Multiwavelength observations in 2019-2020 of a new very-high-energy γ-ray emitter: the flat spectrum radio quasar QSO B1420+326

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QSO B1420+326 (a.k.a. OQ 334)

Fermi LAT detection of renewed GeV gamma-ray flaring activity from OQ 334 (B2 1420+32)

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*on **1 Jan 2020; 20:15 UT***
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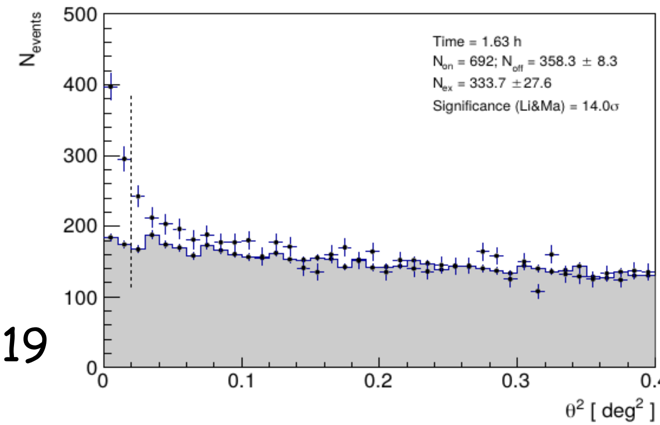
Detection of very-high-energy gamma-ray emission from B2 1420+32 with the MAGIC telescopes

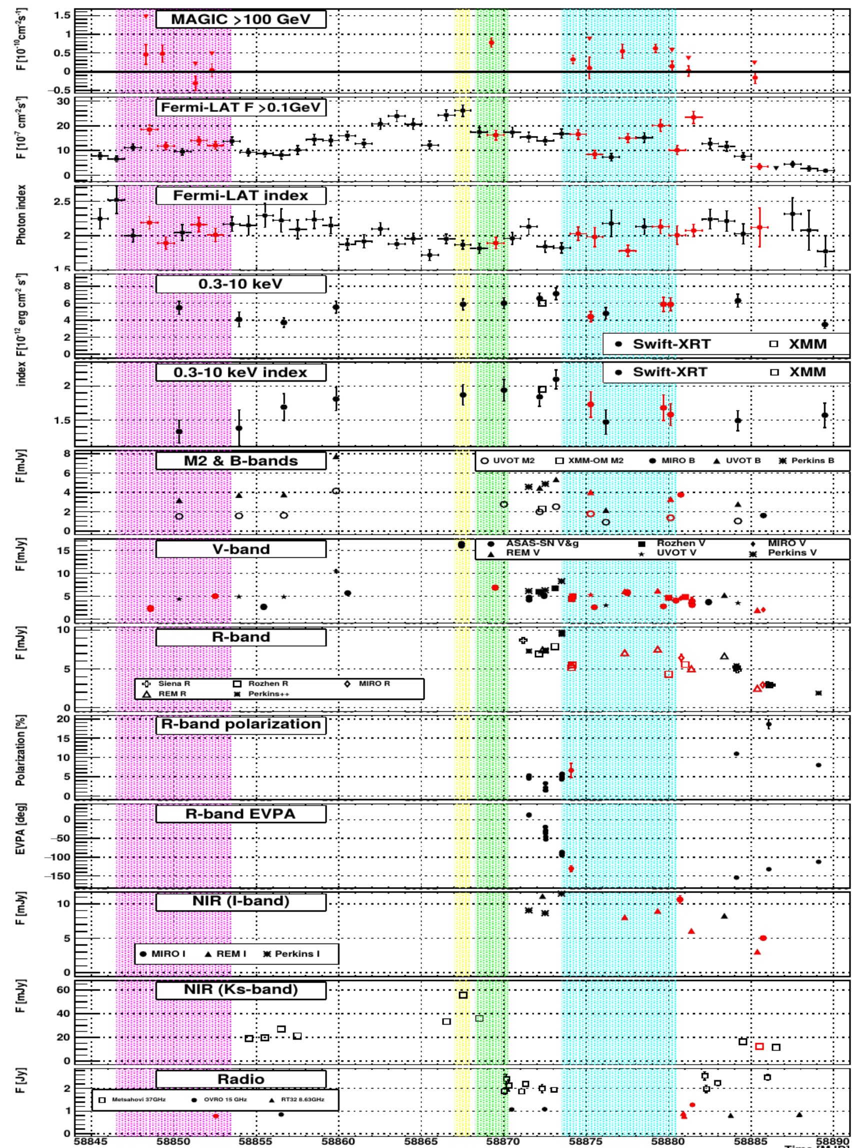
ATel #13412; *Razmik Mirzoyan (Max-Planck-Institute for Physics, Munich), on behalf of the MAGIC collaboration*
*on **21 Jan 2020; 21:03 UT***
Distributed as an Instant Email Notice Transients
Credential Certification: Giacomo Bonnoli (giacomo.bonnoli@unisi.it)



Acciari et al. 2021

- FSRQ located at redshift of **0.682**
- Strongly variable in γ-rays
- Recent flaring activity started in December 2019
- Follow-up observations with the ***MAGIC telescopes*** resulted in adding this source to the rare family of VHE-detected FSRQ
- Multi-wavelength campaign organized between 2019 December and 2020 February

MWL campaign

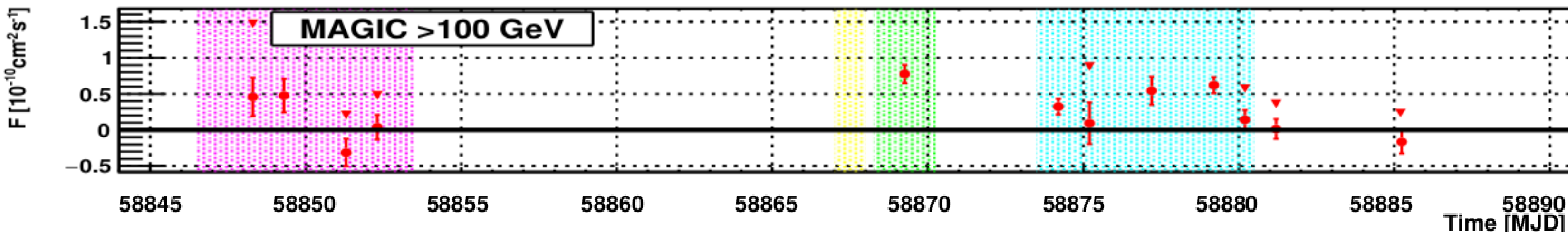


- Flux measurements in radio, NIR, optical, UV, X-ray, HE and VHE γ-rays
- Optical polarimetry
- Optical spectroscopy
- Follow-up with high-resolution VLBA observations
- 4 periods selected for detailed analysis:

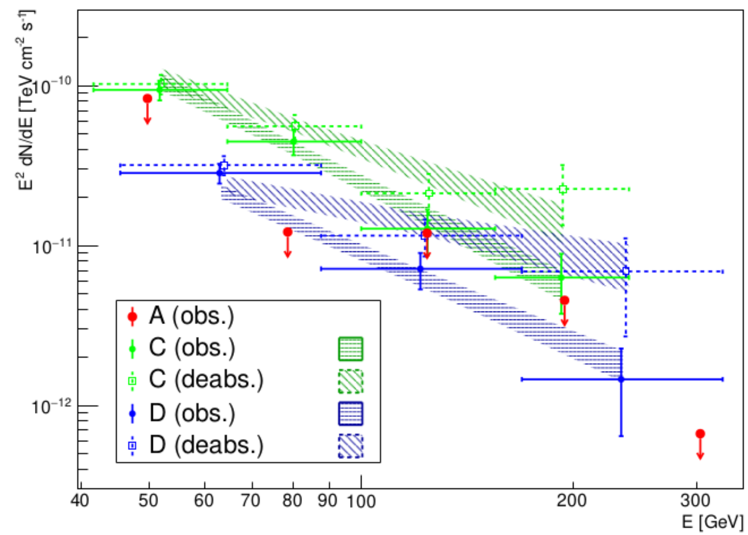
Period	MJD	comment
A	58846.5 - 58853.5	pre-flare
B	58867 - 58868	optical flare
C	58868.3 - 58870.3	VHE flare
D	58873.5 - 58880.5	post-flare

Acciari et al. 2021, A&A, 647, A163

The MAGIC view

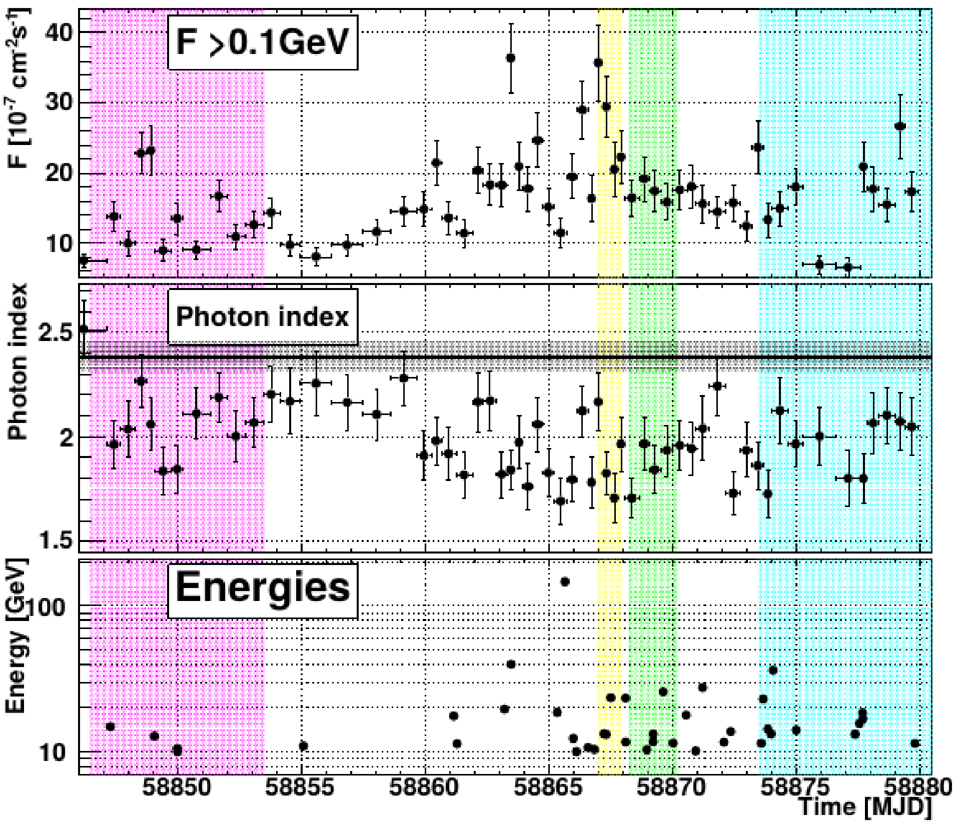


- First detection at VHE obtained on 2020 January 20 (MJD 58868)
- Hints of signal obtained during 2020 January 26 – February 1 (MJD 58874-58880), with a flux half the flare level
- Before the flare, no significant emission is detected
- The spectral indices during (3.57±0.29) and after the flare (2.87±0.36) are consistent within 1.5-σ



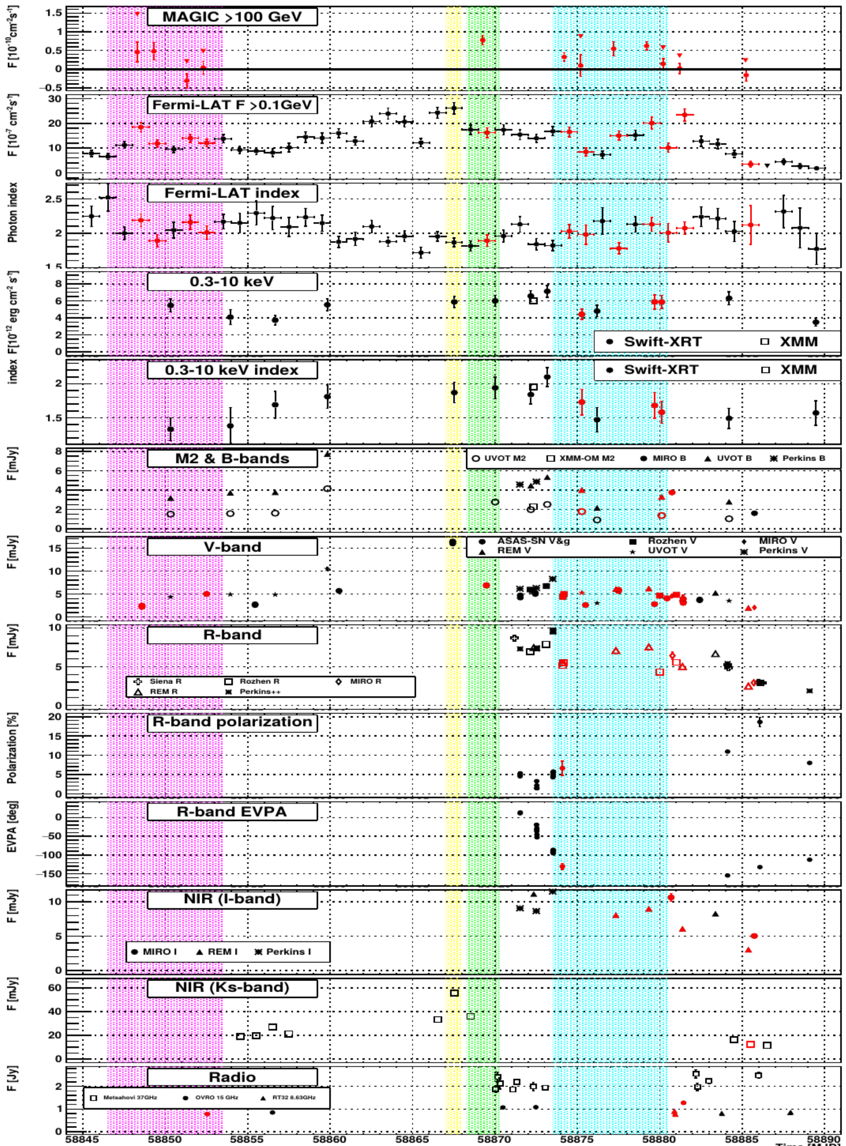
Acciari et al. 2021

The Fermi-LAT view



- Adaptive binning showed variability down to time scales of ~6 hrs
- The flux reached 300 times the 4FGL value
- Evolution of the spectral index
- The highest energy photon observed with an energy of 150 GeV

MWL campaign

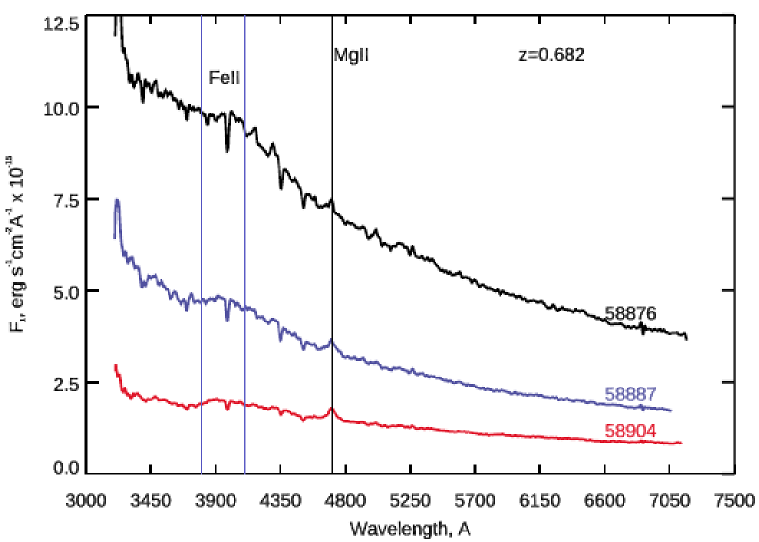


- No strong flux variability, but a harder-when-brighter behaviour in X-rays
- Strong optical flare observed on 2020 January 19 (MJD 58867)
- Optical polarizations showed a dip of the percentage at a few percent level and a rotation of ~150° after the VHE flare
- Moderate variability has been observed in radio bands

Acciari et al. 2021, A&A, 647, A163

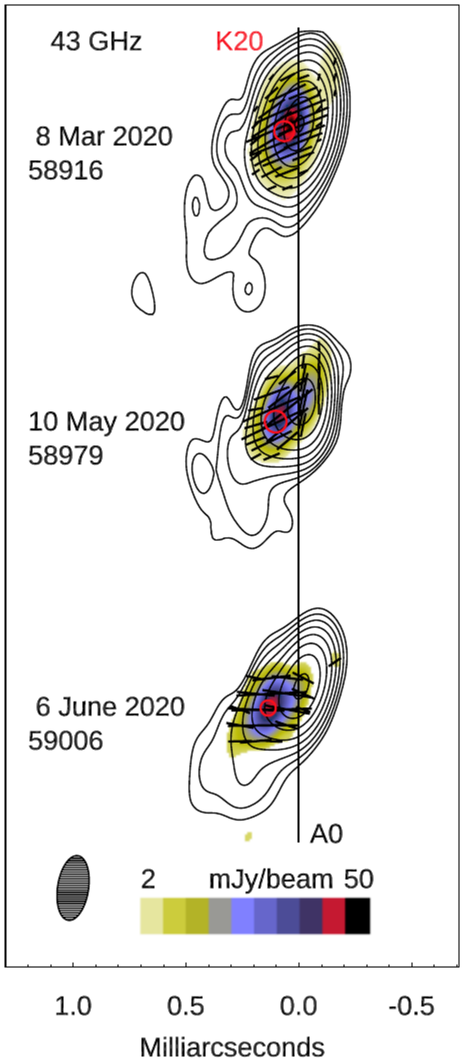
Optical spectroscopy observations

Lowell Discovery Telescope observations on 2020 January 28, February 8 and 25



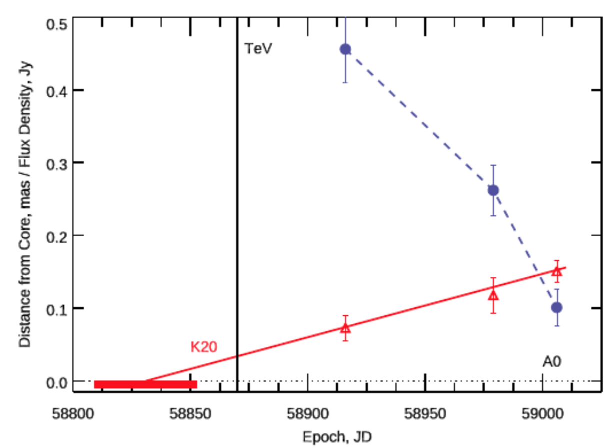
- MgII line: constant flux. Excited by underlying thermal accretion disk continuum
- As the flux evolves EW increases from 2Å (BL Lac-like) to 11Å (FSRQ-like)
- FeII bump: flux correlated with continuum level. Possibly an interaction of non-thermal jet with FeII-emitting cloud
- Estimated accretion disc luminosity of L_{disc} = 2x10^{46} erg s^{-1}

43 GHz VLBA observations

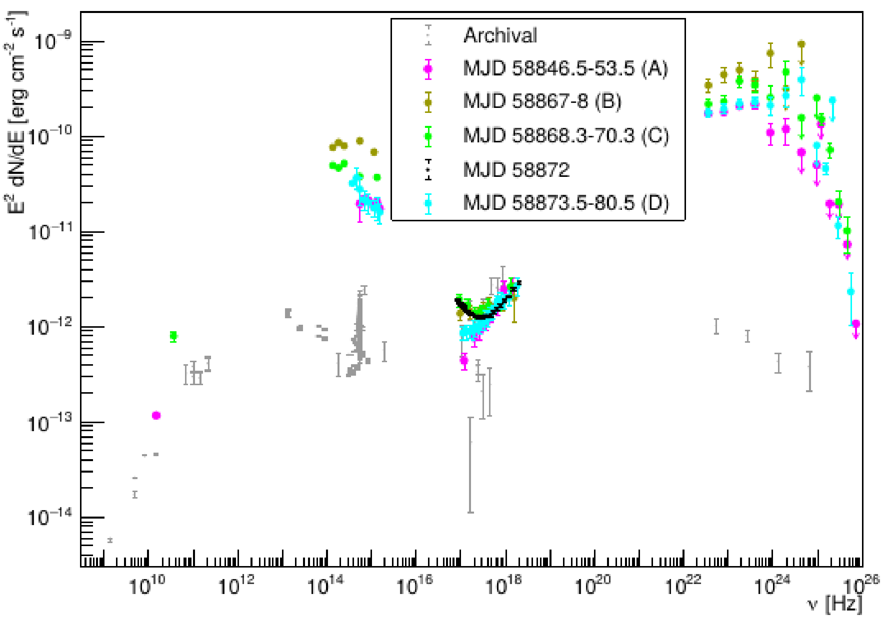


- Follow-up high-resolution radio 43 GHz VLBA observations shown a **new knot (K20)** ejected from the core with Γ = 19±9 and δ = 33±9

- During the time of VHE emission the upstream edge of the knot was passing through the centroid of the VLBA core



SED evolution



- Flux of both SED peaks are **over two orders of magnitude** above the historical measurement

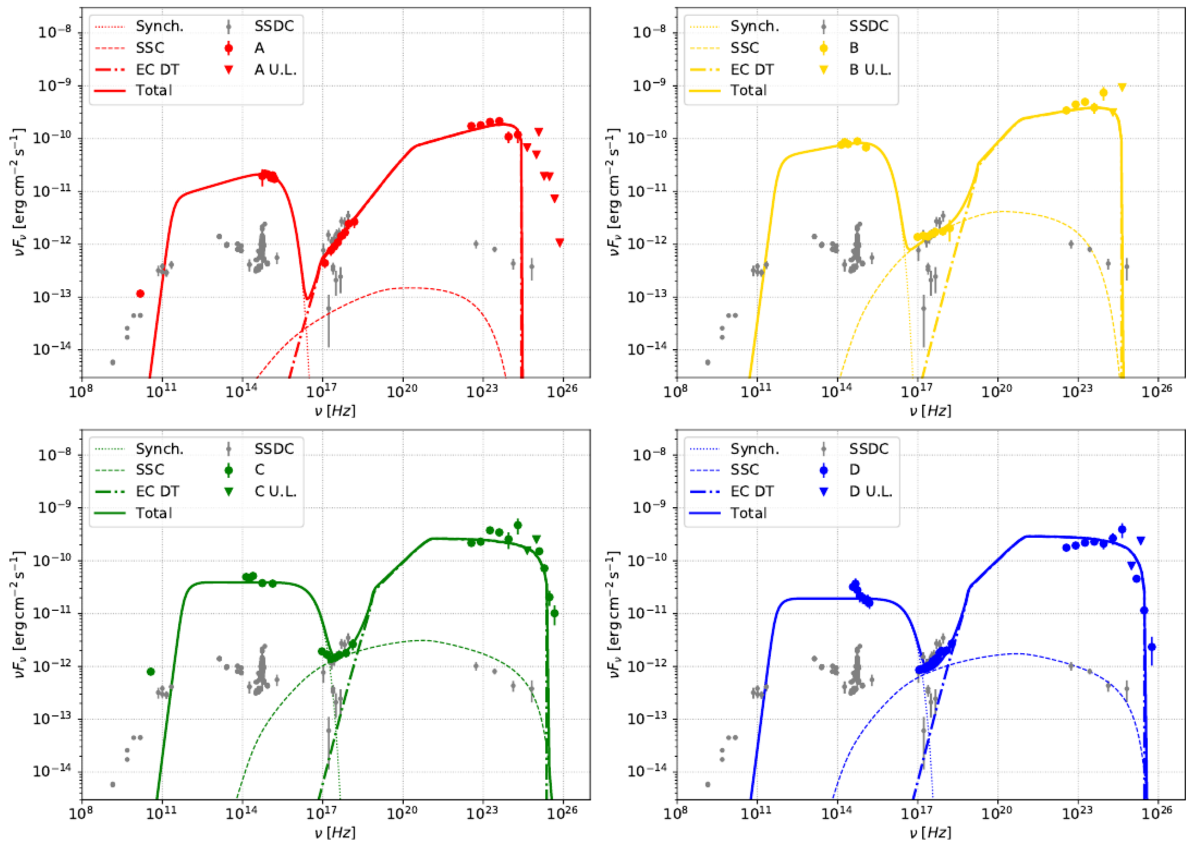
- *Evolution of the shape of the peaks* throughout the campaign – flat optical spectrum during the peak of the flare

- X-ray measurements showed the **transition between synchrotron and IC peak**

Modeling scenario and constraints

- FSRQ ==> likely **External Compton** – radiation fields computed from the estimated accretion disc luminosity
- Large increase of optical flux ==> SSC component
- Size of the emission region r_b ==> limited by ~1 day time scale variability
- Speed of the jet assumed **Γ=δ=40** (roughly inspired by VLBA measurements, which however probe jet at much larger distance)
- VHE γ-rays ==> emission region beyond BLR, assumed the $d \sim \Gamma \, r_b$ – in the **dust torus radiation field**
- Electron energy distribution determined by *balance of the cooling, acceleration and dynamic time scale*
- Modeling performed with `agnpy` (https://agnpy.readthedocs.io) code, each period modeled independently

SED Modeling



Period	δ	r_b [cm]	ξ	B [G]	$U'_e[10^{48}\text{erg}]$	p_1	$\gamma_{\min}$	p_2	γ_{break}	$\gamma_{\max}$	$u'_e[\text{erg cm}^{-3}]$	u'_e/u'_B
A	40	6.16×10^{16}	0.3×10^{-7}	0.70	1.18	1.7	1	2.7	63	6900	1.2×10^{-3}	0.06
B	40	3.70×10^{16}	0.3×10^{-7}	0.95	1.76	1.8	15	2.8	104	8000	8.3×10^{-3}	0.23
C	40	3.08×10^{16}	3.0×10^{-7}	0.83	2.12	2.0	10	3.0	125	23700	17.3×10^{-3}	0.63
D	40	3.08×10^{16}	6.0×10^{-7}	0.55	2.35	2.0	10	3.0	125	27300	19.2×10^{-3}	1.6

Table 6. Parameters used for the modeling: Doppler factor δ ($\Gamma=\delta$ is assumed), co-moving size of the emission region r_b, acceleration parameter ξ, magnetic field B, total energy of electron U'_e, EED: slope before the break: p_1, minimum Lorentz factor $\gamma_{\min}$, slope after the break p_2, the Lorentz factor of the break γ_{break}, maximum Lorentz factor $\gamma_{\max}$, electron energy density u'_e, energy equipartition u'_e/u'_B. Free parameters of the model and derived parameters are put on the left and right side of the double vertical line respectively

Scenario from the modeling

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- The γ-ray emission is explained as **EC emission on DT** radiation field
- X-ray emission (highly variable in shape) explained as a *combination of falling edge of synchrotron, bulk of SSC and raising edge of EC emission*
- Proposed solution is **close to u_e/u_B equipartition** (0.06 – 1.6)
- The different phases of the enhanced state is explained mainly by a combination of *variations* of **compactness of the emitting region**, the **minimal injection energy electrons** and increase of the **acceleration parameters**

Summary

- QSO B1420+326 is a new member of the rare **VHE-emitting FSRQ** family
- The rich MWL campaign allowed us to track and model the evolution of broadband emission
- The ejection of **a new radio knot** and the **rotation of optical EVPA** were detected *close in time to VHE emission* – similar cases were reported also for other VHE-detected FSRQ
- SED at different epochs around the VHE detection explained in **EC(+SSC) scenario on DT photons** with electron energy distribution limited by an interplay of acceleration, dynamic and cooling time scales