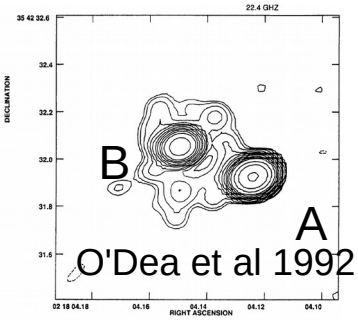
Multiwavelength monitoring of gravitationally lensed blazar QSO B0218+357 between 2016 and 2020

J. Sitarek, V. Fallah Ramazani, A. Lamastra, E. Lindfors, M. Manganaro, K. Nilsson, for the MAGIC Collaboration,
F. Longo, F. de Palma, F. D'Ammando for the Fermi-LAT Collaboration
and A. Barnacka, K. Hada, D. K. Sahu, A. Lähteenmäki

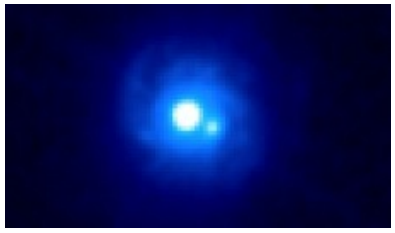
2021.07 ICRC2021

QSO B0218+357

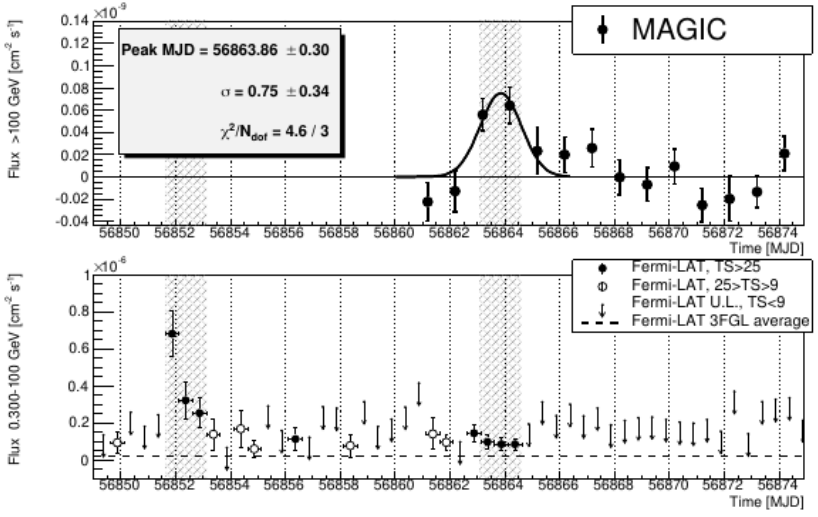
- Distant FSRQ (z=0.94)
- Gravitationally lensed – the emission is observed in two distinct images (visible in radio and optical), separated by ~11 days
- Detected in VHE gamma rays by MAGIC in response to a *Fermi*-LAT flare
- In years 2016-2020 optimized MWL monitoring was organized to allow to observe the same flare in both images



O'Dea et al 1992



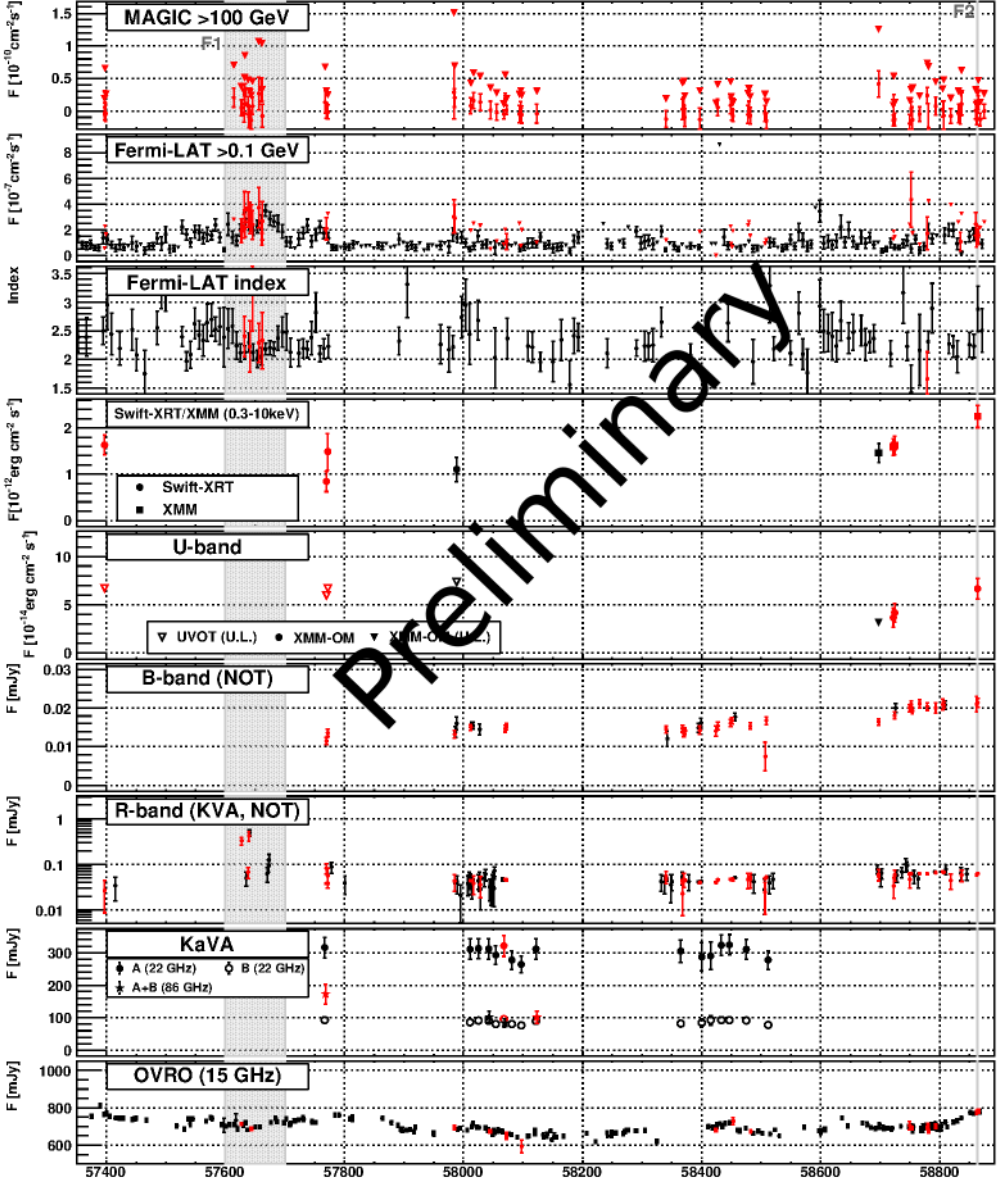
Hubble, NASA/ESA



Ahnen et al. 2016

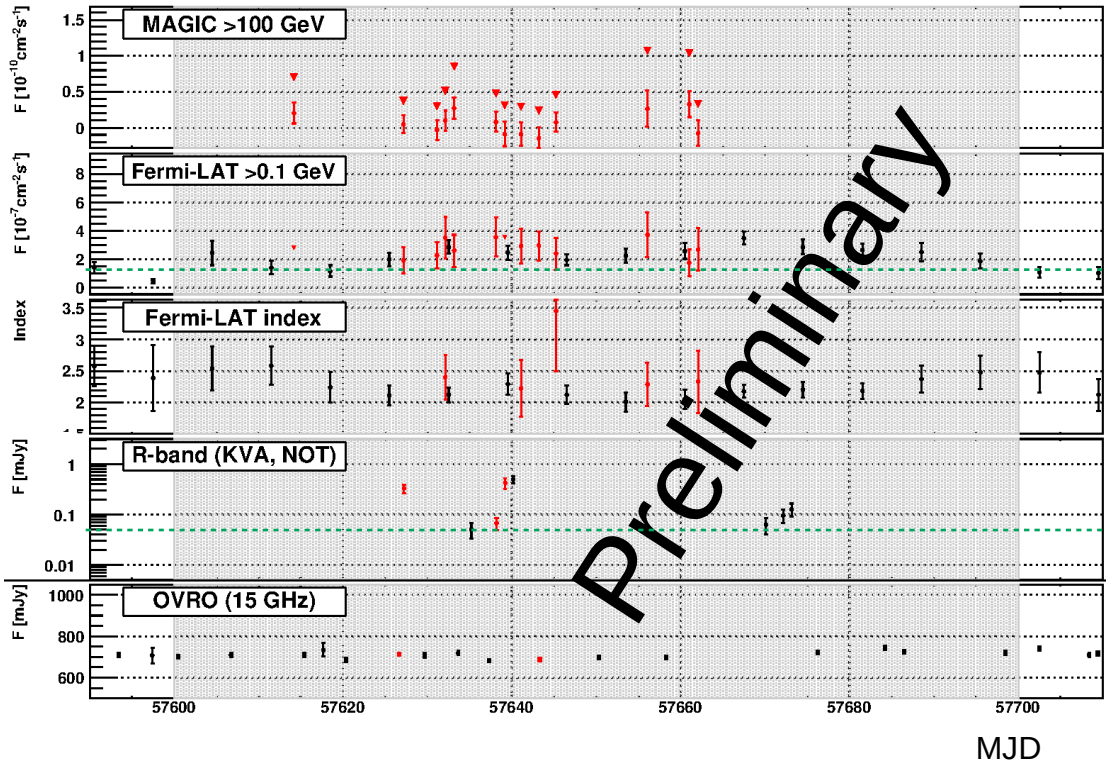
2016-2020 MWL monitoring

- Gamma rays: MAGIC, *Fermi*-LAT
- X-ray (*Swift*-XRT, XMM) – only a few pointings
- Optical: KVA, NOT
- Radio: OVRO 15 GHz
- Radio interferometry: KaVA 22-86 GHz
- **Flares and hints of enhanced emission in the GeV range, optical and X-ray**



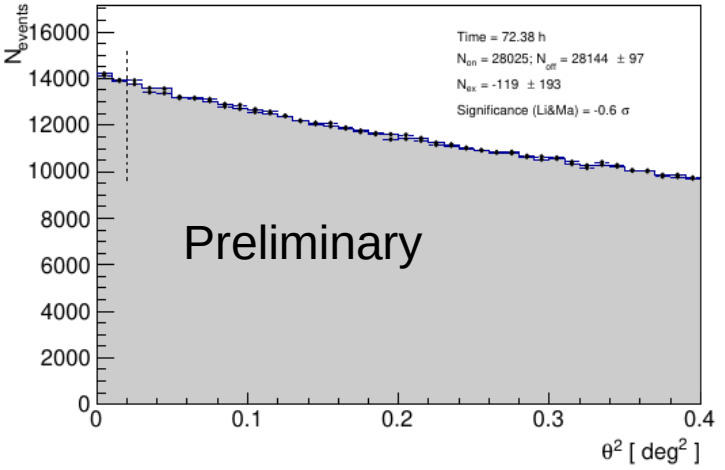
Enhanced GeV and optical state

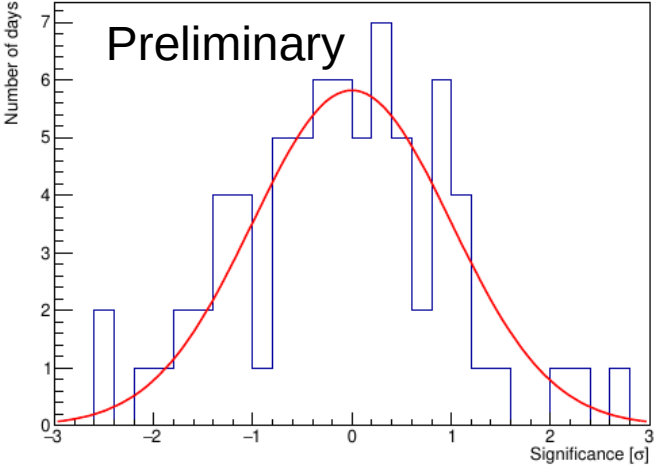
- A few months long high GeV state during which we detected a short increase of optical flux by an order of magnitude
- The distance between the optical peaks is consistent with the one expected from lensing, but sparse sampling does not allow to measure the optical delay



Search for VHE gamma-ray emission

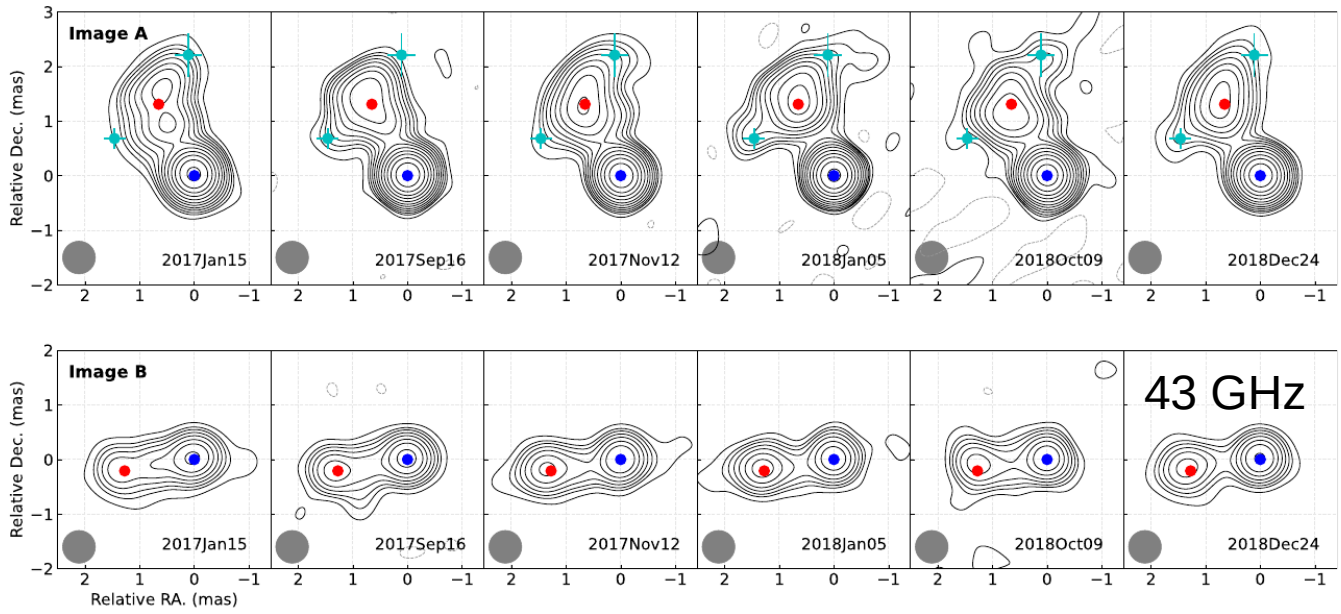
- Deep exposure with the MAGIC telescopes: 72hrs in 73 nights during 2016-2020 monitoring.
- No significant transient emission detected on any nights (including the nights of enhanced GeV, optical or X-ray activity)
- No detection of a low-state VHE gamma-ray emission





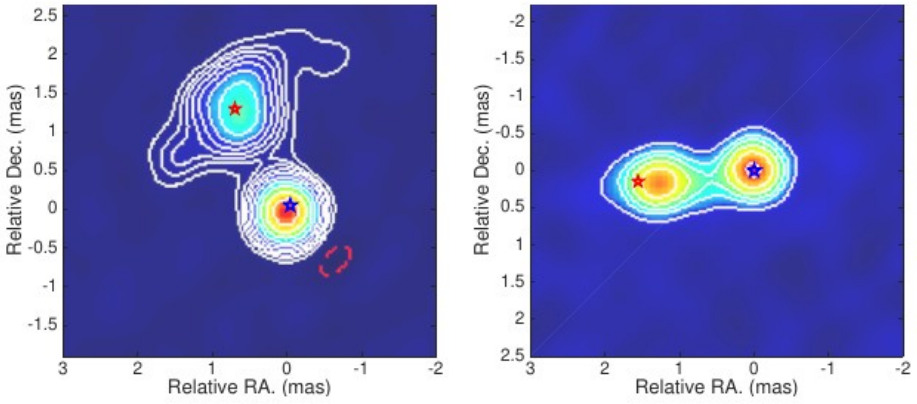
KaVA image of the source

- Clear radio core and jet component seen in both radio images
- Projected distance from the core to the jet: 10 pc
- Sideways wings seen in the brighter (A) image



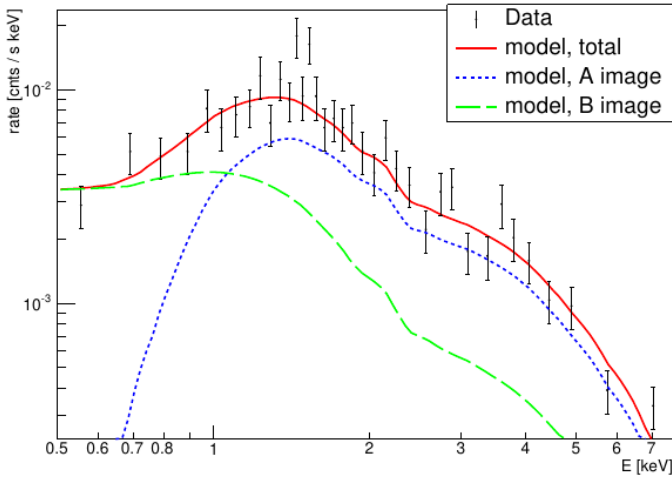
Lens model

- The radio images were used to update the lens model of the source
- The modeled positions of the lens images of the core and the jet agree within 0.034-0.26 mas
- Predicted magnification ratio: 3.81 for the core and 3.67 for the jet

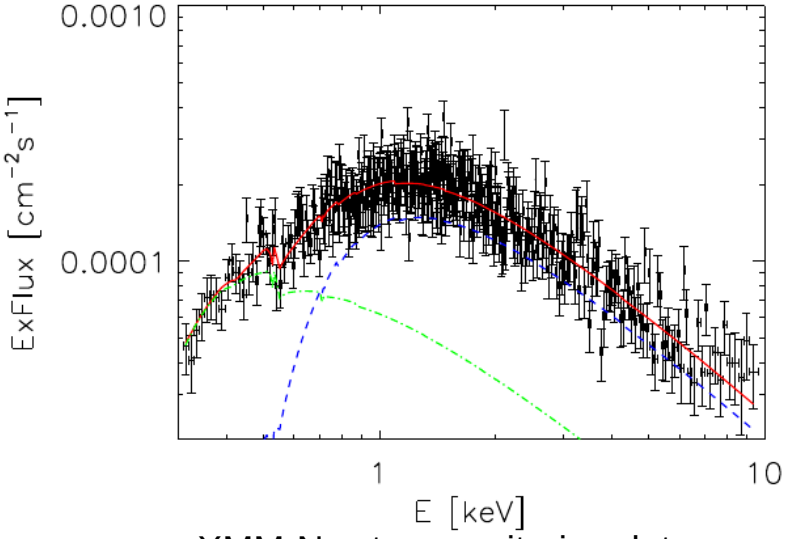


Absorption at the lens

- **High quality X-ray spectrum** of XMM is fitted by a combination of two A and B images of the source using derived magnification ratios and allowing for absorption at A image.
- Obtained column density of $(8.10 +- 0.93) \times 10^{21}$ cm^{-2}
- Previous measurements:
  $(24 +- 5) \times 10^{21}$ cm^{-2} (*Swift*-XRT, Ahnen et al. 2016)
  $(5 – 50) \times 10^{21}$ cm^{-2} (molecular absorption line, Menten & Reid, 1996)



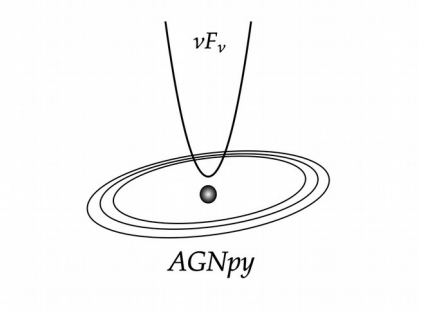
Swift-XRT data of 2014, Ahnen et al 2016



XMM-Newton monitoring data

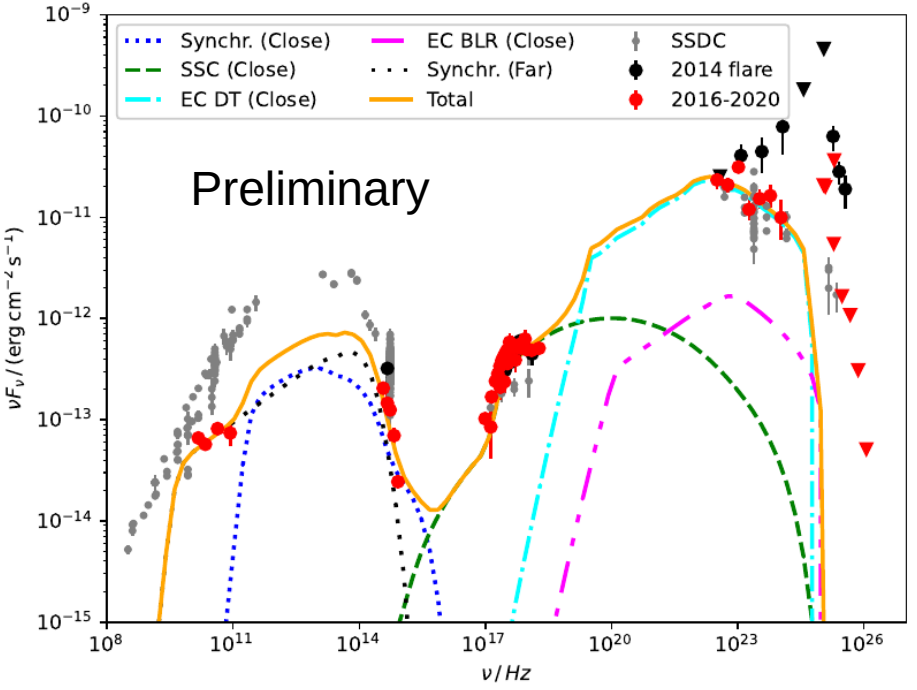
Modeling of the broadband emission

- Need to take into account:
  - Lensing magnification (sum of both images)
  - Absorption of optical-UV and X-ray (only A image)
- Modeling scenario typical for FSRQ: external Compton (on dust torus radiation field) with a possible SSC emission
- Computed with agnpy code https://github.com/cosimoNigro/agnpy



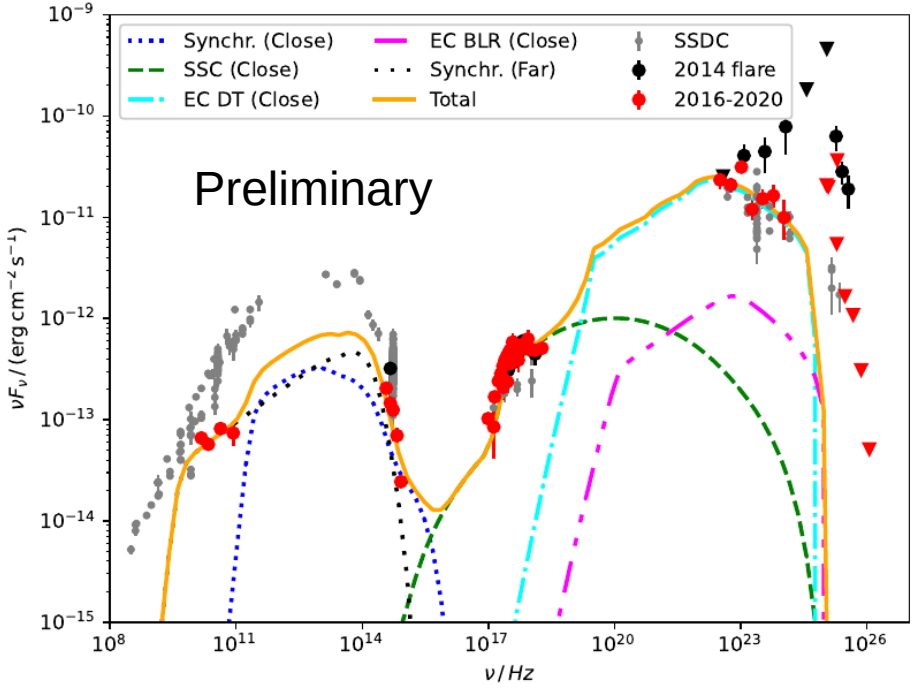
Broadband SED

- Comparing low state with **2014 flare**:
  - Slightly lower optical emission
  - GeV emission slightly lower but much softer
  - VHE gamma-ray emission constrained at the level at least an order of magnitude below the flaring one



Two emission regions

- Low energy bump: mostly synchrotron emission of the “Far” region (connected with the “jet” component seen in radio) with a contribution at optical-UV from the “Close” component
- X-ray emission – explained as SSC of “Close” component
- GeV emission explained as EC on DT photons in “Close” component



Conclusions

- 4 years of MWL monitoring of the only known gravitationally lensed blazar at VHE gamma-ray energies
- Improved lens model and measurement of column density of absorbing material in the lens galaxy
- Broadband low-state emission fitted with a two zone model with GeV emission explained as EC on DT radiation and X-ray emission stemming from SSC process