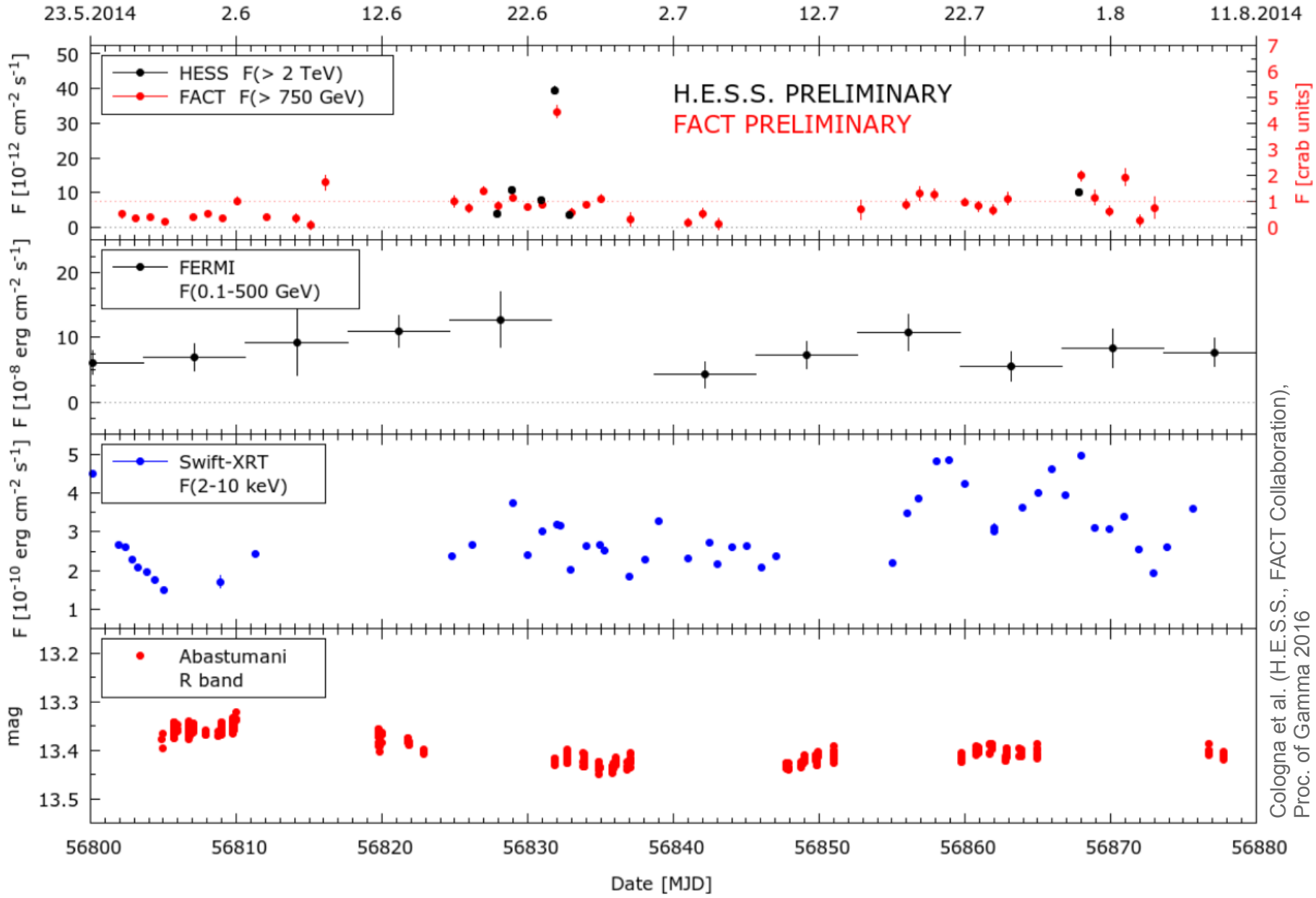
Mrk 421 – 2015 flare



Kreikenbohm, A., Dorner, D., Kadler, M., et al. 2017, The X-ray Universe 2017, 119, abs.harvard.edu/abs/2017xru..conf..119K

→ **FACT triggered simultaneous X-ray satellite observations**

Mrk 501 (z~0.03) – Summer 2014 outburst



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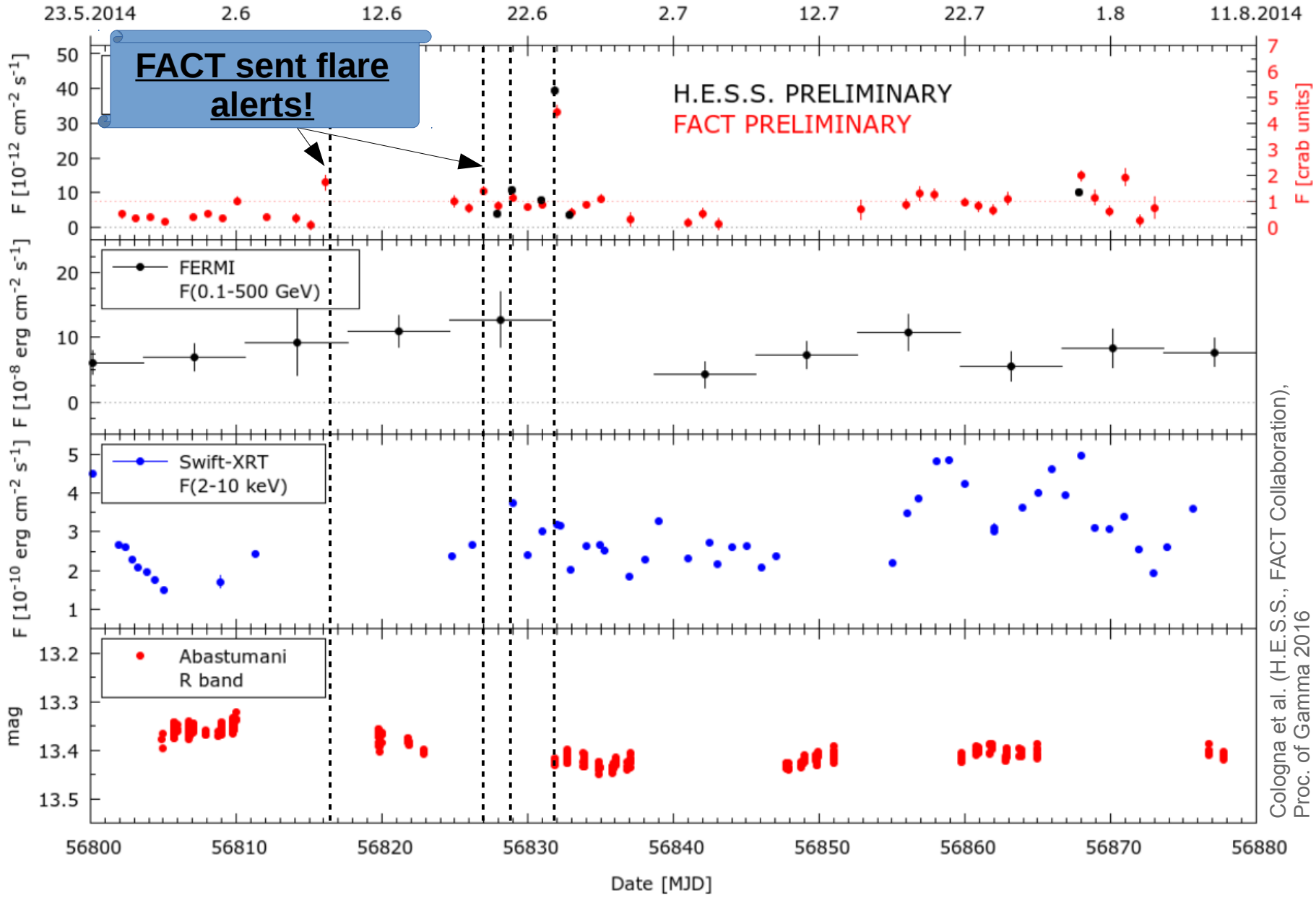

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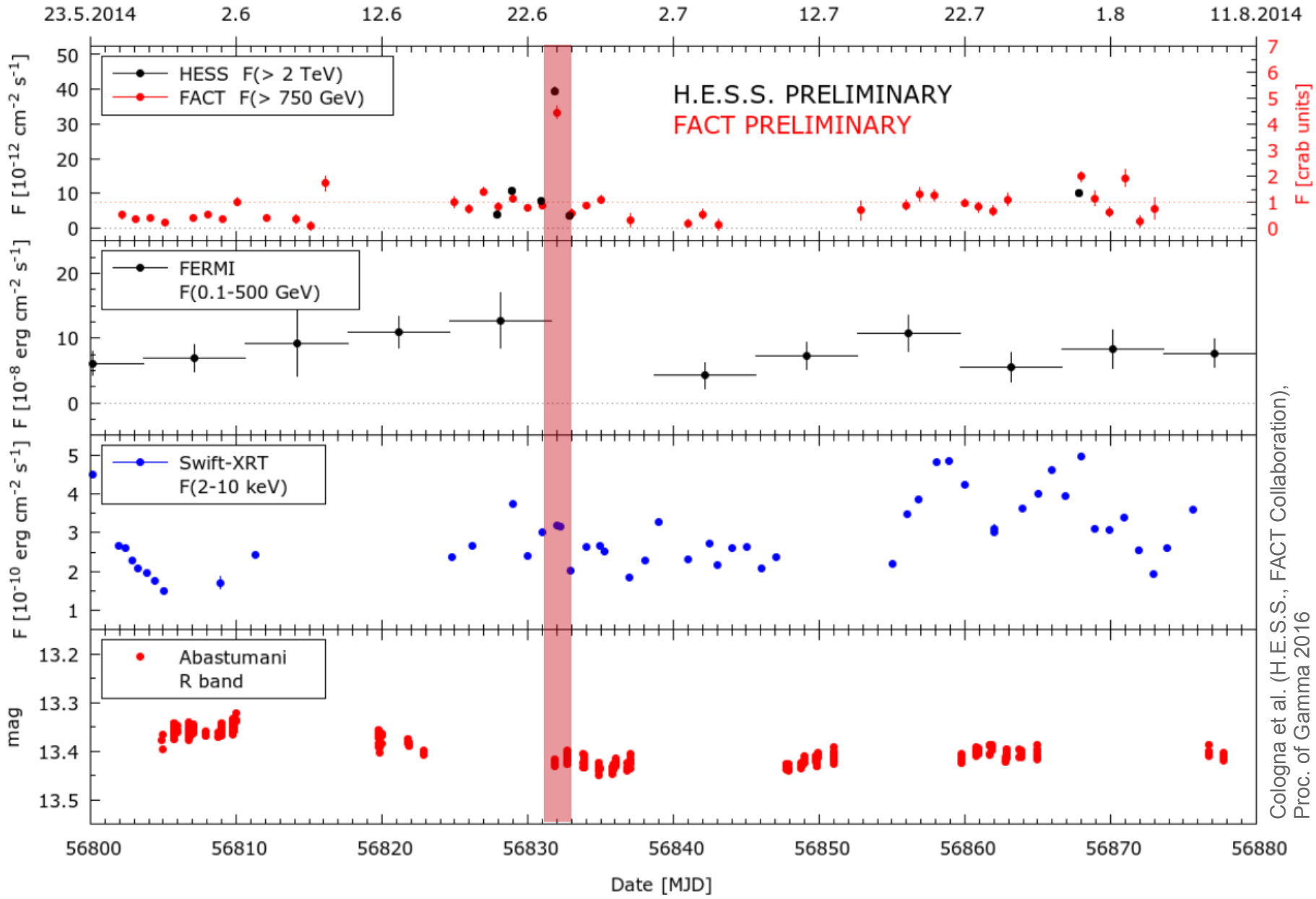

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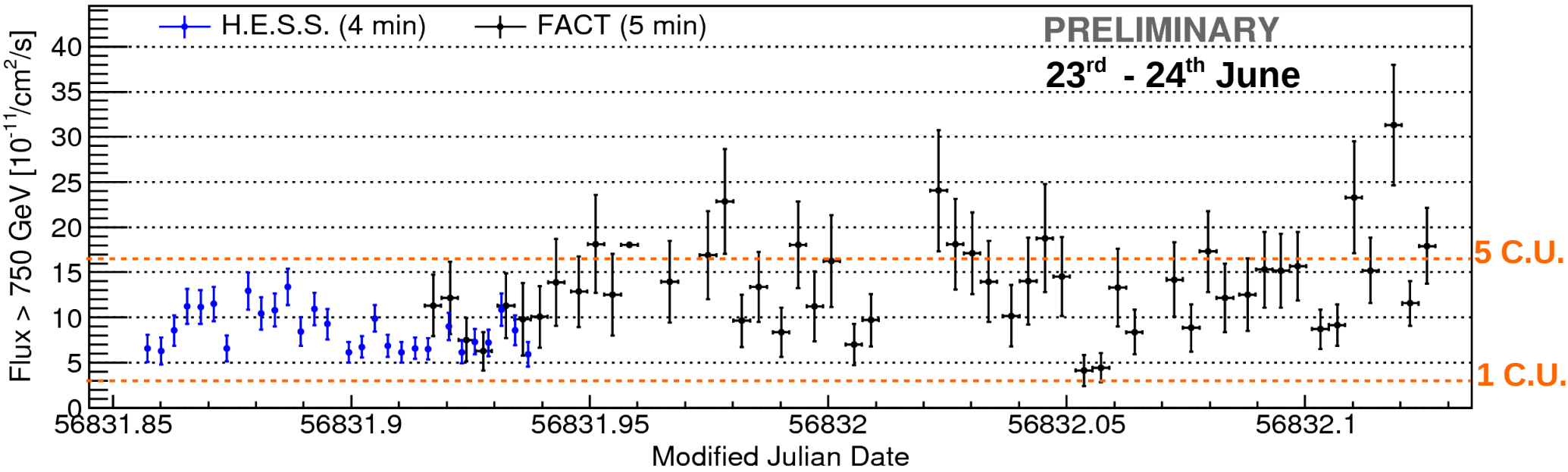

→ **Good agreement between FACT & H.E.S.S.**

→ **FACT also provides flux measurements on 5 minutes time scale**

Conclusion

- Ideal Telescope to monitor the sky at TeV energies
- Publishing unprecedented *dense & unbiased* light curves
- Continuously sending alerts to community since March 2014
- Contributing to Multi-wavelength and Target-of-Opportunity programs with other Cherenkov Telescopes & X-ray satellites