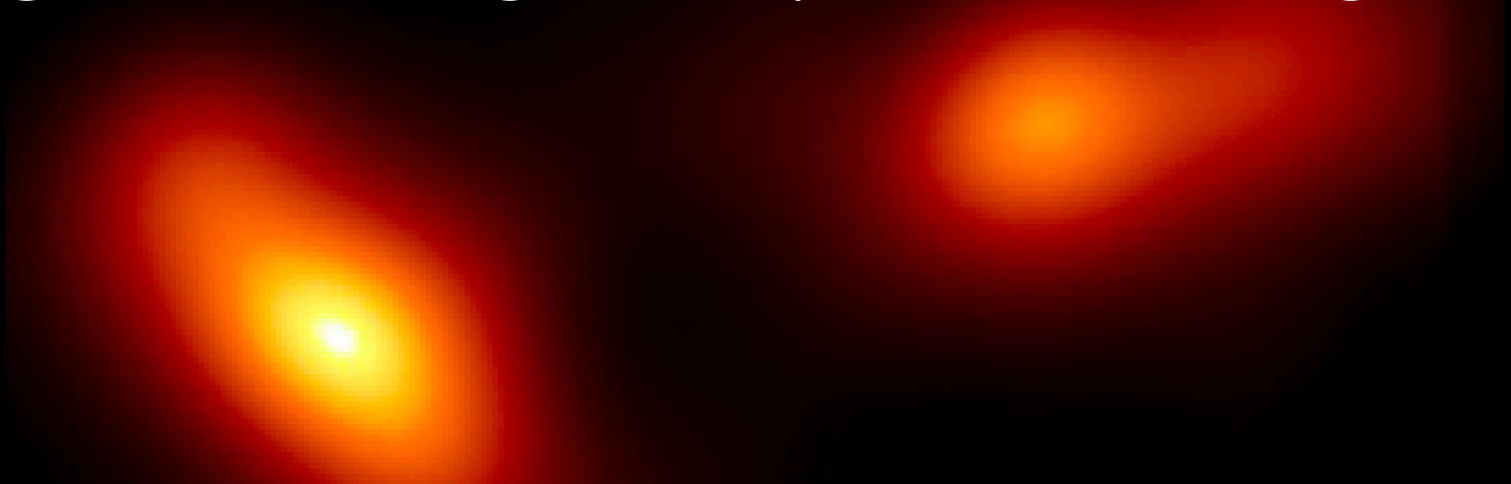
Multi-wavelenght view of 3C 279 during the 2017-2018 EHT campaigns including an unprecedented gamma-ray flare



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EHT-MWL science-working group, EHT, Fermi-LAT, H.E.S.S., MAGIC and VERITAS collaborations

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3C 279

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3. EHT-MWL 2017
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    - Preliminary modelling
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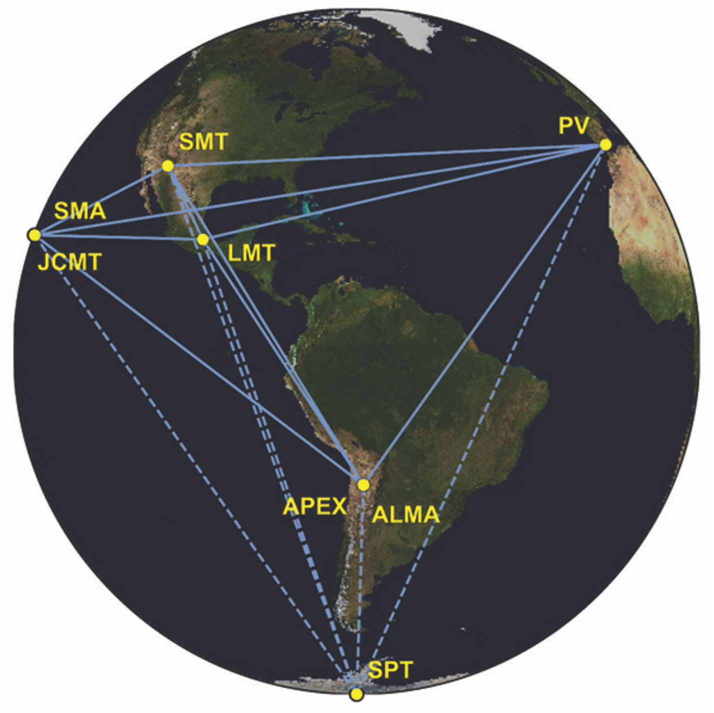
5. Outlook

Event Horizon Telescope



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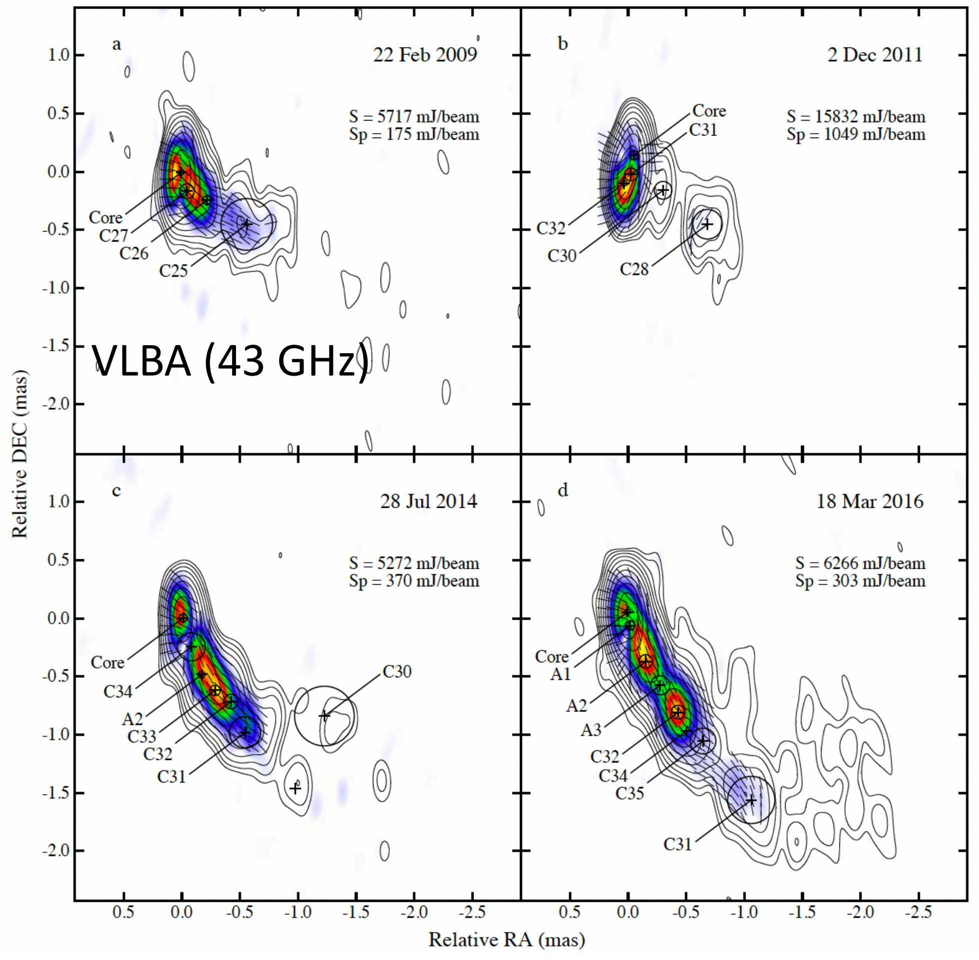
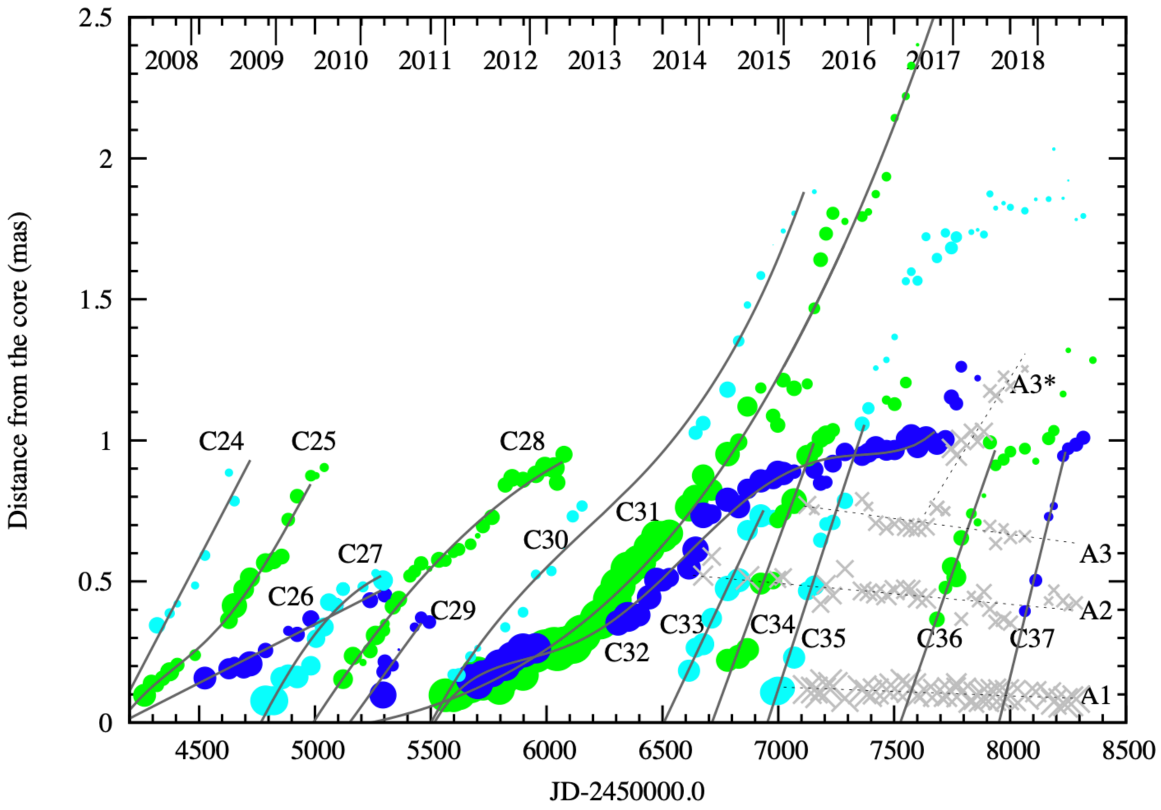
3C 279 radio components

The 3C 279 is an archetypal blazar (viewing angle <3˚), one of the first evidence of **rapid structure variability** (Knight et al. 1971) and apparent **superluminal motions** with Lorentz factors ranging from 20 (on parsec scale) to 40 downstream in the jet (Whitney et al. 1971; Cohen et al. 1971).



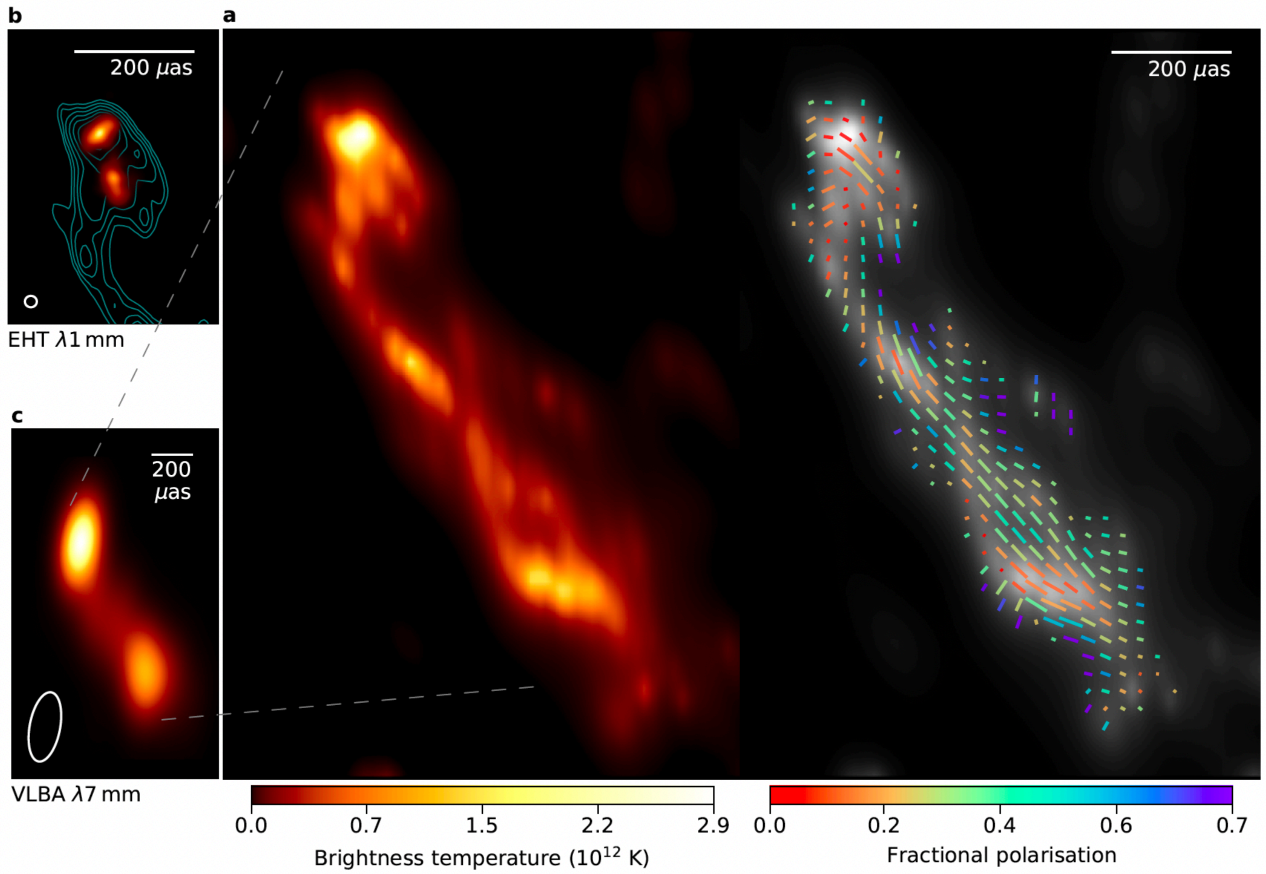


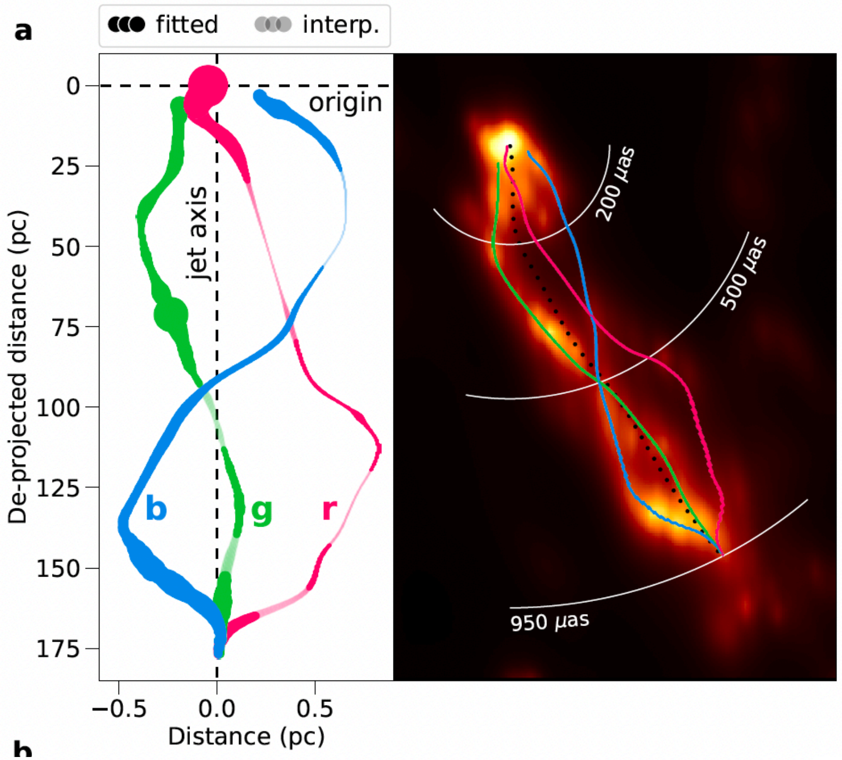
Larionov et al., 2020

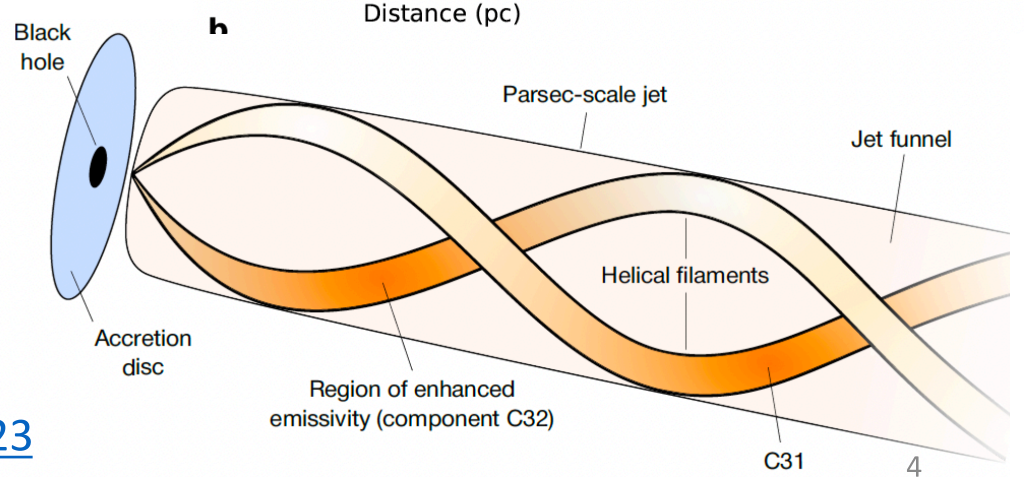
RadioAstron and 3C 279 jet

RadioAstron observations (high-resolution, high-dynamic-range)

- Extended **filamentary** structures observed
  ->proposed as the origin of blazar jet radio variability: (rather than shock-in-jet)
- The filaments may be threaded by a clockwise-rotating **helical magnetic field**.



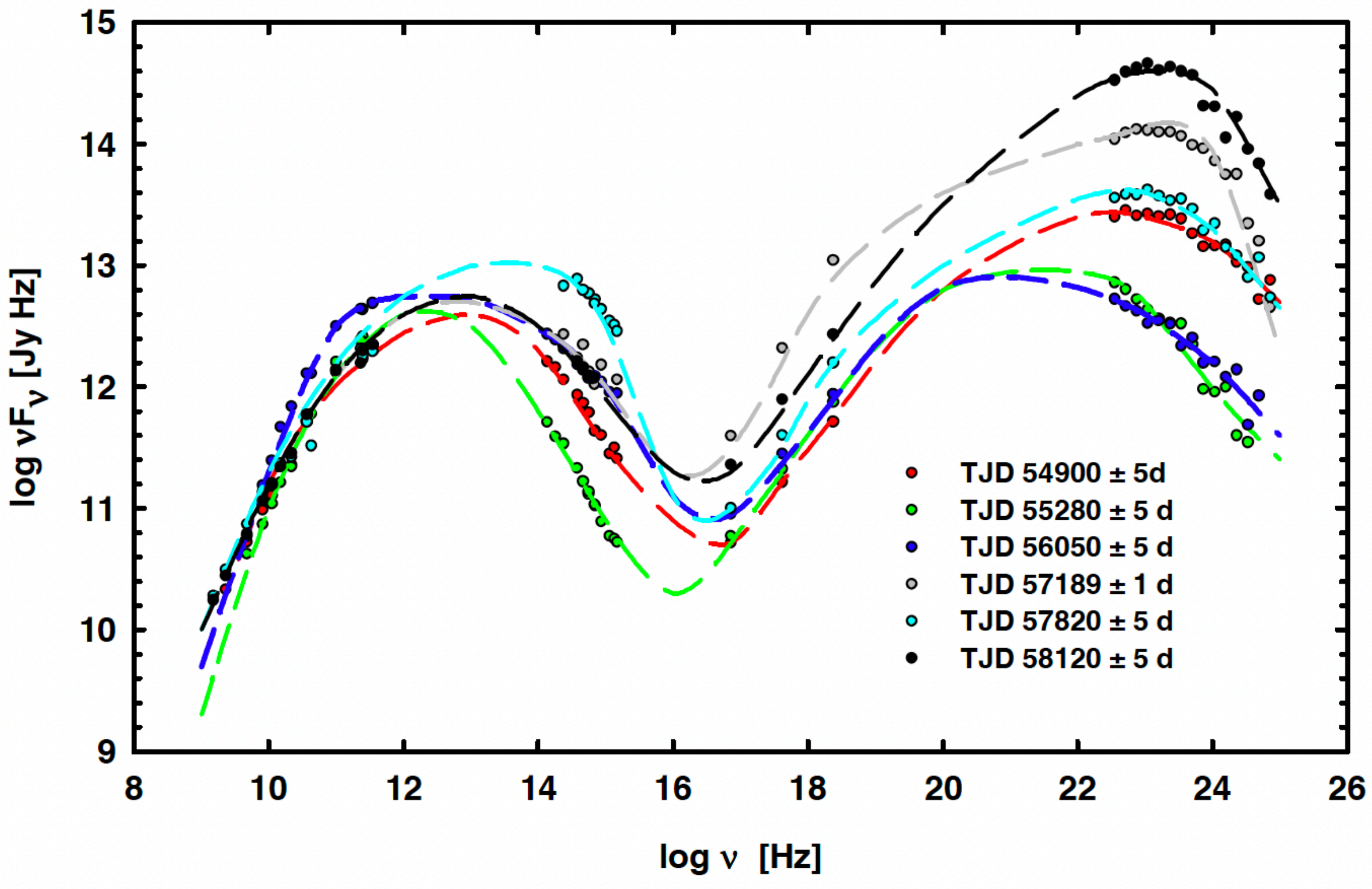




Fuentes et al., 2023

Decade-long MWL emission

Larionov et al., 2020

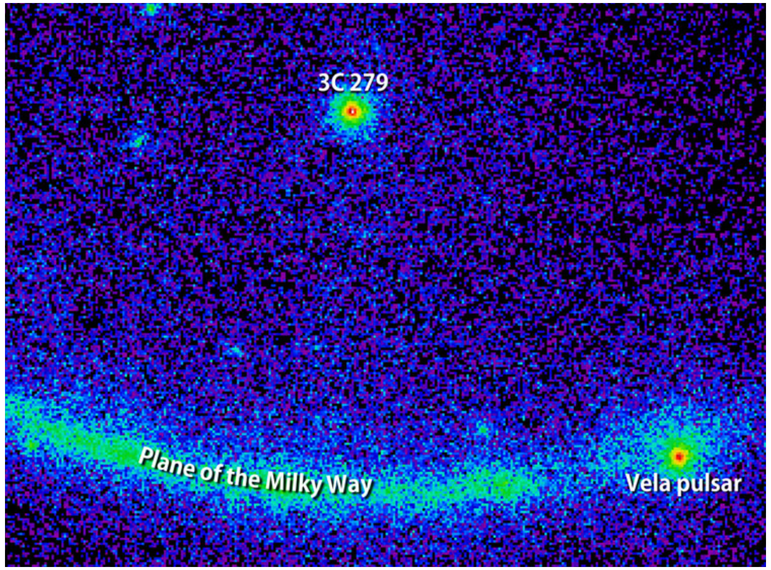


Strong variability observed, particularly at high energies.

Results support:

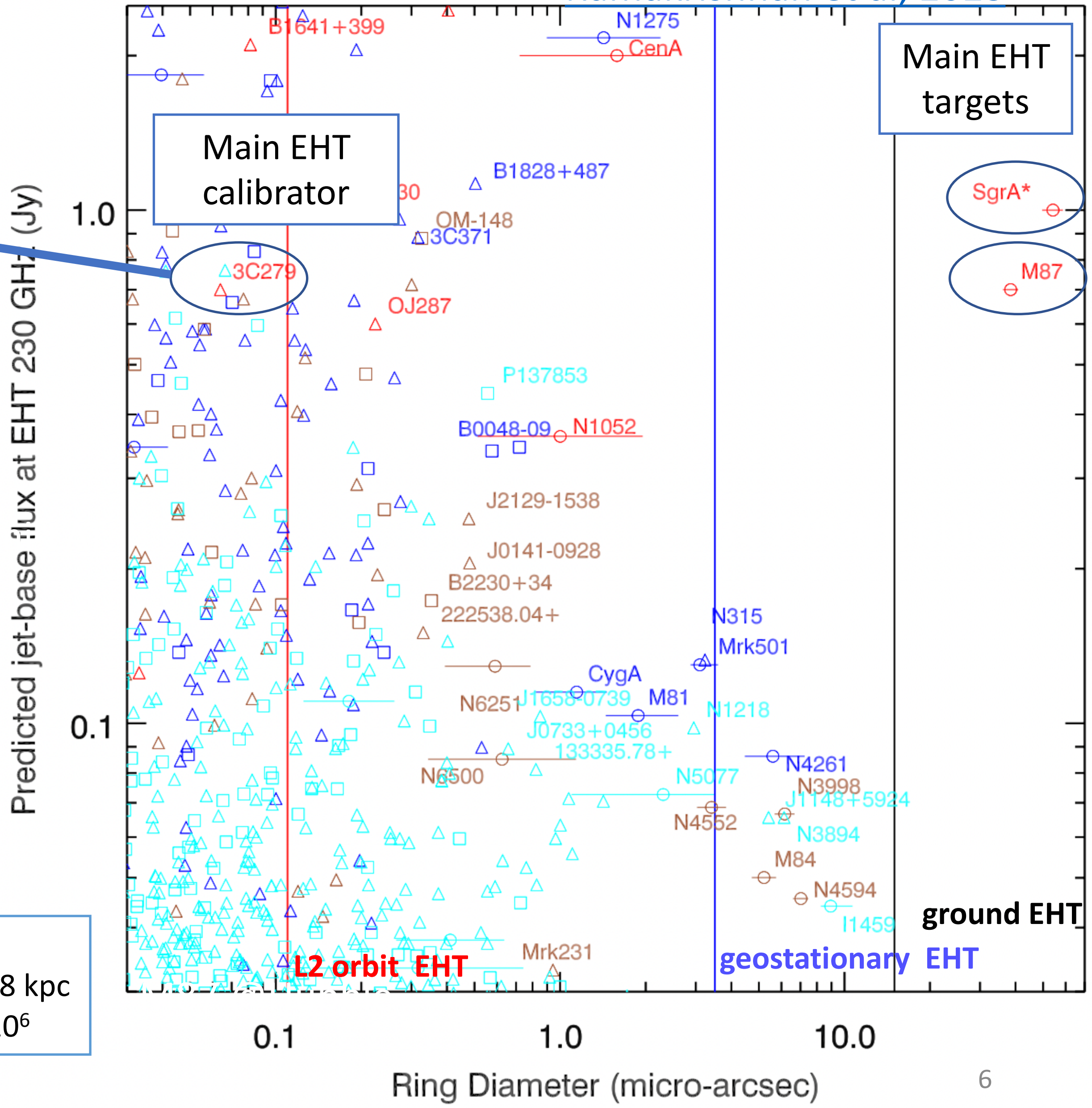
- either a predominantly **helical magnetic field** or motion of the radiating plasma along a spiral path.
- or a **different Doppler boosting** of stratified radio-emitting zones in the jet

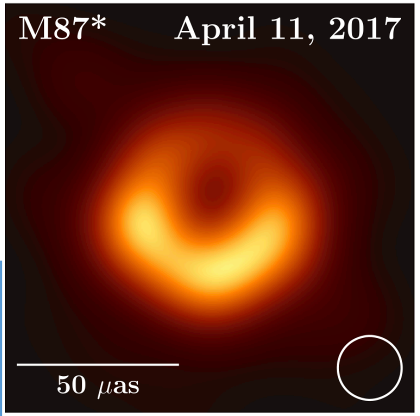
3C 279 – main calibrator for EHT observations

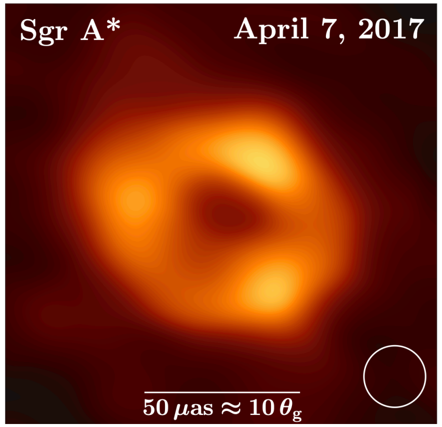


3C 279: a radio bright blazar located at about 3 Gpc (z~0.54)

Ramakrishnan et al, 2023





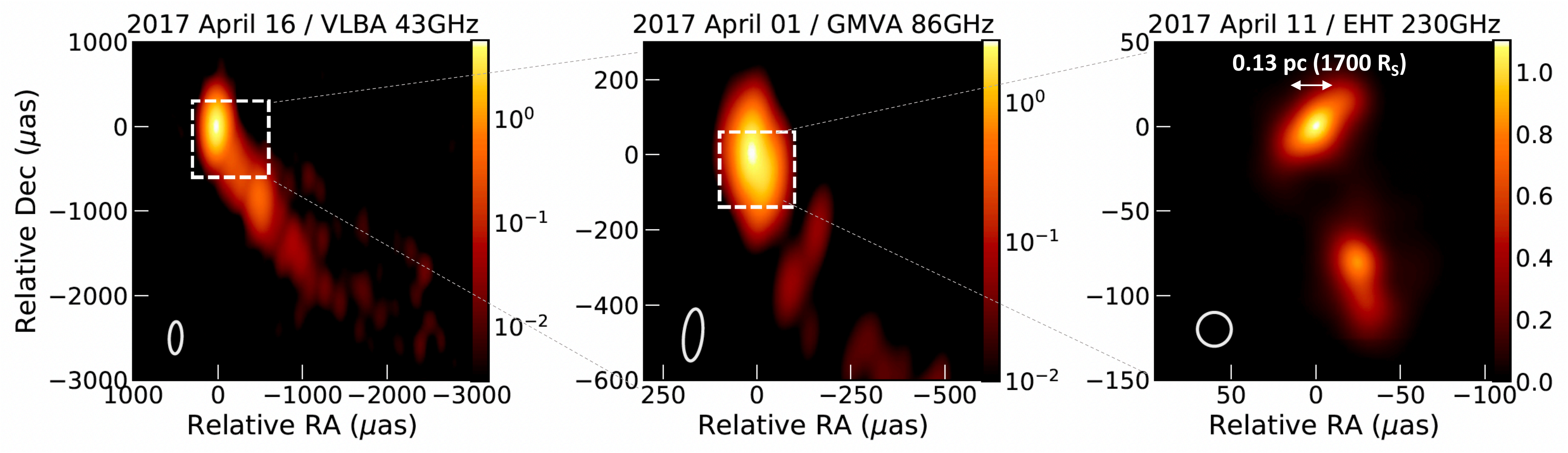


M87
dist. ~ 17 Mpc
M_{BH} ~ $6x10^9$

SgrA*
dist. ~ 8.18 kpc
M_{BH} ~ $4x10^6$

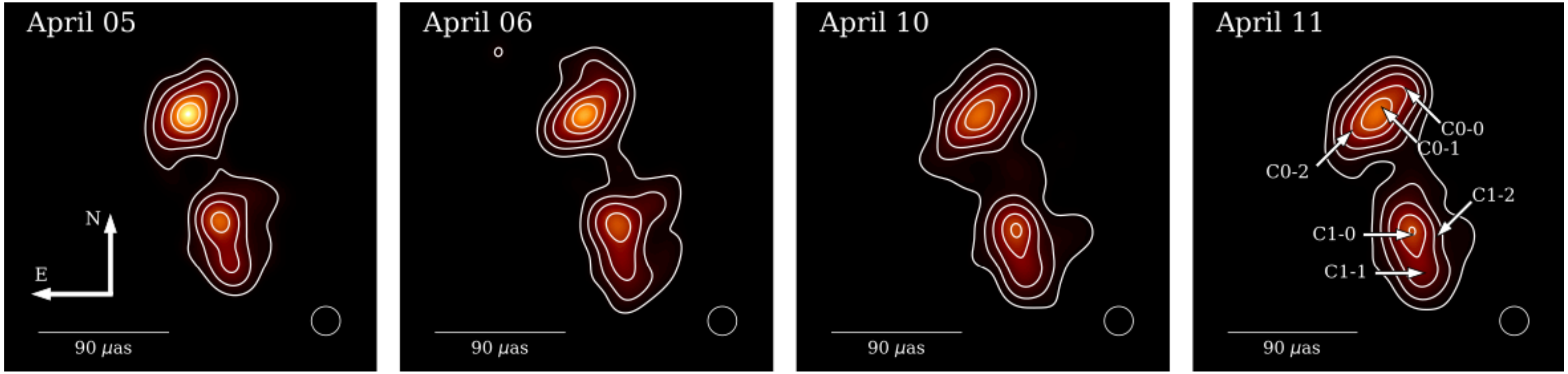
EHT and VLBI observations of 3C 279

EHT observations reveal peculiar substructures in the core, which can be interpreted as **abent jet**, or a **knotty structure.**



Kim et al., 2020

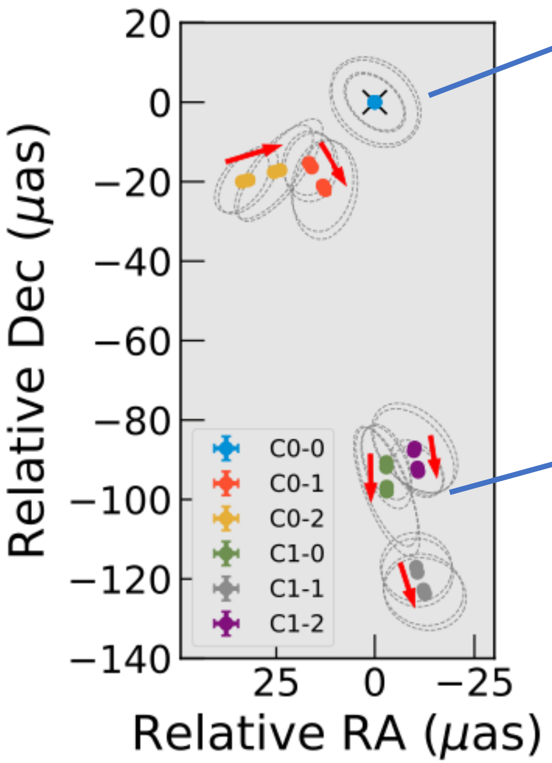
EHT observations of 3C 279

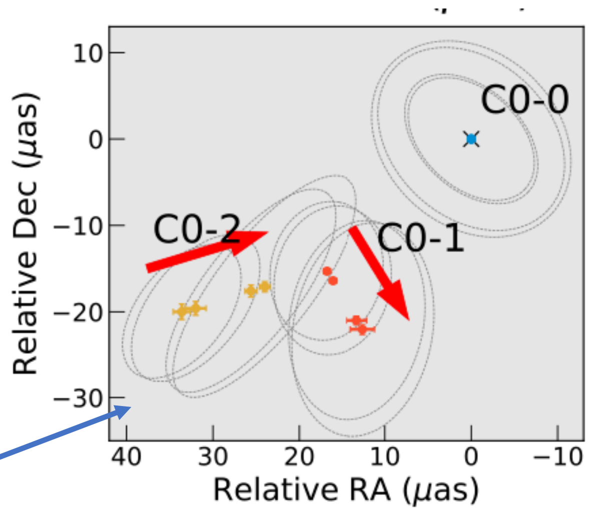


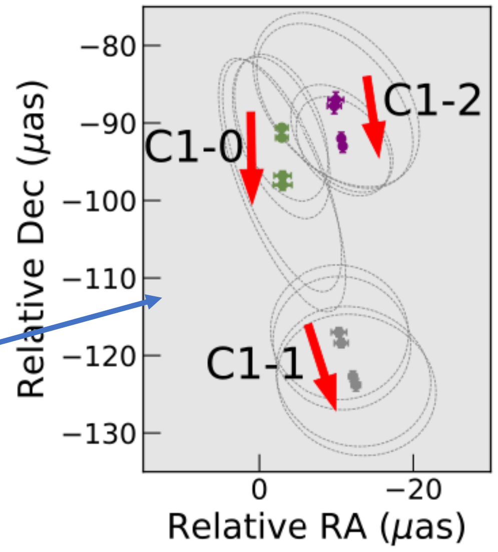
[Kim et al., 2020](#)

EHT revealed for the first time **jet component motion on a daily scale**, with high apparent motion speeds of the components.

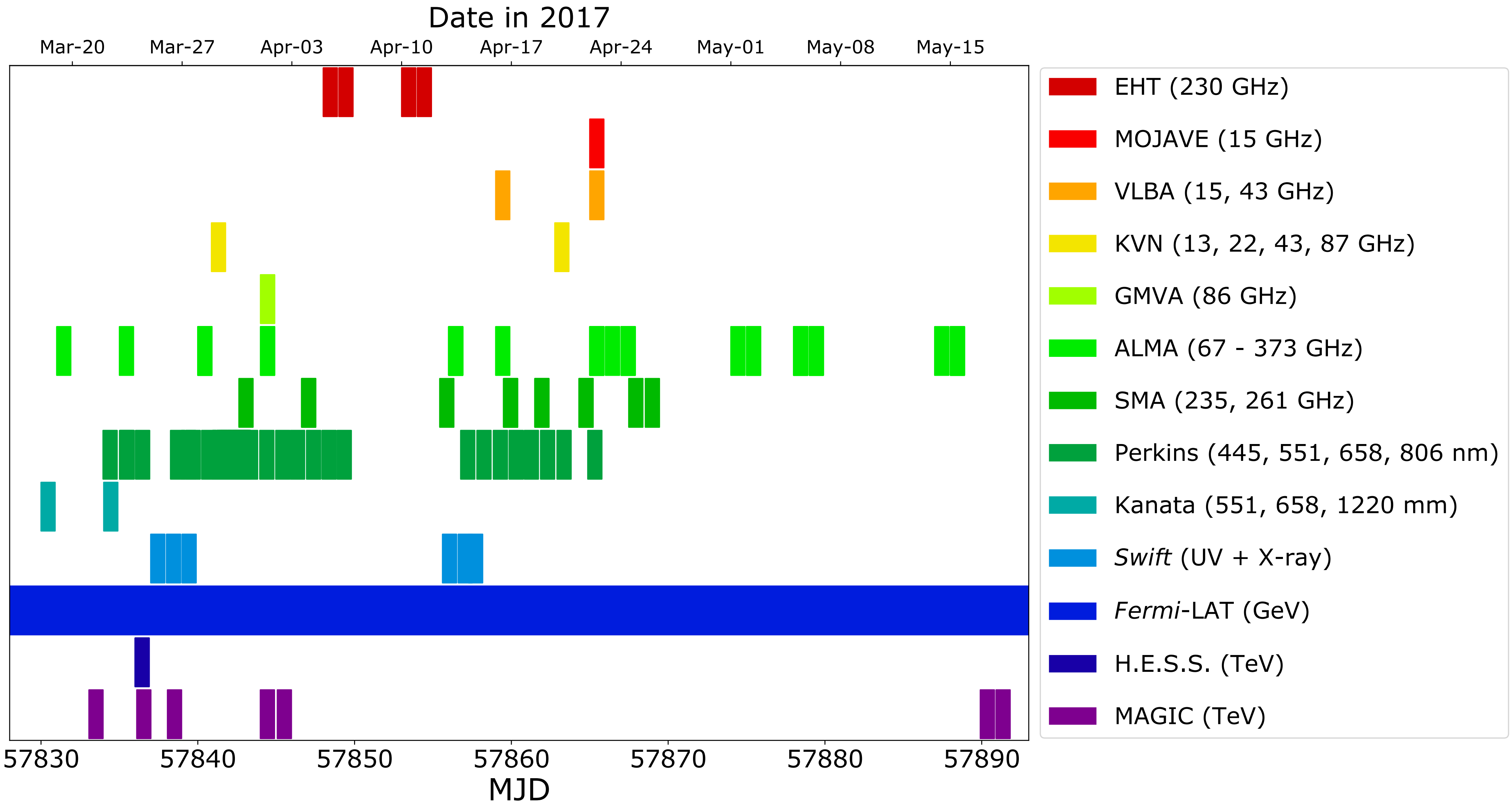
ID	β_{app} (c)	θ (°)	Γ	δ
Curved jet case [(a)]				
C0-1	16^{+3}_{-2}	≤ 1.5	≥ 20	≥ 32
C0-2	20 ± 1	≤ 2.9	≥ 20	≥ 20
C1-0/1/2	$(13{-}15) \pm 2$	$\geq 6{-}8$	≥ 20	$\leq 5{-}7$
Straight jet case [(b)]				
C1-0/1/2	$(13{-}15) \pm 2$	2	16–17	24–25







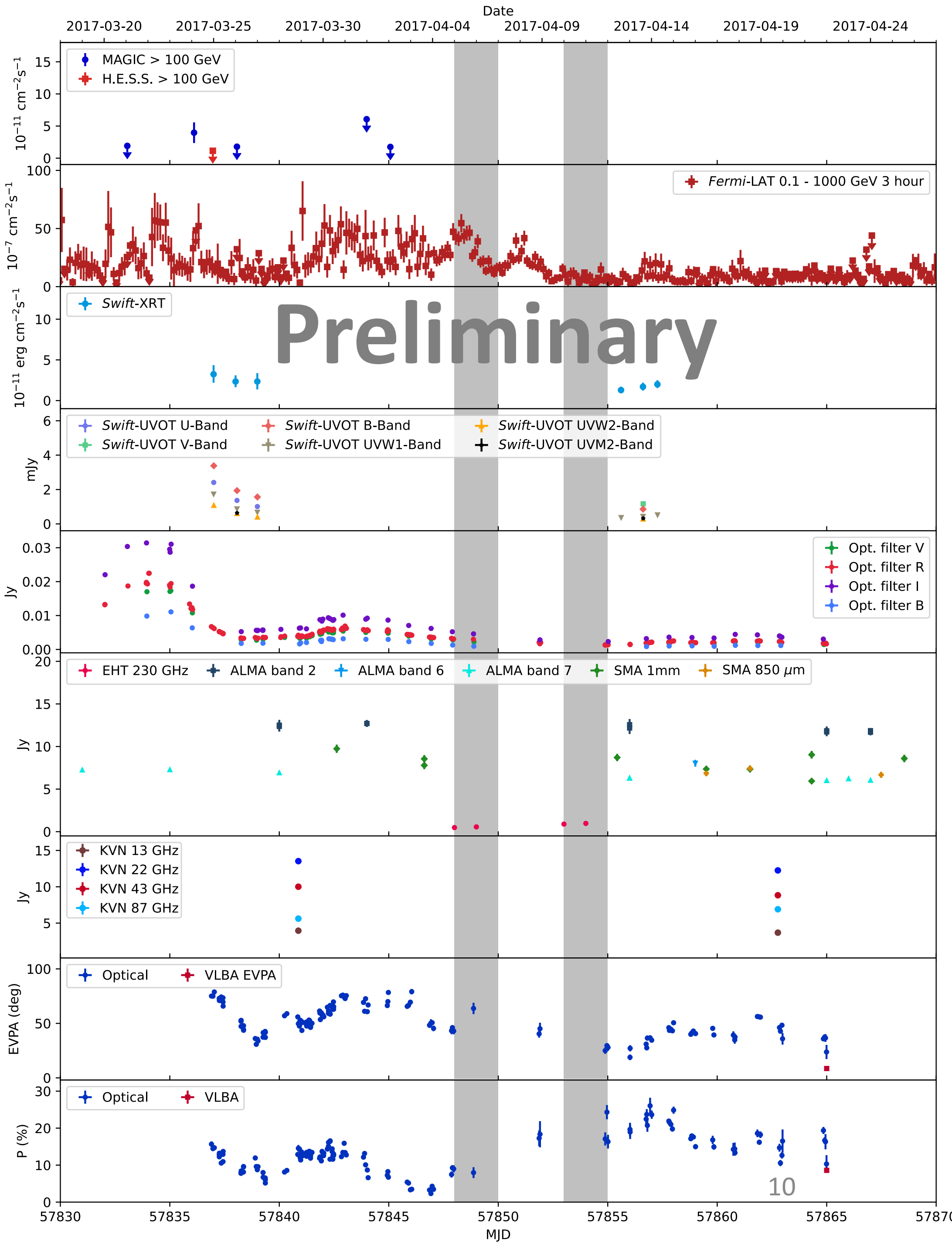
3C 279 2017 EHT-MWL instrument coverage



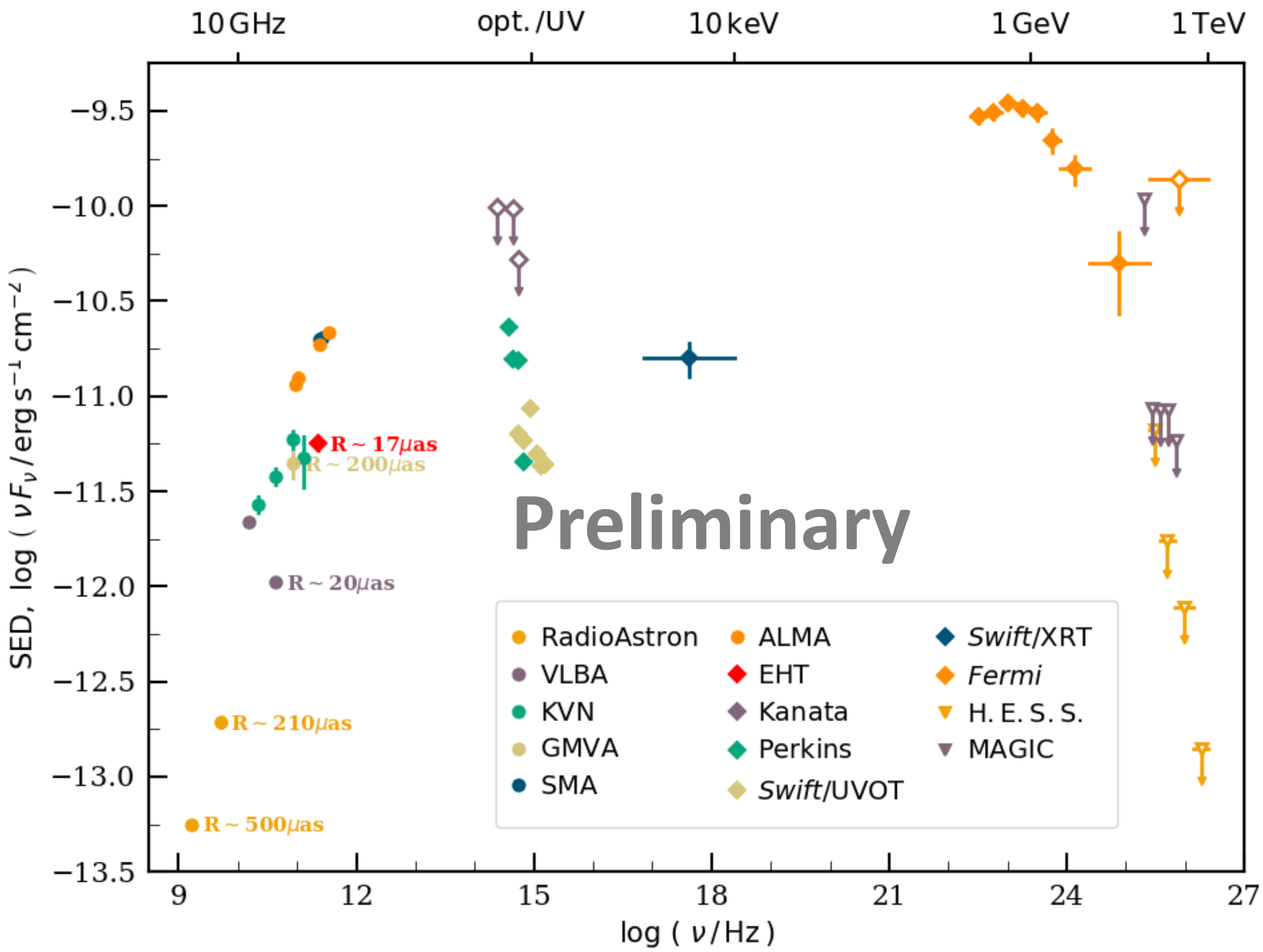
In addition, **RadioAstron** cumulative (2016-2018) observations were included

3C 279 2017 EHT-MWL results

- The source underwent a period of **gamma-ray flaring episodes** during the 2017 EHT campaign
- **flaring** activity in the **UV–optical** band, with a peak flux observed around March 22–23, while the source was fading in optics during the campaign
- **optical polarisation** shows substantial **variability** (polarisation degree ranging from 5% to 25%)
- **polarisation angle varying** between 20º and 80º following a similar temporal trend



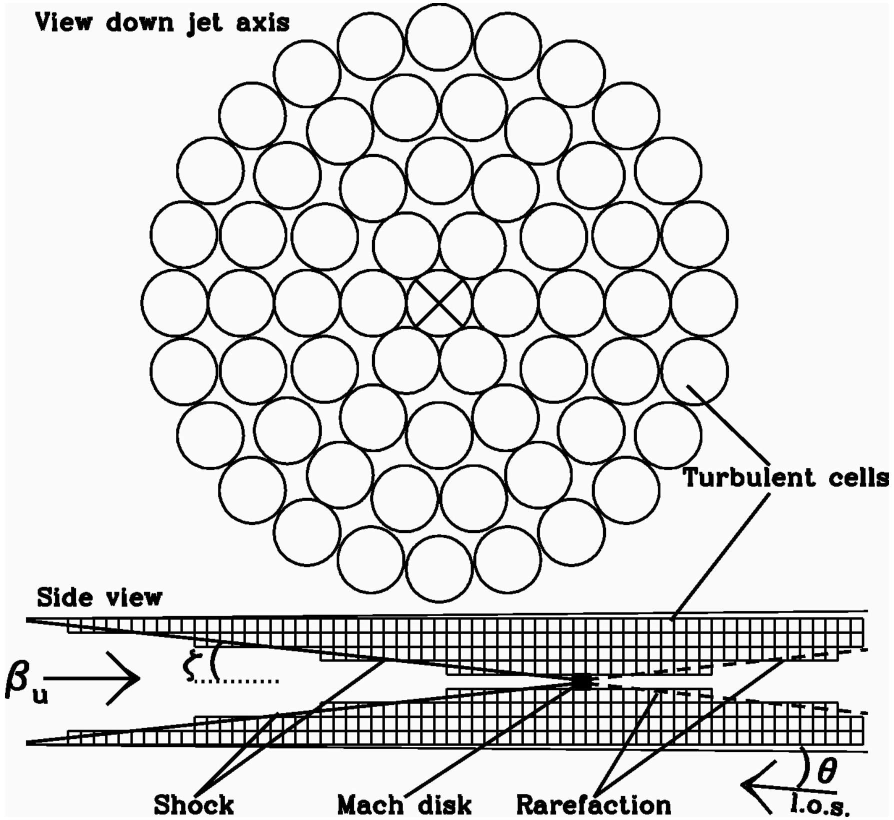
3C 279 2017 EHT-MWL SED

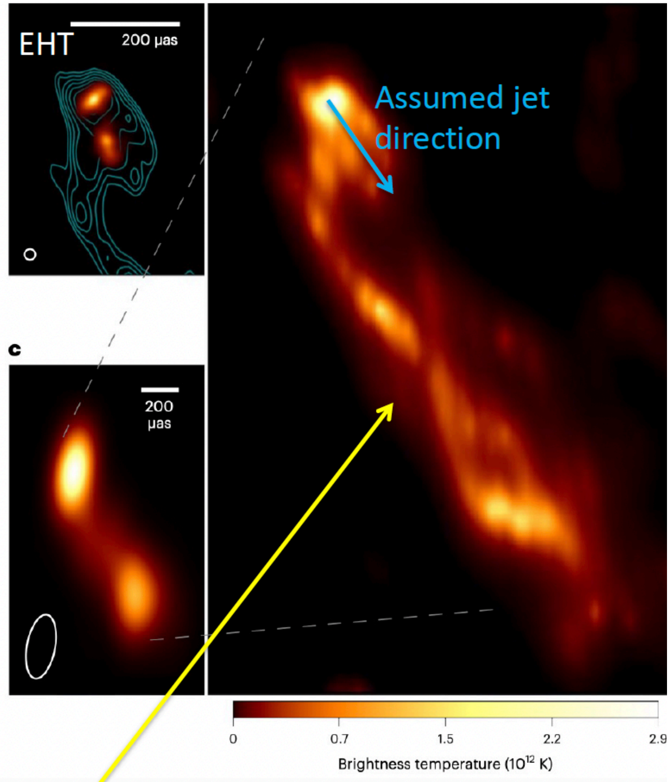


Reference date EHT obs April 5, 2017

Adopting **Turbulent Extreme Multi-zone (TEMZ) Model** (Marscher 2014)
Aim to describe also

- Flux variability: flares + rapid fluctuations
- Polarization variability: P ~ 2 – 30% (weekly)+ rapid fluctuations
- Polarisation angle changes





VLBI at 1.3 cm including RadioASTRON

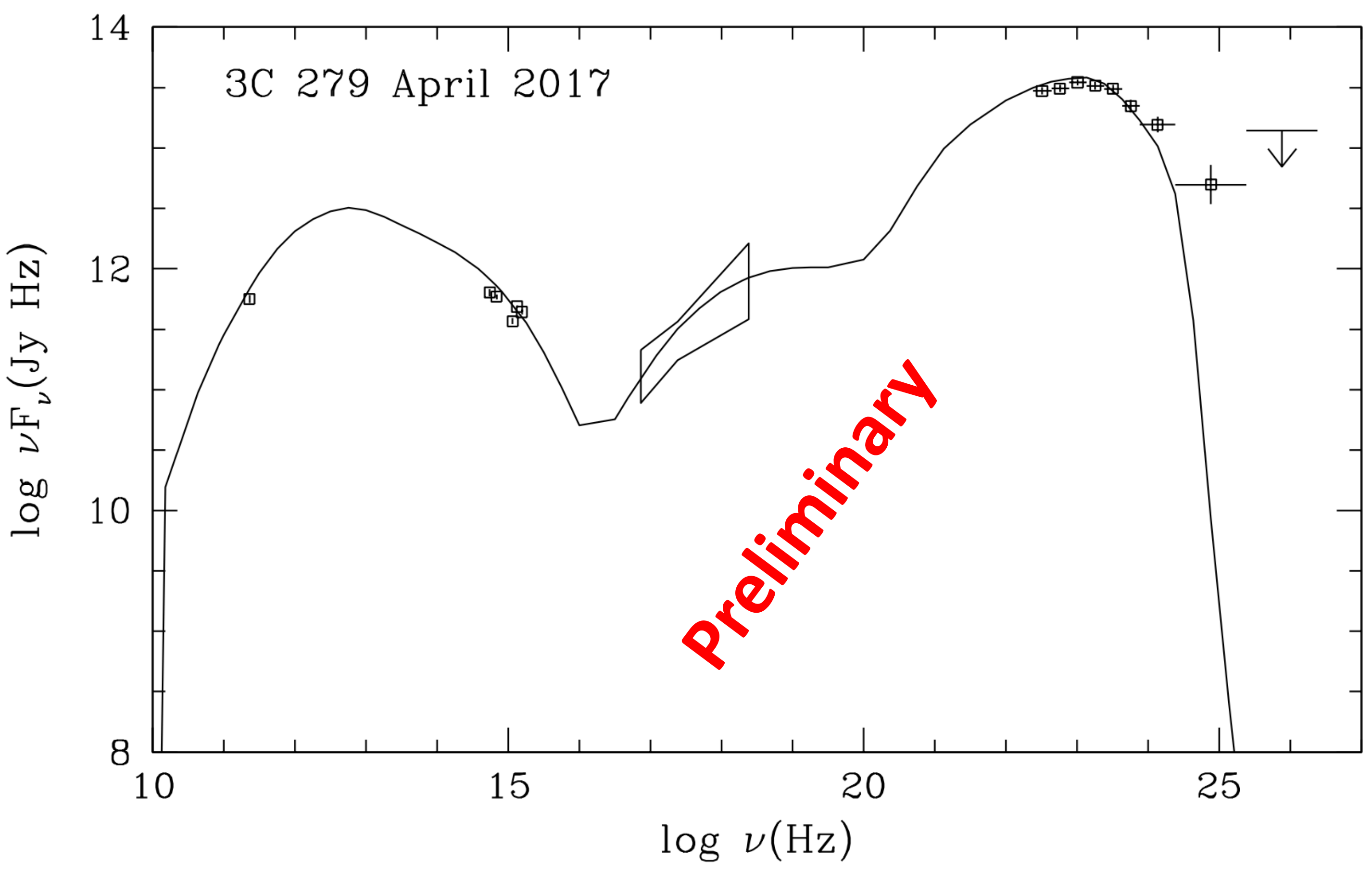
General assumptions

- Width of jet similar to observed value
- 2880 turbulent cells, each 0.03 pc in size
- gamma-rays from Compton scattering of emission-line photons 0.6 pc from black hole (*next step*: investigating the origin also from outside the BLR)
- B field is 50% helical, 50% turbulent

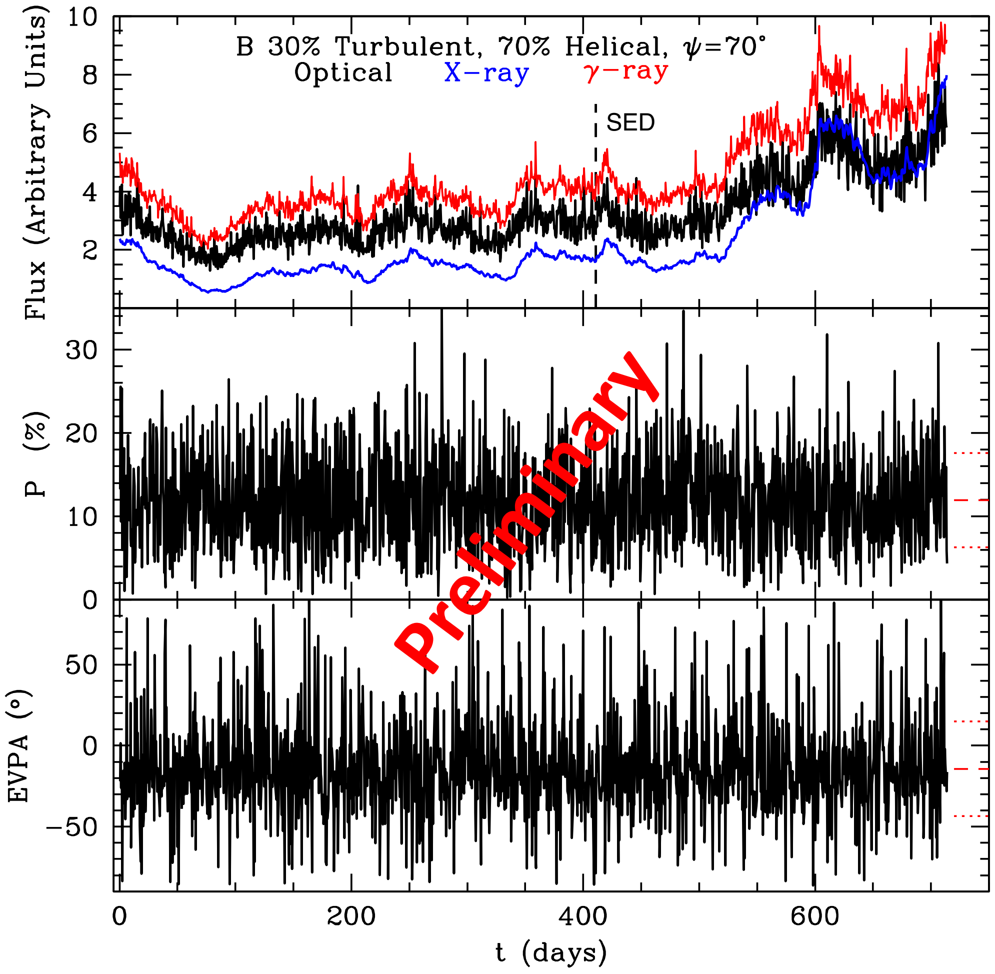
3C 279 EHT-MWL 2017 – Modelling

Preliminary modelling results adopting the TEMZ Model (Marscher 2014)

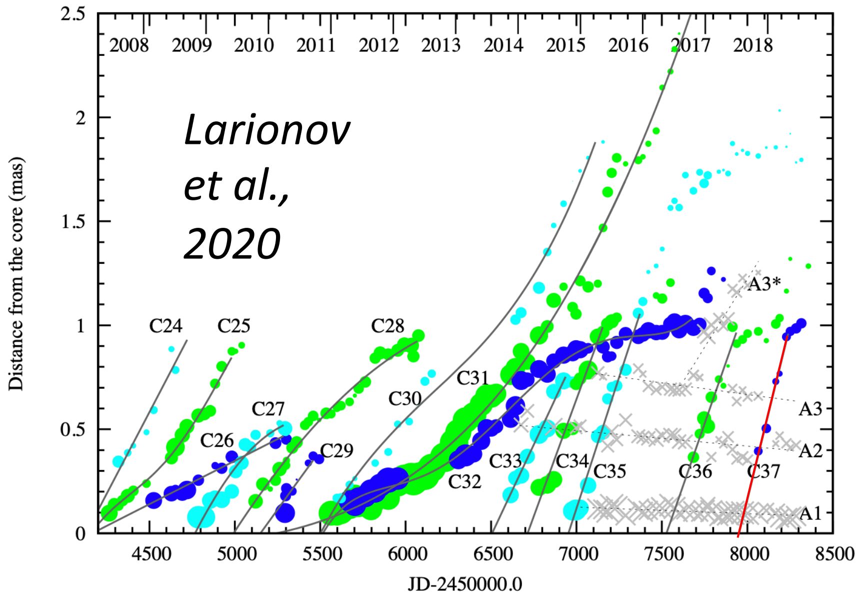
Preliminary simulations



Preliminary simulations



3C 279 EHT-MWL 2017 – Gamma-ray flare origin

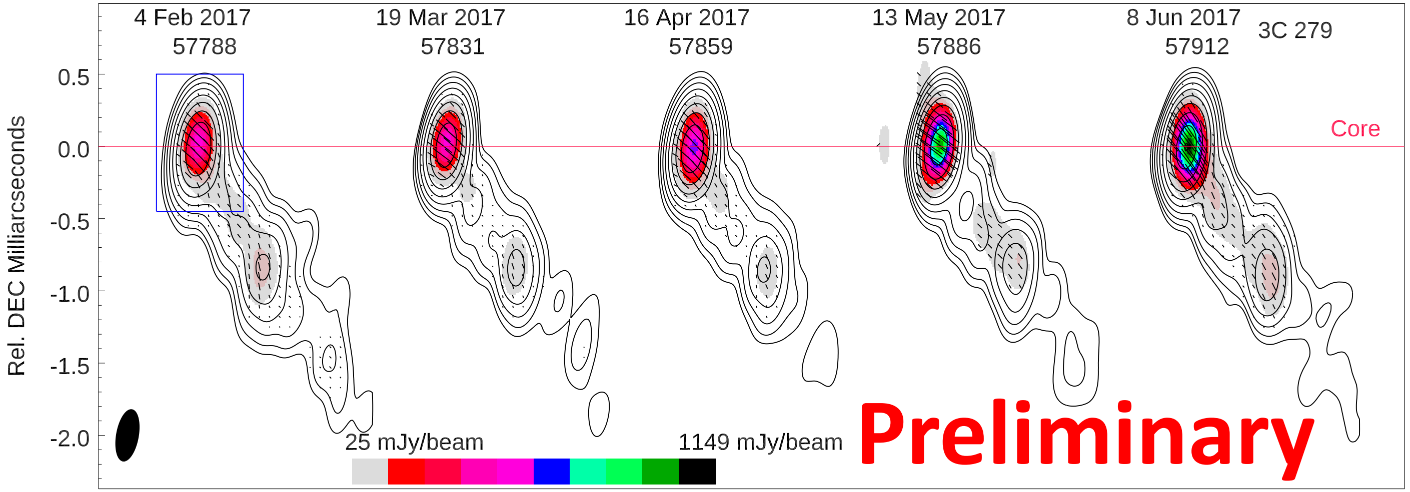


Possible scenarios

1) <u>Turbolent cells in the jet</u>:
Turbulent cells passing through a stationary conical shock experience compression that can trigger rapid gamma-ray flares (as investigated in the modelling)

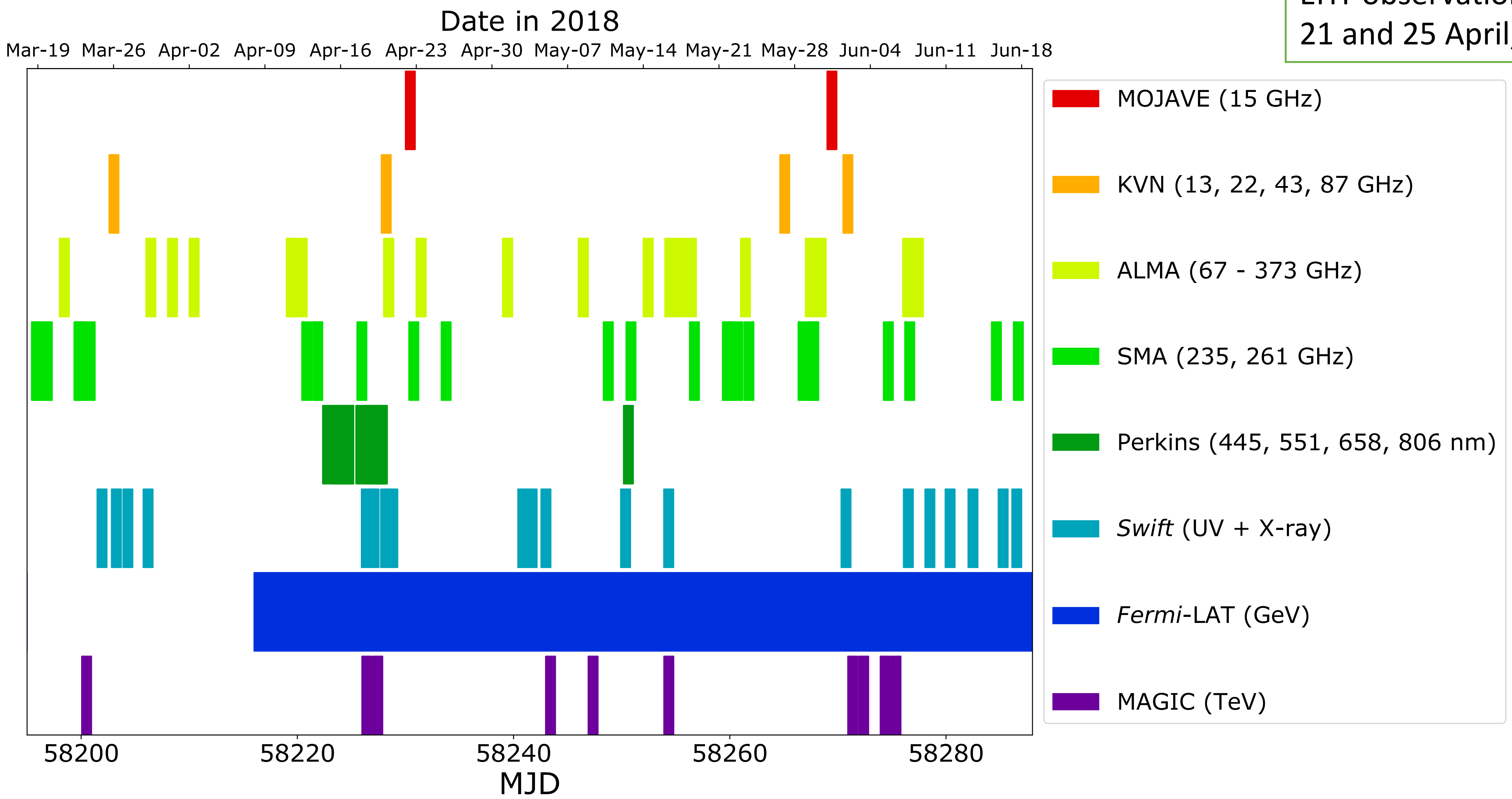
2) <u>Magnetic reconnection</u>:
Kink or shear-flow instabilities in a turbulent plasma can create filamentary current structures that trigger rapid, relativistic reconnection and intense high-energy emission.

3) <u>Shock-in-Jet scenario / knot ejection</u>:
A superluminal ($v \sim 25c$) knot was ejected around April 2($\pm$13days). pronounced increase in the radio-core polarisation intensity in April-May.



3C 279 2018 EHT-MWL instrument coverage

EHT observations:
21 and 25 April, 2018



In addition, **RadioAstron** cumulative (2016-2018) observations were included

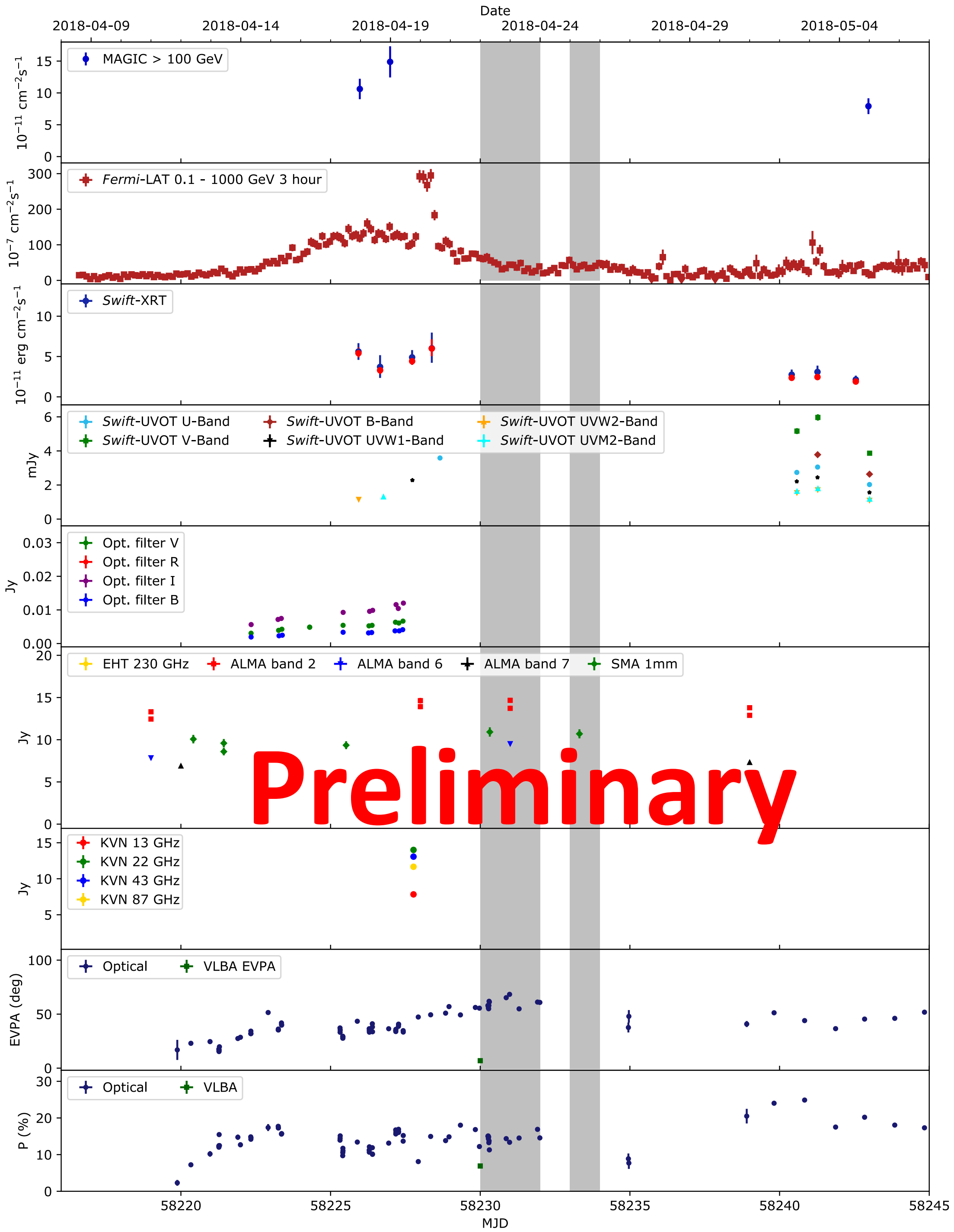
3C 279 2018 MWL variability

- EHT observations performed on
  - April 21
  - April 25

(EHT analysis ongoing)

- Few days before the EHT observations the source underwent a **record gamma-ray flaring episode**

- No clear variability was observed at other frequencies/energies.



Outlook

Multi-wavelength observations of 3C 279 in coordination with the EHT campaign

3C 279, primary calibrator for **EHT**, was observed during the first two EHT campaigns at an angular resolution of 20 μas:

April 5–11, 2017

April 21–25, 2018

- EHT data reveals peculiar substructures in the core, which can be interpreted as abent jet, or a knotty structure; as well sa rapid variability on daily timescales was detected.

A broad **MWL campaign**, spanning from radio (cm) to very-high-energy (VHE) gamma rays, was conducted in parallel to:

- Perform a long-term MWL study of 3C 279 to characterize its activity and variability,
- Characterise **Gamma-ray flaring episodes** observed during both the 2017 and 2018 campaigns,
- Investigate the origin of the high energy emission.

Forthcoming publications:

- The EHT-MWL paper presenting the results of the 2017 MWL campaign will be submitted soon.
- the results of the 2018 EHT and MWL campaign will also be submitted early next year

STAY TUNED!

Thanks for your attention!