

Multi-wavelength study of Mrk 421 during a TeV flare

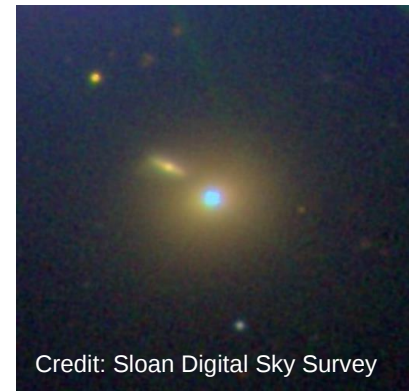
Andrea Gokus^{1,2},

A. Kreikenbohm², K. Leiter², T. Bretz^{3,4,*}, T. Dauser¹, D. Dorner^{2,*}, F. Eppel², J. Heßdörfer²,
M. Kadler², A. Kraus⁵, M. Kreter⁶, I. Kreykenbohm¹, M. Langejahn², K. Mannheim^{2,*},
P. Thalhammer¹, J. Wilms¹, and the FACT collaboration: A. Arbet-Engels³, D. Baack⁷, M. Balbo⁸,
N. Biederbeck⁷, A. Biland³, J. Buss⁷, L. Eisenberger², D. Elsaesser⁷, D. Hildebrand³, R. Iotov², A.
Kalenski², D. Neise³, M. Noethe⁷, A. Paravac², W. Rhode⁷, B. Schleicher², V. Sliusar⁸ and R. Walter⁸

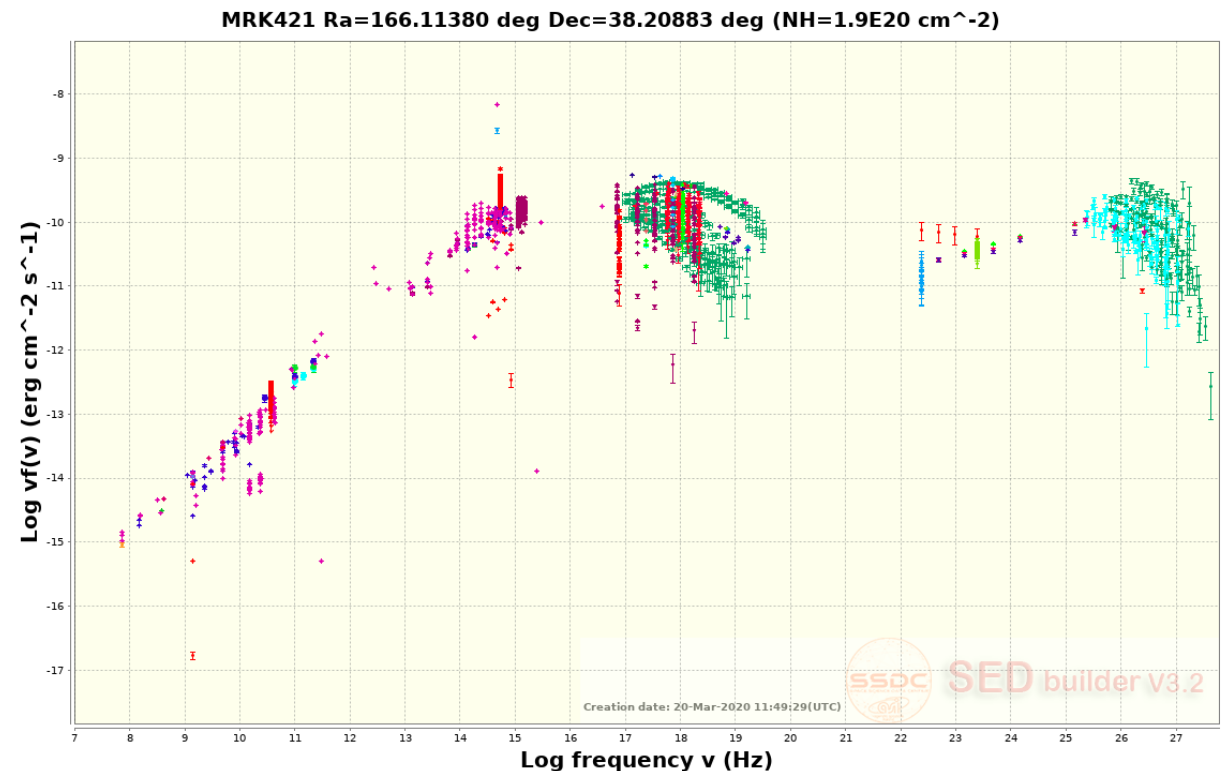
¹Remeis Observatory/ECAP - ²University of Würzburg - ³ETH Zürich - ⁴RWTH Aachen - ⁵Max-Planck Institute for
Radioastronomy - ⁶North-West University, South Africa - ⁷TU Dortmund - ⁸University of Geneva

*also in FACT

Markarian 421



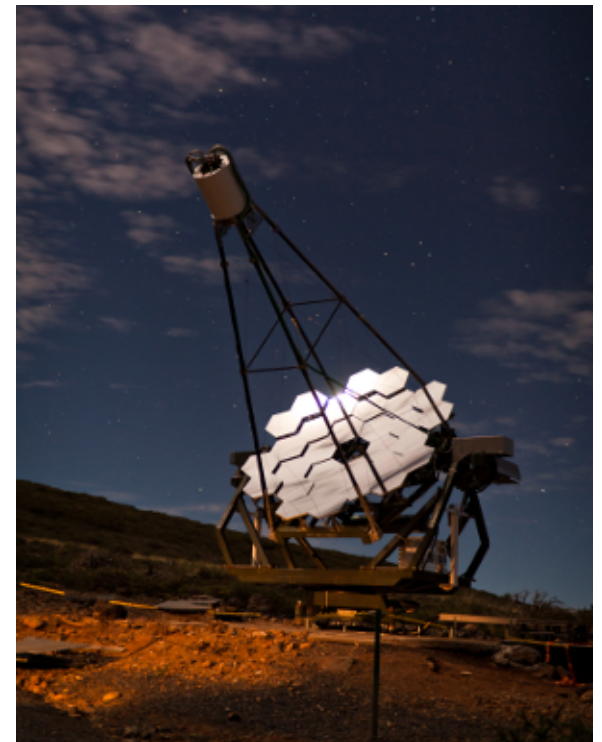
- One of the closest blazars ($z = 0.031$)
- Highly variable source, especially in X-rays and TeV
- Classified as high-peaked BL Lac type object and also shows extreme behaviour
- Well-sampled flare data shows limits of one-zone emission models (e.g.,
[Aleksić J. et al., 2015, A&A, 578, A22;](#)
[Abeysekara A. U. et al., 2020, ApJ, 890, 97](#))



FACT – Monitoring at TeV energies

See also talk by
Daniela Dorner!

- FACT = First G-APD Cherenkov Telescope, operational since Oct 2011 ([Anderhub H. et al., 2013, JINST, 8, P06008](#))
- Special features ([Biland A. et al., 2014, JINST, 9, P10012](#)):
 - observations during bright ambient light
 - excellent, stable detector performances
 - minimizing observational gaps while maximizing instrumental duty cycle
 - **ideal for monitoring**
- Monitoring of small sample of sources
→ unbiased data sample

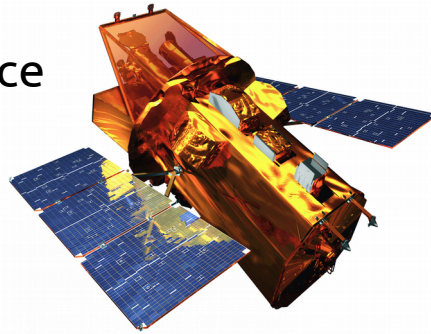


Credit: José Luis Lemus

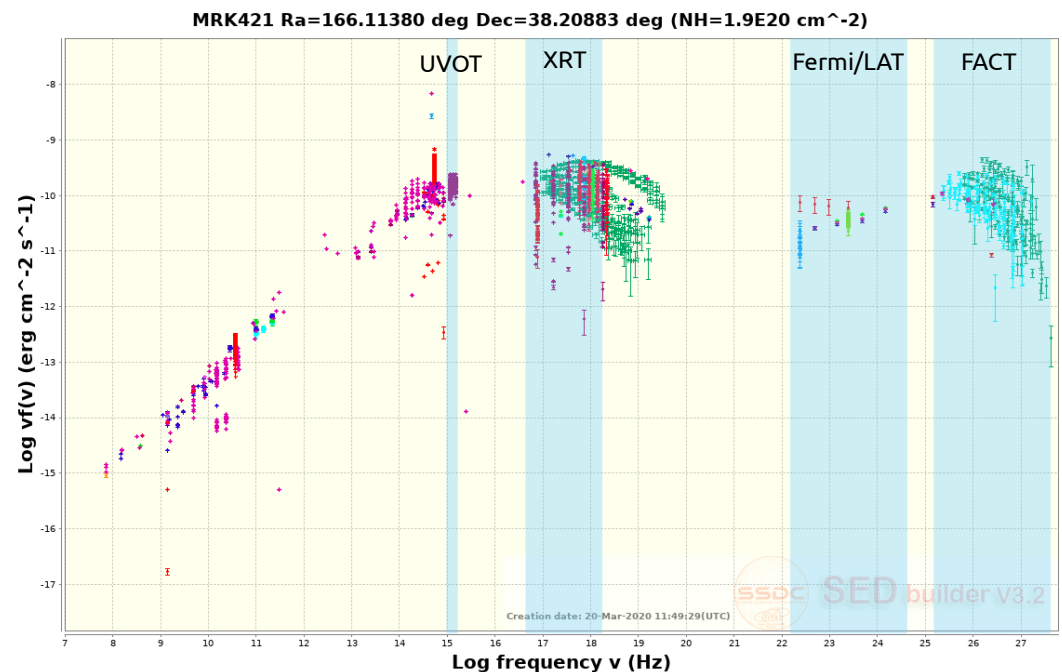
MONITORING



Swift: weekly cadence

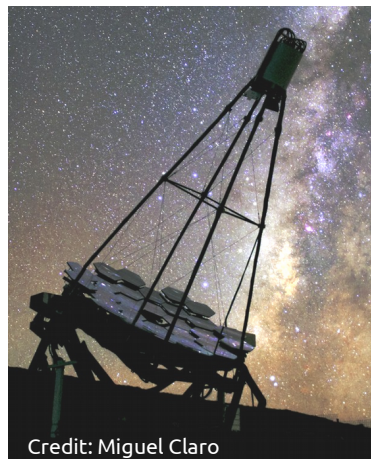


Fermi/LAT:
continuous monitoring



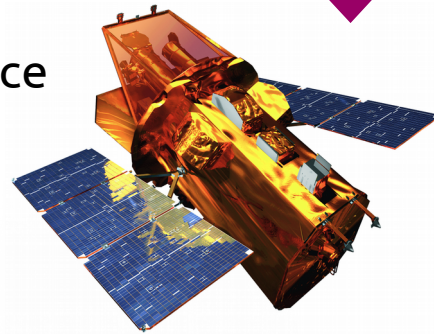
Pre-planned ToO program

MONITORING



FACT:
nightly cadence

If TeV flux
> 2 Crab Units



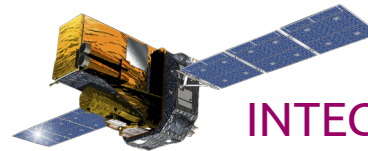
Swift: weekly cadence
+ daily 1 ks upon
trigger



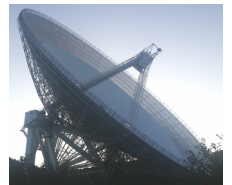
Fermi/LAT:
continuous monitoring

Trigger

TARGET OF OPPORTUNITY



INTEGRAL

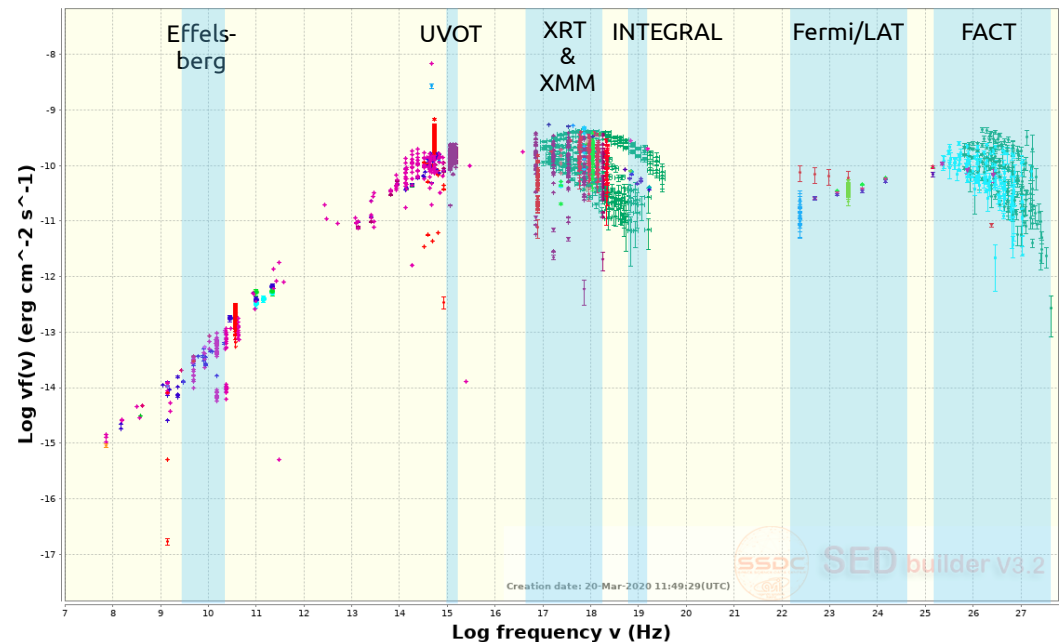


Effelsberg



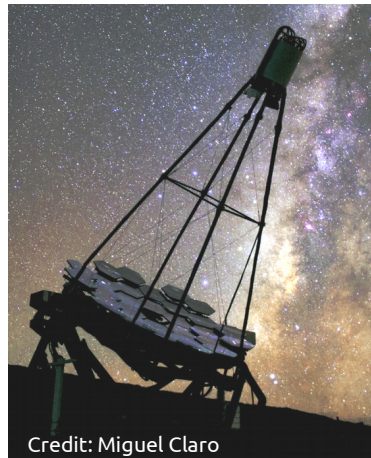
XMM-Newton

MRK421 Ra=166.11380 deg Dec=38.20883 deg (NH=1.9E20 cm⁻²)



Pre-planned ToO program

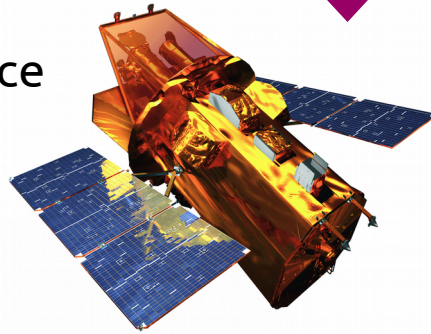
MONITORING



FACT:
nightly cadence

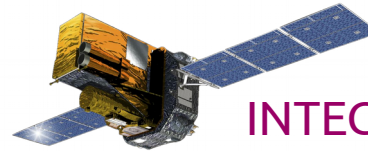
If TeV flux
> 2 Crab Units

Swift: weekly cadence
+ daily 1 ks upon
trigger

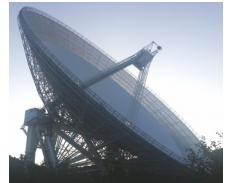


Trigger

TARGET OF OPPORTUNITY



INTEGRAL: 150 ks



Effelsberg

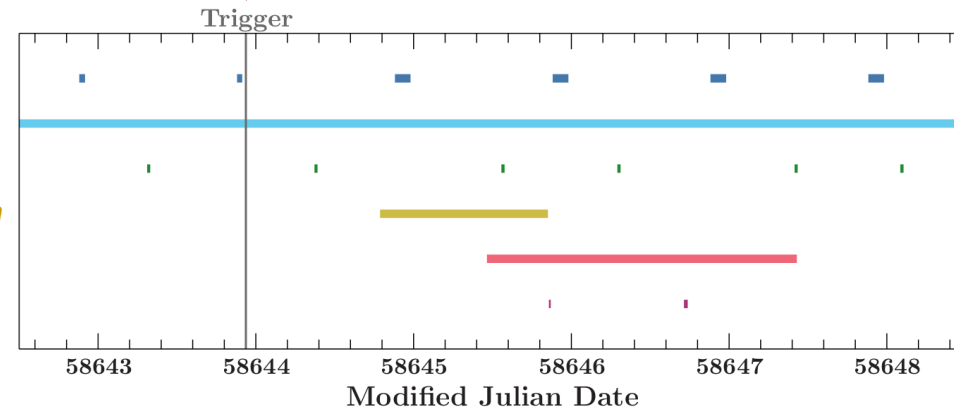


XMM-Newton: 90 ks

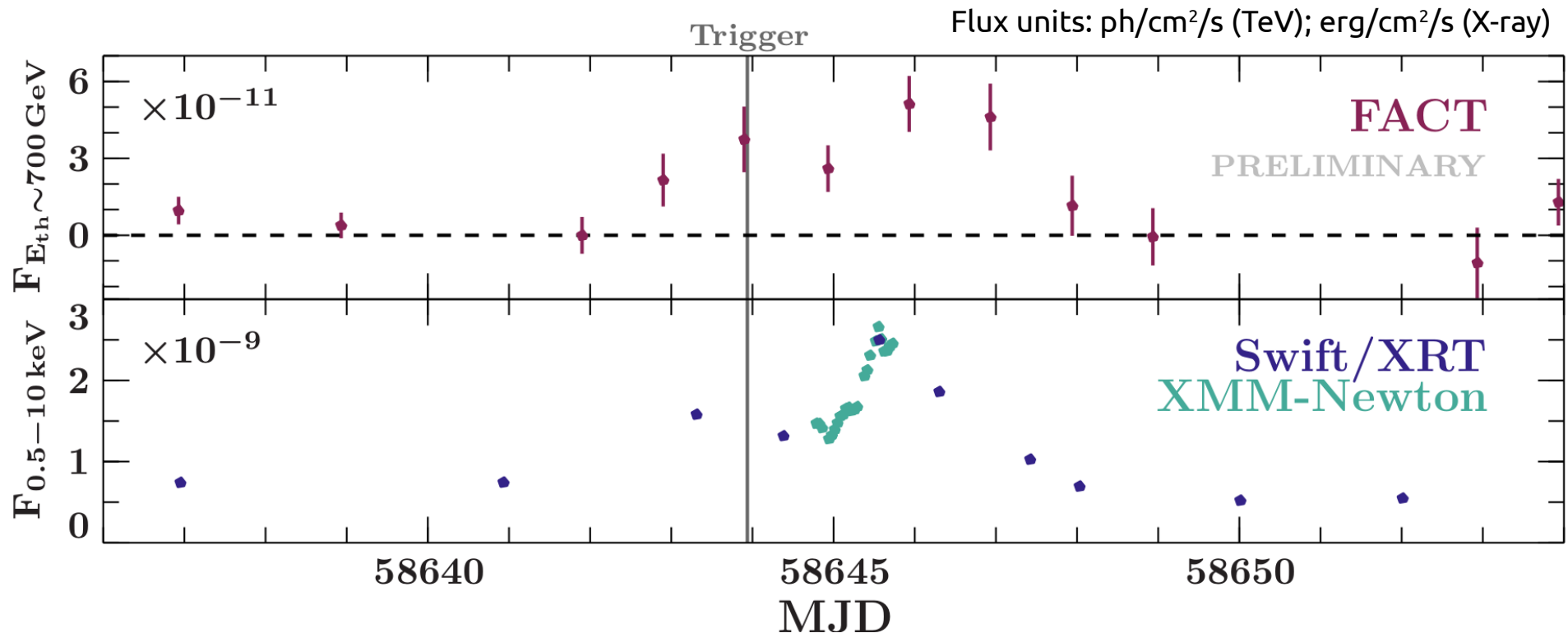
Trigger sent < 1 hr after FACT observation

Flare on 2019 June 9

FACT
Fermi-LAT
Swift
XMM-Newton
INTEGRAL
Effelsberg



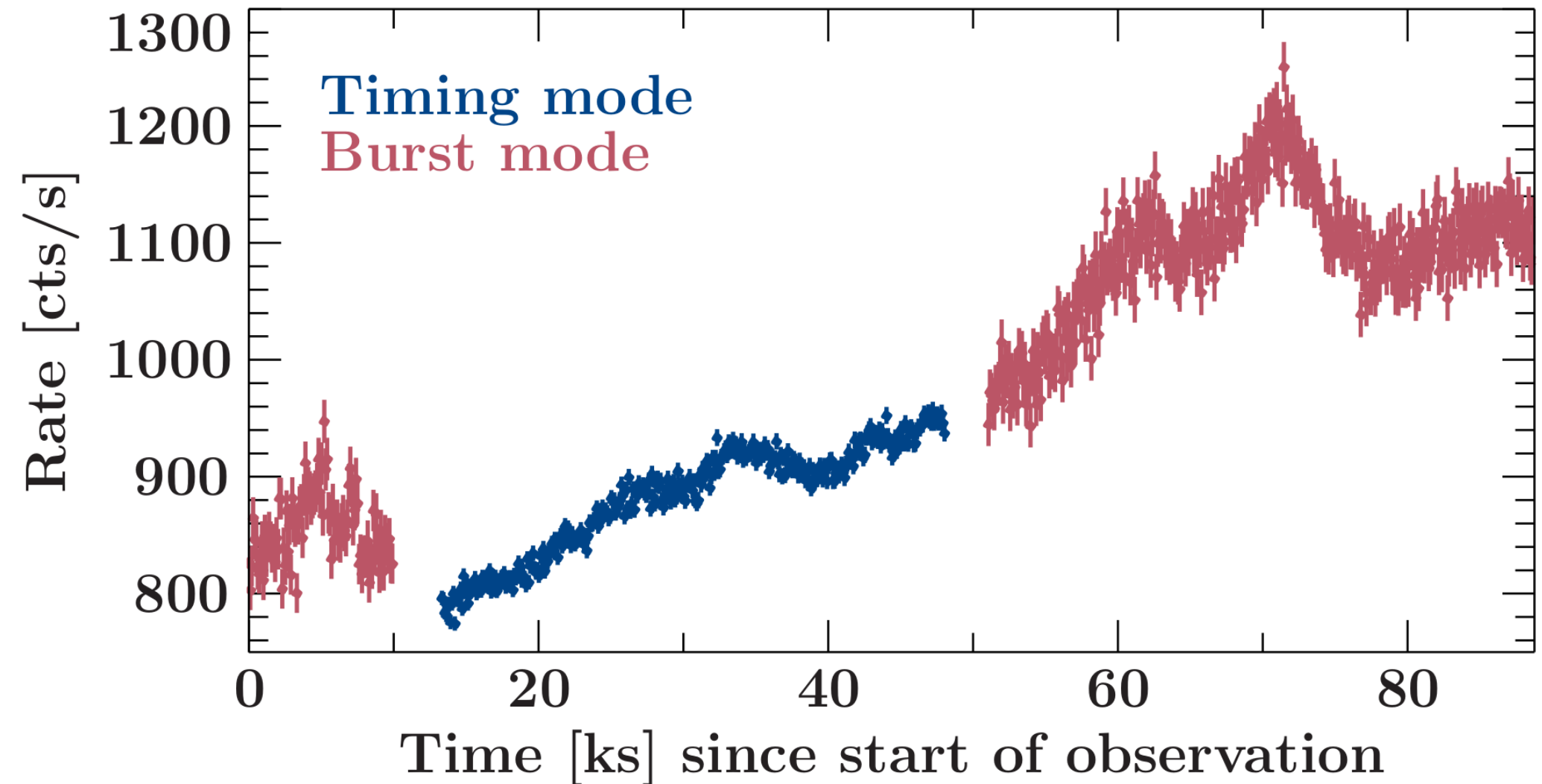
High-energy light curves



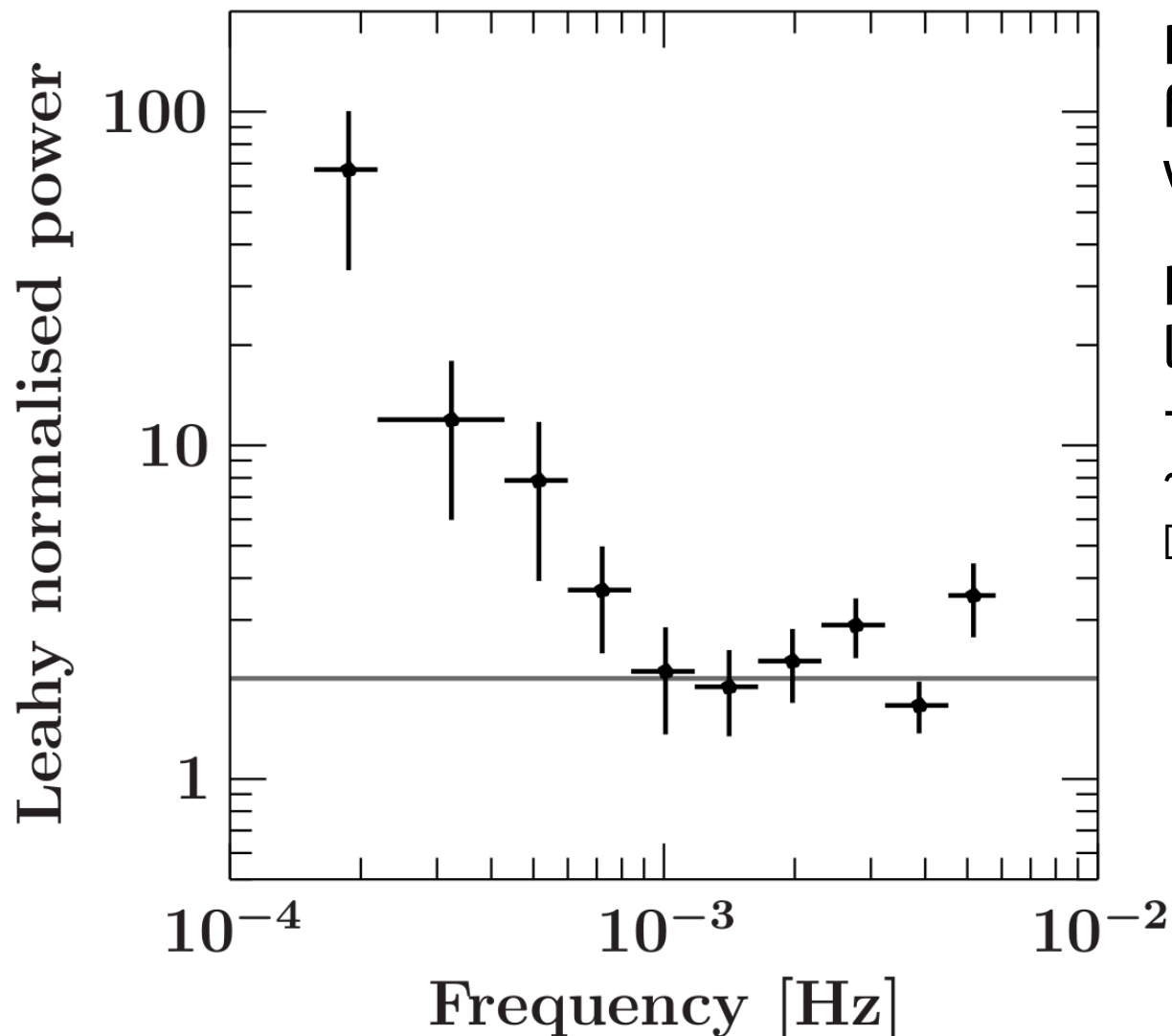
- Gamma-ray flare on June 9 2019 led to high state of TeV activity for 4 days
- X-ray emission during that time densely tracked
- Highest γ -ray and X-ray flux seem to coincide

XMM-Newton observation

Full energy range: 0.3 – 10 keV



Timing analysis with XMM-Newton light curve

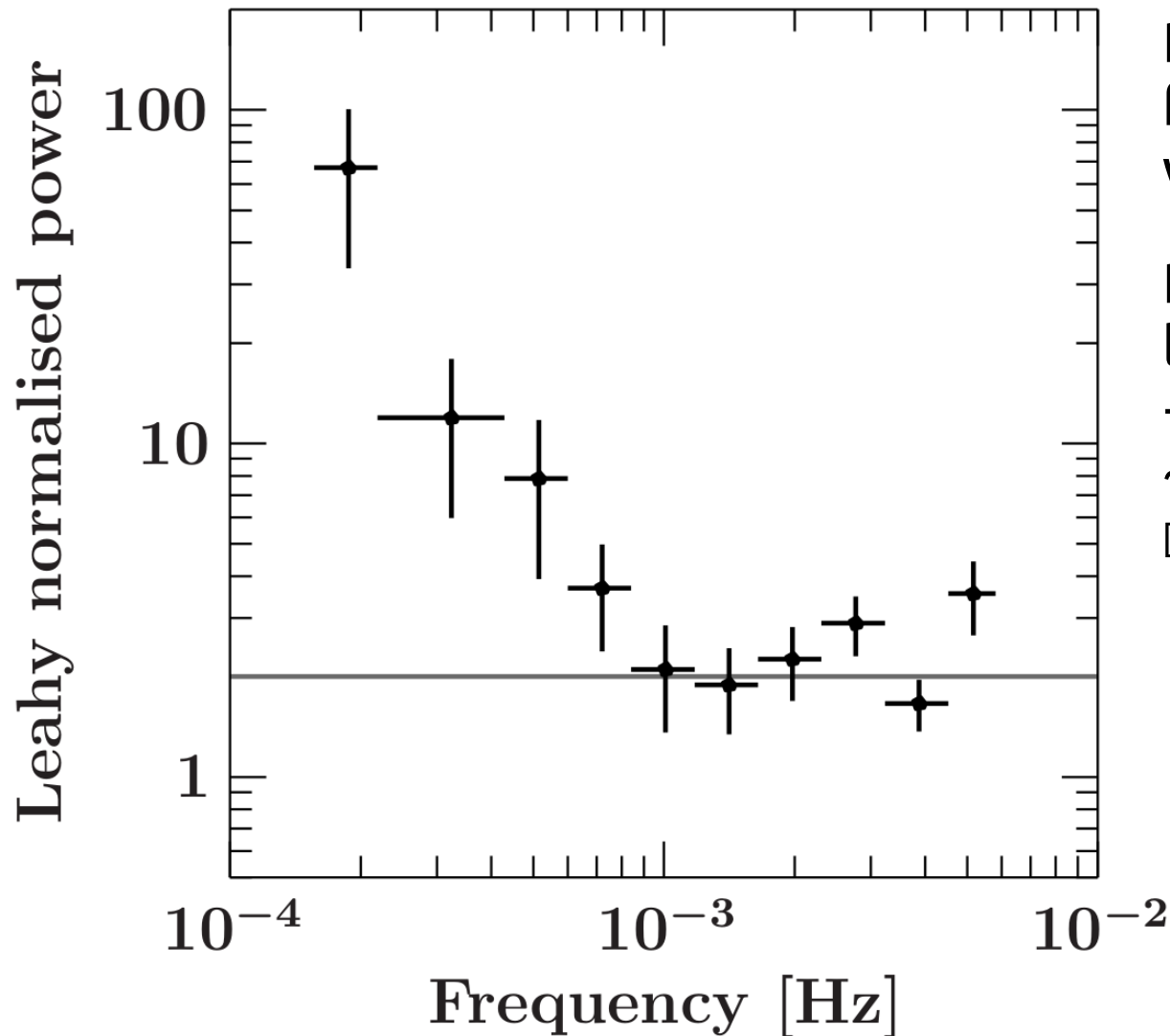


Power Spectral Density (PSD)
from 100s binned light curve
with Leahy normalisation:

PSD reaches Poisson noise
level at $\sim 10^{-3}$ Hz
→ variability on time scale of
 ~ 16 minutes

[Similar timescales to Abeysekara et al. (2017)]

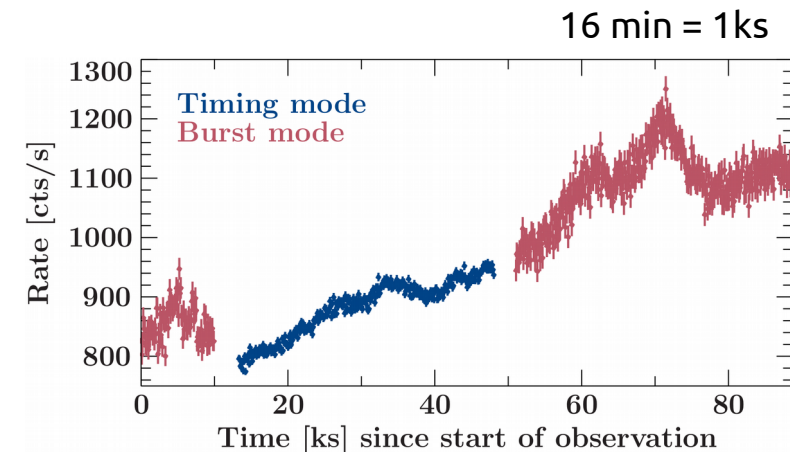
Timing analysis with XMM-Newton light curve



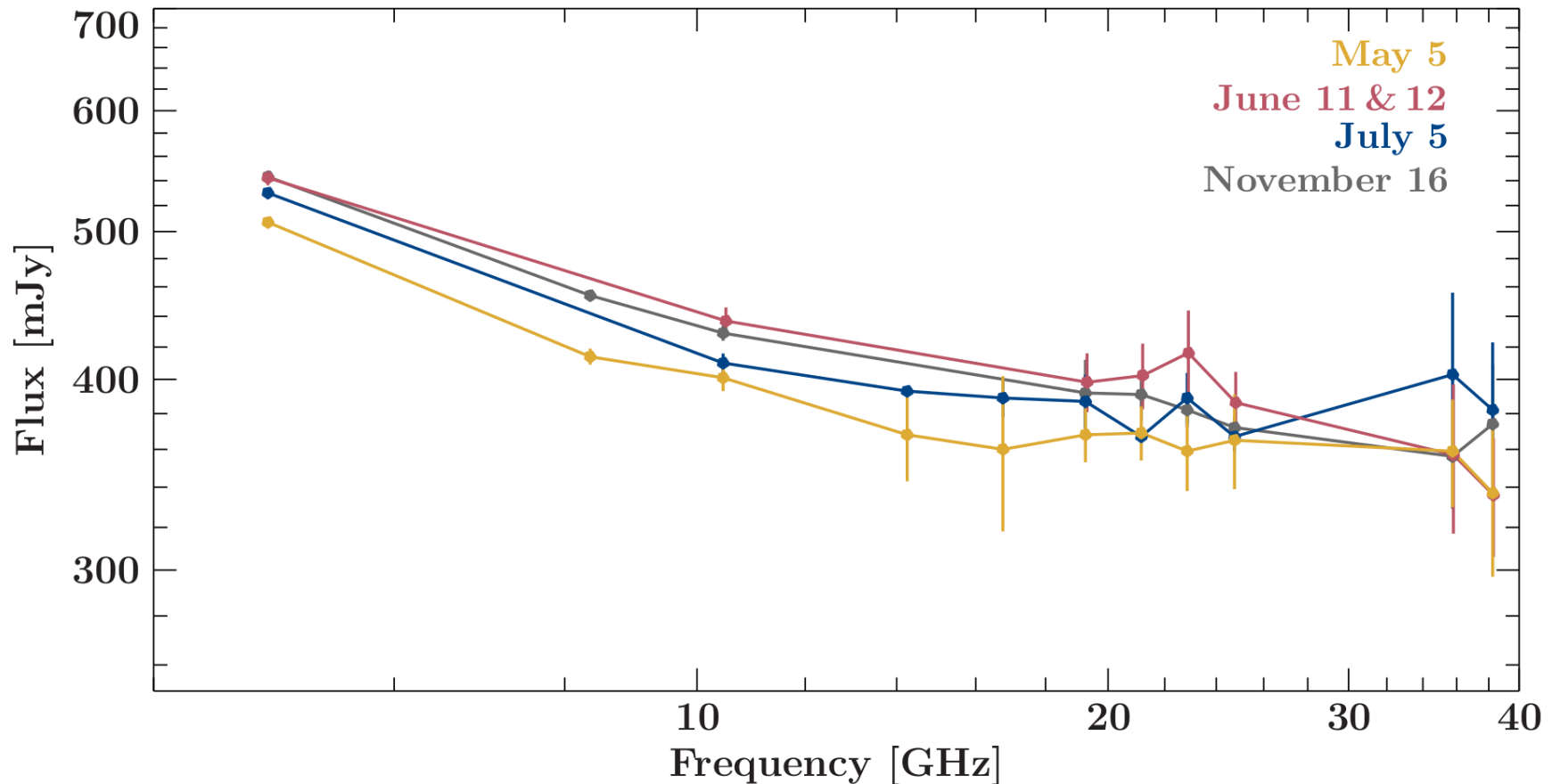
Power Spectral Density (PSD)
from 100s binned light curve
with Leahy normalisation:

PSD reaches Poisson noise
level at $\sim 10^{-3}$ Hz
→ variability on time scale of
 ~ 16 minutes

[Similar timescales to Abeysekara et al. (2017)]

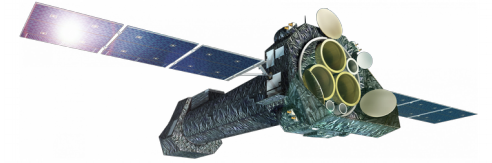


Radio spectra from 6cm to 8mm in 2019



- Taken with the 100m-dish radio telescope Effelsberg
- Hint for slight flattening at 35 GHz in July?
- No major response by pc-scale radio jet within 5 months

Summary & Outlook



- Caught Mrk 421 during a TeV flare that is coincident with a flare in the X-rays
- Monitoring program = unprecedented dense follow-up of MWL emission, covering both the low- and high-energy peak of its SED
- PSD shows variability on time scales of 16 minutes
- No major response by pc-scale jet after the flare



Paper including a full MWL analysis (incl. also *INTEGRAL* and *Fermi*-LAT data) is in preparation

