

Variable structures in M87* from space, time and frequency resolved interferometry

Philipp Arras⁽¹⁾⁽²⁾, Philipp Frank⁽¹⁾⁽³⁾, Jakob Knollmüller⁽¹⁾⁽²⁾, Reimar Leike⁽¹⁾, Martin Reinecke⁽¹⁾,
Torsten A. Enßlin⁽¹⁾⁽³⁾

(1) Max-Planck Institut für Astrophysik, Karl-Schwarzschild-Str. 1, 85748 Garching, Germany

(2) Technische Universität München (TUM), Boltzmannstr. 3, 85748 Garching, Germany

(3) Ludwig-Maximilians-Universität München (LMU), Geschwister-Scholl-Platz 1, 80539 München, Germany

Observing the dynamics of compact astrophysical objects provides insights into their inner workings, thereby probing physics under extreme conditions. The immediate vicinity of an active supermassive black hole with its event horizon, photon ring, accretion disk, and relativistic jets is a perfect place to study general relativity and magneto-hydrodynamics. The observations of M87* with *Very Long Baseline Interferometry* (VLBI) by the *Event Horizon Telescope* (EHT, [1]) allows to investigate its dynamical processes on time scales of days. Compared to regular radio interferometers, VLBI networks typically have fewer antennas and low signal to noise ratios (SNRs). Furthermore, the source is variable, prohibiting integration over time to improve SNR. We discuss an imaging algorithm that copes with the data scarcity and temporal evolution, while providing uncertainty quantification [2]. This algorithm views the imaging task as a Bayesian inference problem of a time-varying brightness, exploits the correlation structure in time, and reconstructs a $2 + 1 + 1$ dimensional time-variable and spectrally resolved image at once. This method is applied to the EHT observation of M87* [3] and furthermore validated on synthetic data. The time- and frequency-resolved reconstruction of M87* confirms variable structures on the emission ring. The reconstruction indicates extended and time-variable emission structures outside the ring itself. The sky brightness for each day of the observation together with the absolute and relative differences between adjacent days is displayed in Figure 1. We report mild temporal brightness changes of up to 6% per day [2], in particular within the western and southern parts of the ring, validating the observations made by [4].

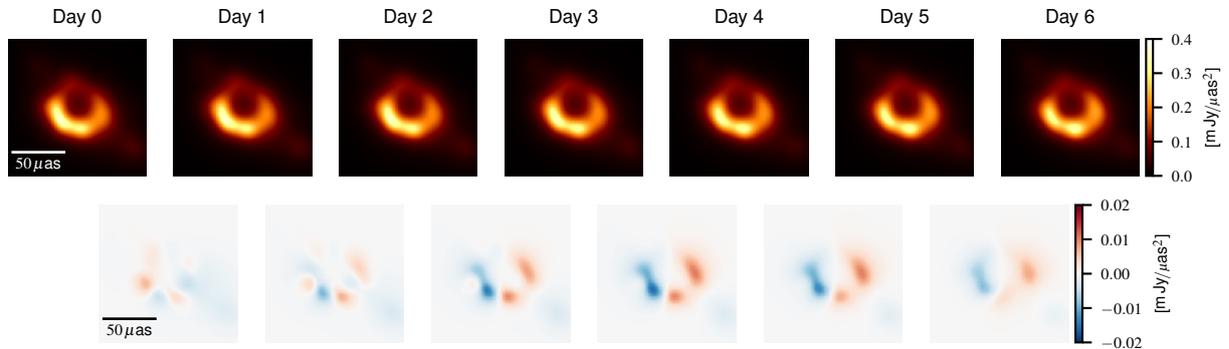


Figure 1. Temporal evolution of the mean brightness distribution. The first row shows time frames of the image cube, one for each day. The second row visualises the brightness for day $N + 1$ minus day N . Red and blue visualises increasing and decreasing brightness over time, respectively (see also [2]).

References

- [1] Event Horizon Telescope Collaboration *et al.*, “First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole,” *Astrophys. J. Lett.*, vol. 875, no. 1, p. L1, Apr. 2019.
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- [4] Event Horizon Telescope Collaboration *et al.*, “First M87 Event Horizon Telescope Results. IV. Imaging the Central Supermassive Black Hole,” *Astrophys. J. Lett.*, vol. 875, no. 1, p. L4, Apr. 2019.