Multiwavelength Analysis of the TeV-Gamma-Ray Emitting Radio Galaxy NGC 1275 (3C 84)

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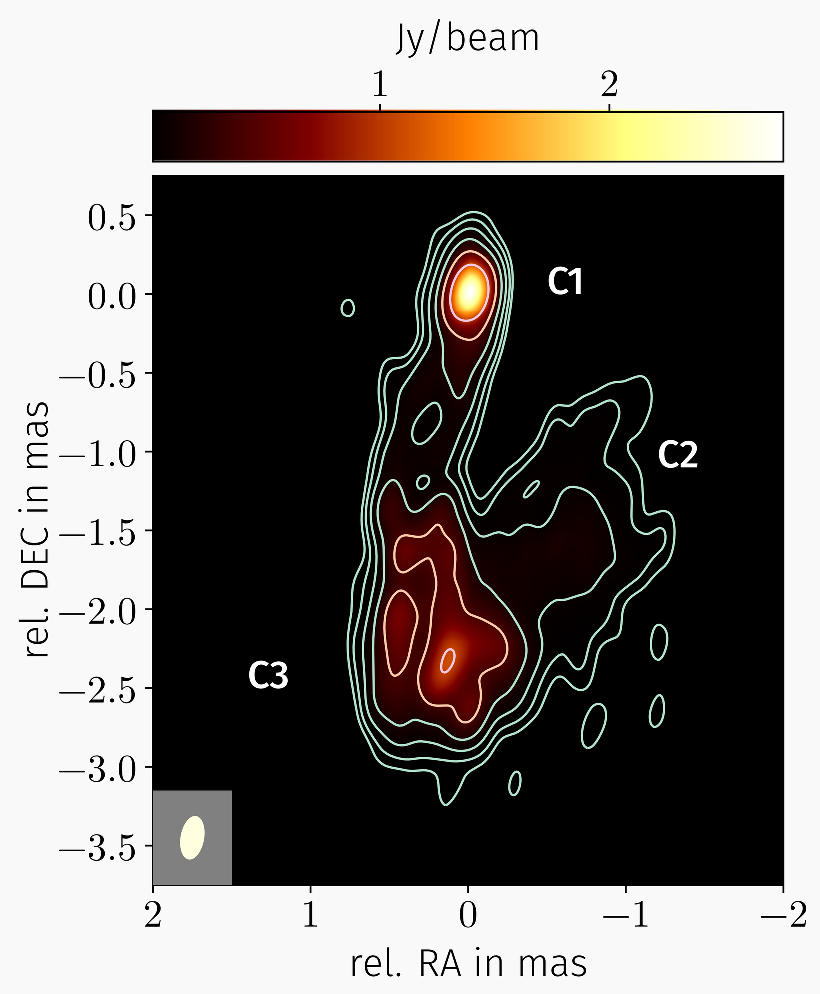
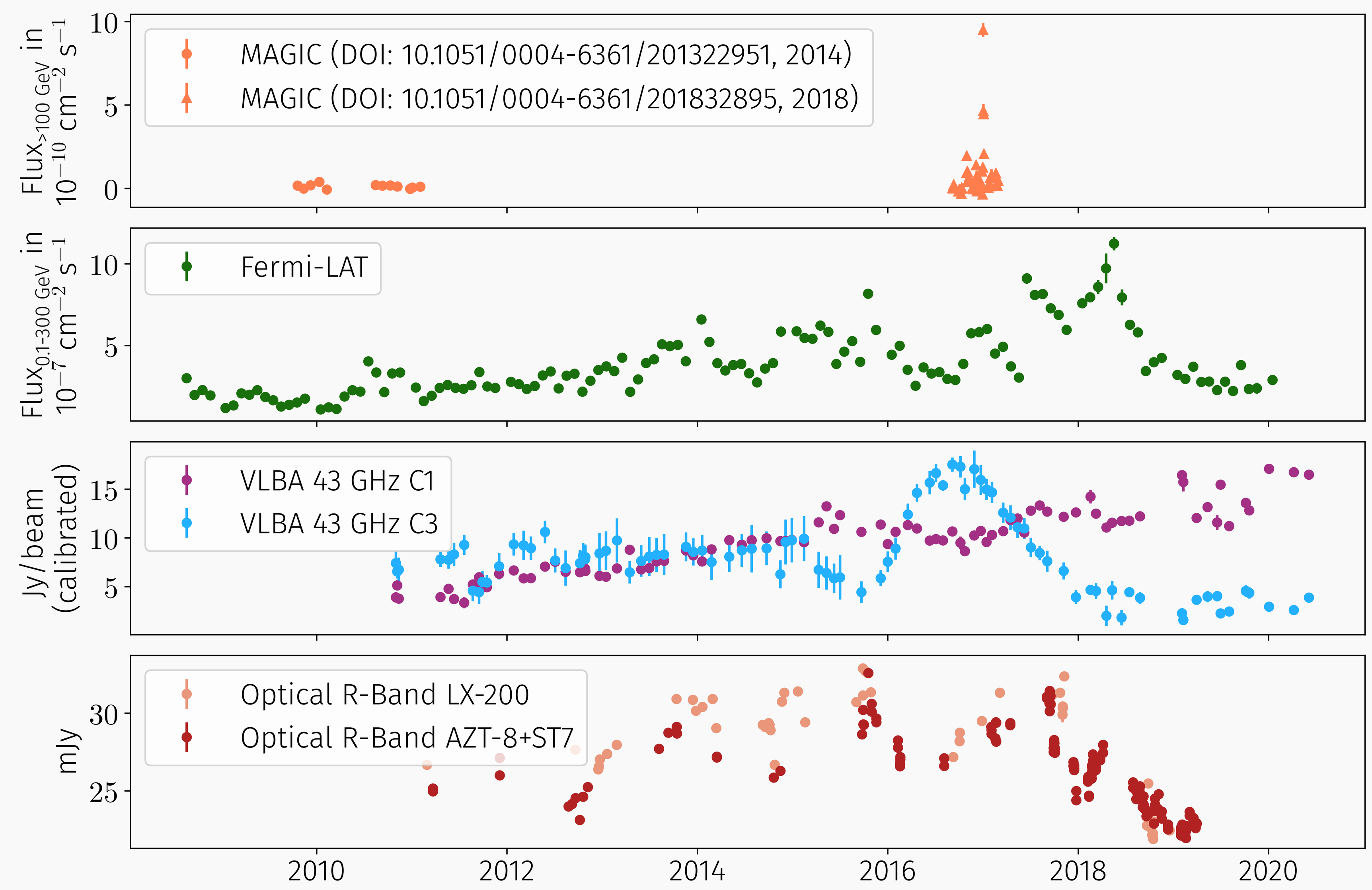
NGC 1275 aka 3C 84



Common Names 3C 84, NGC 1275, 0316+413
Source Type FR I (BL Lac characteristics)
Redshift 0.0176
Position RA: 49.9507 °, DEC: 41.5117 °
Radio VLBA since 1995
Viewing Angle $30°$ to $50°$ (1994) [1]/ $25°$ (2009) [2] / $65°$ (2018) [3]

3C 84 is a well monitored misaligned TeV-radio galaxy and was first detected as radio emitter in the 1960s. In 2008, Fermi-LAT detected gamma-emission as well. There are three identified radio components [4] called C1, C2 and C3. C1 names the contract innermost core of the source, where the central black hole is assumed. C2 is a faint and currently not detectable region south-west from C1. C3 emerged from the core in 2005, moving along the jet and varying in brightness and size. There has been strong indication that 3C 84's jet is precessing [5](see Poster by Rune Dominik).

Multiwavelength Observations



Emission Region Segmentation

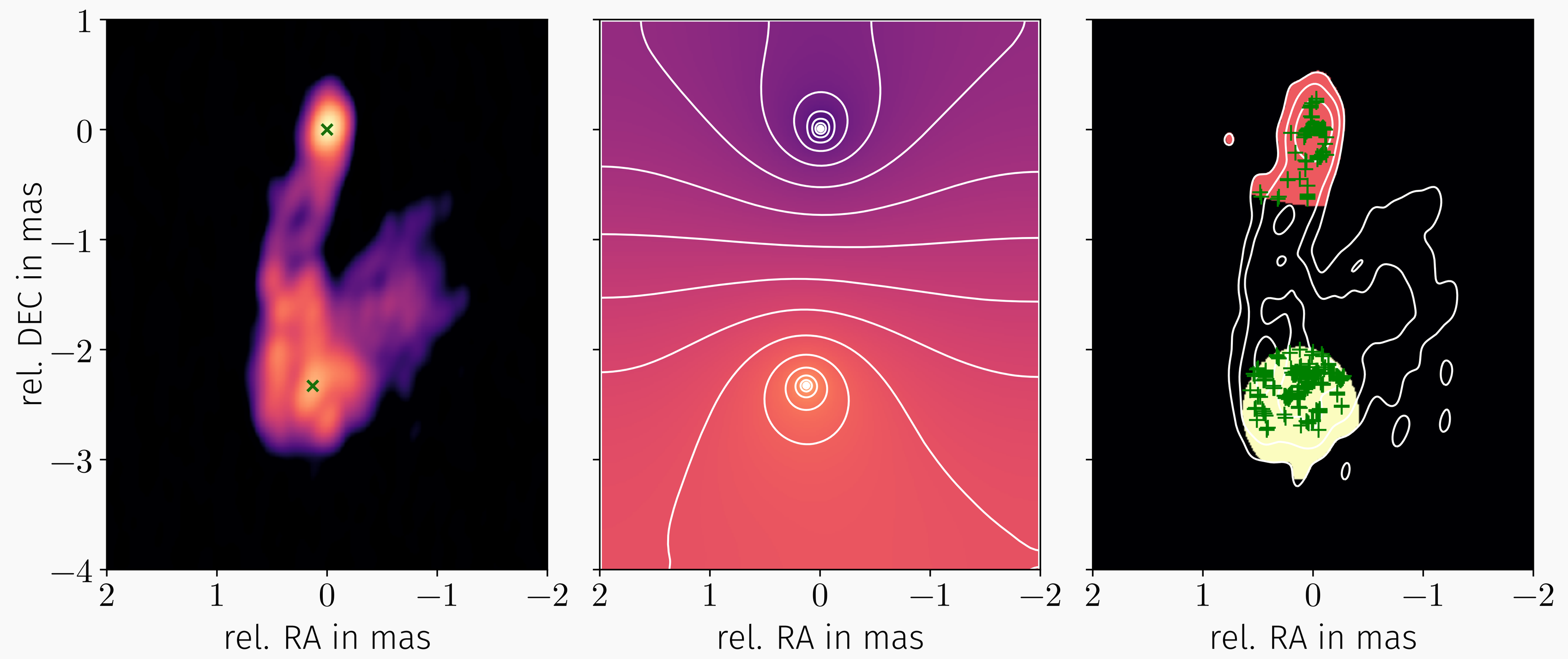


Figure 1: Left: VLBA 43 GHz clean map with marked region seeds (C1 and C3). Center: Random Walker profile for two seeds. Right: Selected region for both components and contained flux components (green cross). The flux components are summed up for the flux value of one component. Based on the adjustment of the Random Walker algorithm, the size of the selected region varies and an error for the component's flux value can be obtained.

Total Flux Calibration

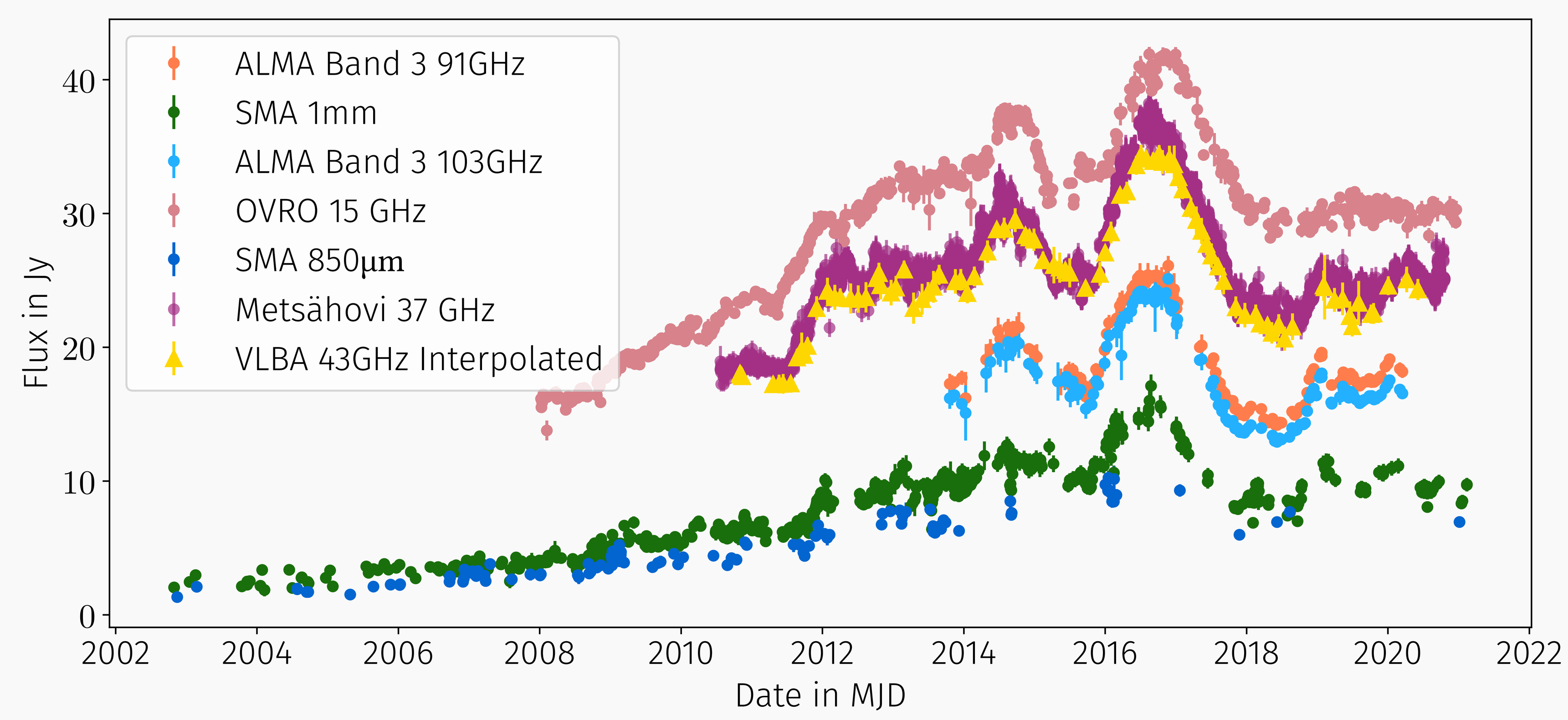


Figure 2: Total flux calibration of the VLBA 43 GHz data with measurements from OVRO, ALMA, SMA and the Metsähovi radio telescope. To correct for flux calibration errors in the original data, the flux at 43 GHz is interpolated from other wavelengths (yellow triangles). The resulting gain is used to rescale the lightcurves of the radio-bright components C1 and C3.

Optical Depth of the Broad Line Region: Origin of γ-rays

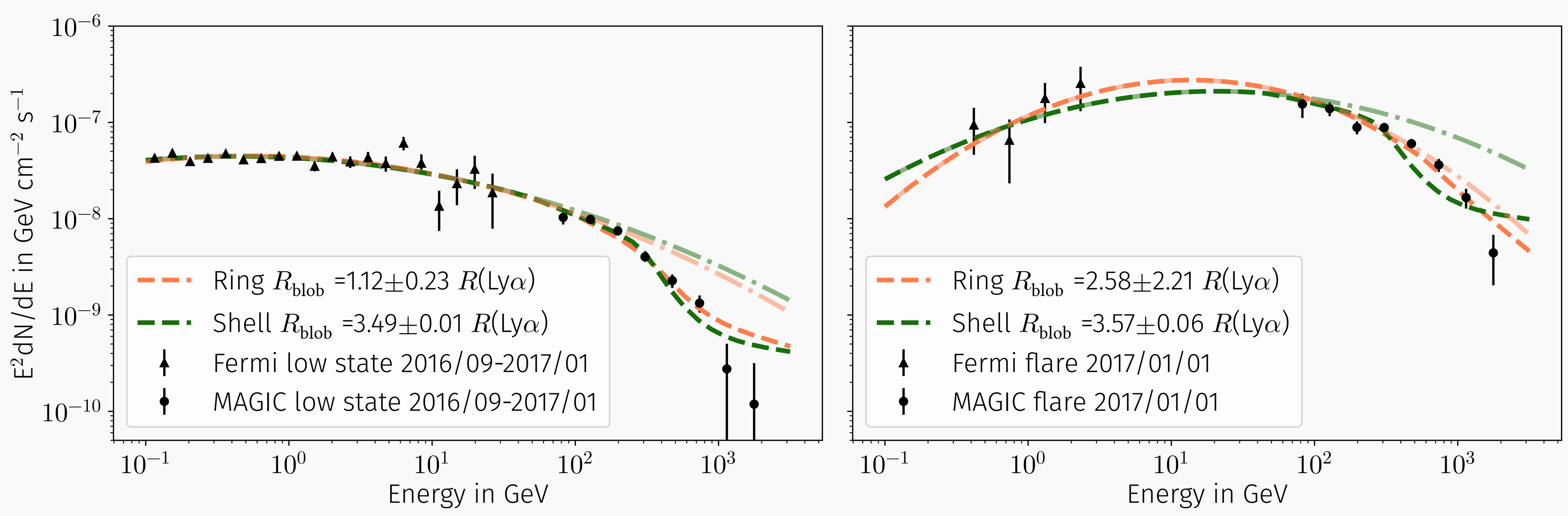
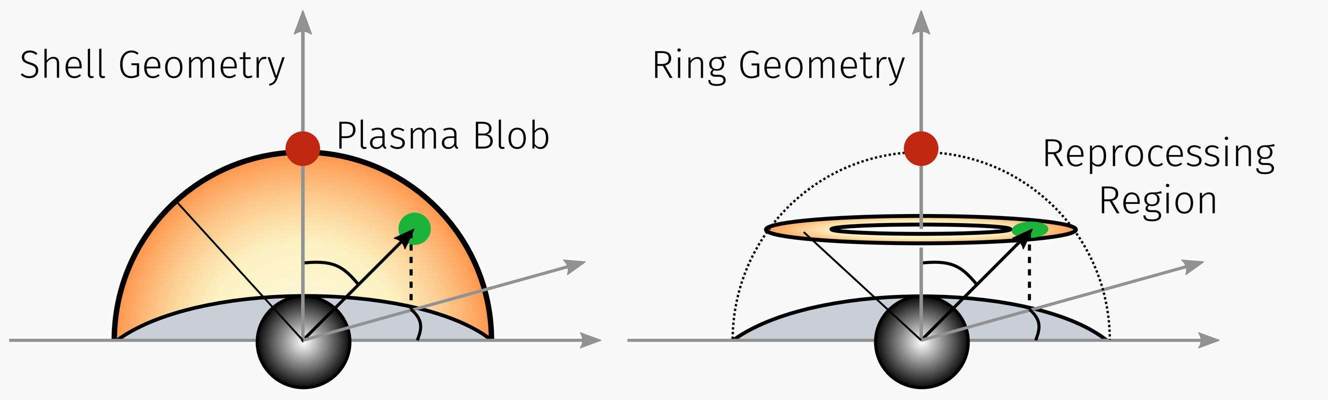


Figure 3: Combined flux points from Fermi-LAT and MAGIC with log-parabola fit for the low and the flaring state at 2017-01-01. Both datasets are fitted by modelling the BLR with a ring and a shell geometry. The dot-dashed lines represent the log-parabola model without photo-absorption ($\tau = 0$).

The optical depth of the broad line region is used to constrain the distance between the origin of the γ-ray emission and the black hole R_{blob}. The SED is fitted with a log-parabola distribution, which is modified with an absorption term:

$$e^{-\tau(E, R_{\text{blob}}, L(H\beta), R(H\beta))} .$$

For the calculations of τ, we follow the calculations for photon absorption in the BLR by Finke [6]. Best fit using shell and ring geometry for both states calculates the minimal distance to be greater than the Lyα radius. Therefore, we assume the gamma-ray emission region to be outside the BLR and not close to the central black hole. Only in case of the flaring state modelled with a ring geometry, the result is not significant. For further reading, see [7].



References

[1] R. Walker, J. Romney, and J. Benson. Detection of a VLBI counterjet in NGC 1275: A possible probe of the parsec-scale accretion region. In: The Astrophysical Journal 430 (1994), pp. L45–L48. [2] A. A. Abdo et al. Fermi discovery of gamma-ray emission from NGC 1275. In: The Astrophysical Journal 699.1 (2009), p. 31. [3] S. Ansoldi et al. Gamma-ray flaring activity of NGC 1275 in 2016-2017 measured by MAGIC. In: Astronomy and Astrophysics 617 (2018), A91. [4] H. Nagai et al. VLBI and single-dish monitoring of 3C 84 for the period 2009–2011. In: Monthly Notices of the Royal Astronomical Society: Letters 423.1 (2012). [5] R. M. Dominik et al. 3C 84: a possibly precessing jet in 43-GHz observations. In: Monthly Notices of the Royal Astronomical Society 503.4 (2021), pp. 5448–5454. [6] J. D. Finke. External compton scattering in blazar jets and the location of the gamma-ray emitting region. In: The Astrophysical Journal 830.2 (2016). [7] L. Linhoff et al. Excluding possible sites of high-energy emission in 3C 84. In: Monthly Notices of the Royal Astronomical Society 500.4 (2021), pp. 4671–4677. [8] J. L. Richards et al. Blazars in the FERMI Era: The OVRO 40 m telescope monitoring program. In: The Astrophysical Journal Supplement Series 194.2 (2011), p. 29.

Acknowledgements

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