Decelerating jets from black hole X-ray binaries

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THE ROYAL SOCIETY

Credits: ICRAR

Discrete ejecta from BH XRBs

- Bipolar blobs of plasma moving away from the core at **relativistic speeds**

- Ejected during the outburst, at the hard-to-soft state transition (Fender, Belloni, Gallo 2004)

- Only resolved in the radio band in a **dozen of sources in 25+ years**

- Still many open problems: jet **powering mechanism**, **energetics,** launching sequence, **composition**

Mirabel & Rodriguez (1994)

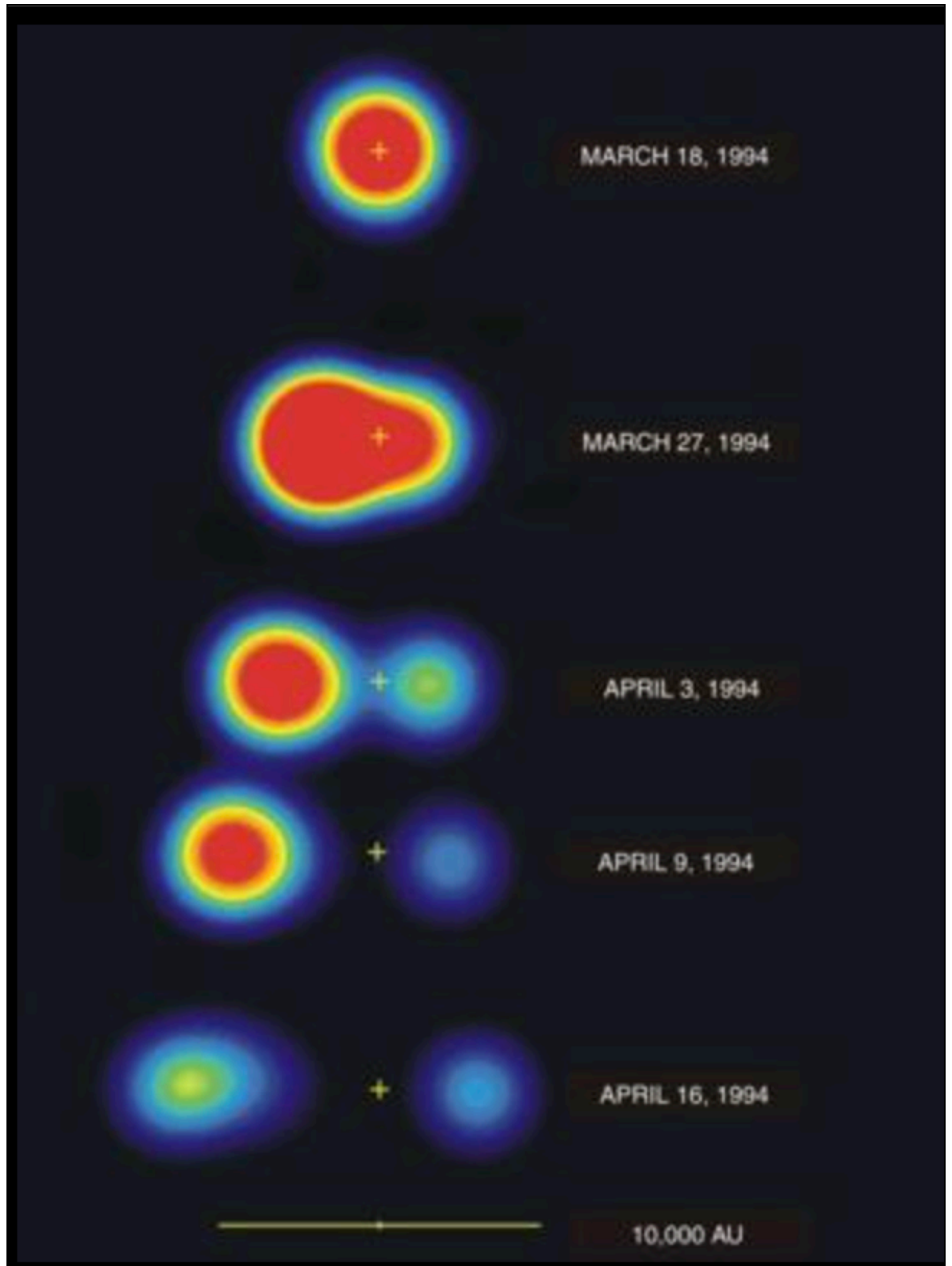
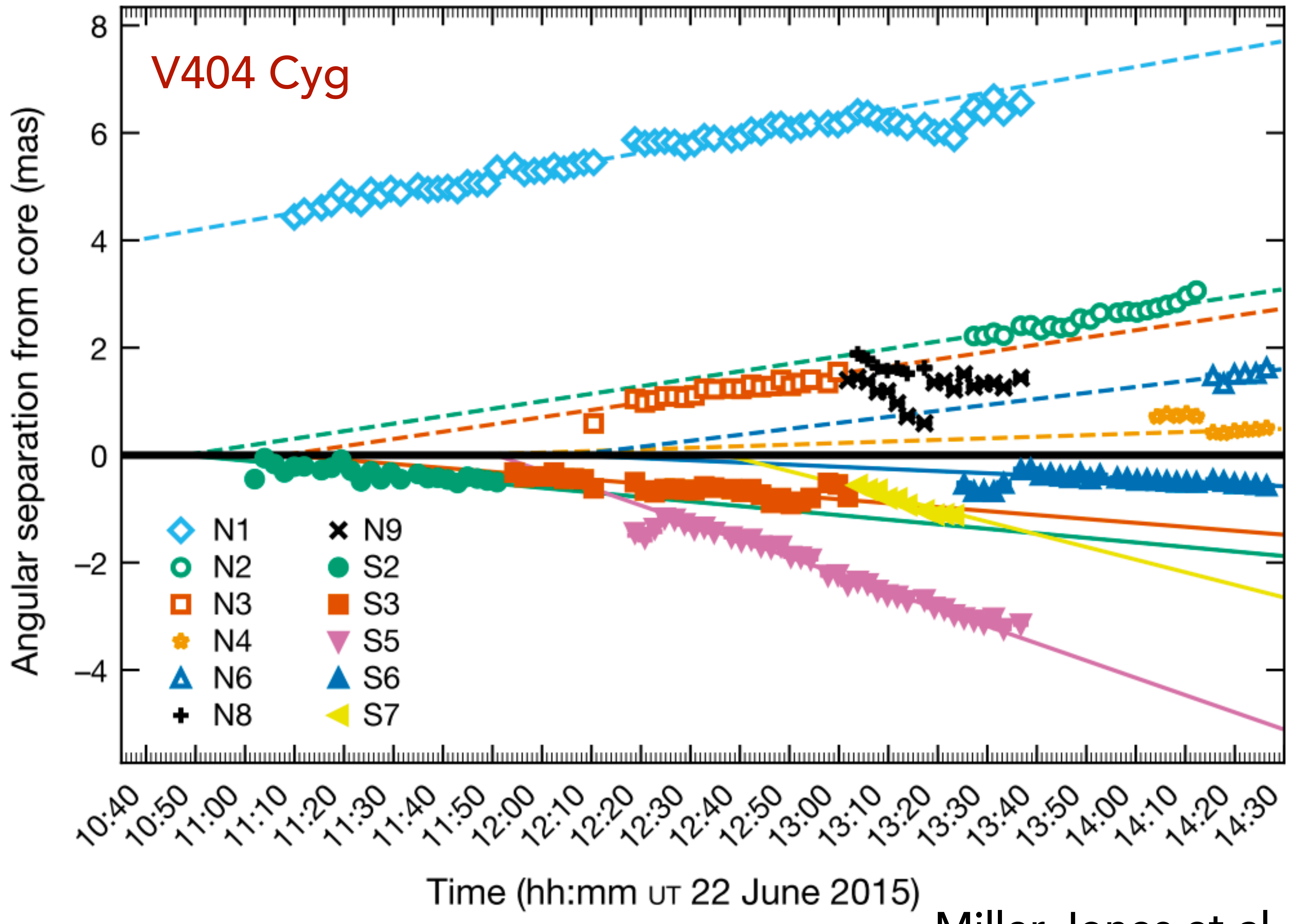


Photo: Image courtesy of NRAO/AUI

Jet kinematics

First phase of **ballistic** motion, often apparently **superluminal** (with $\Gamma \gtrsim 2$)



Miller-Jones et al. (2019)

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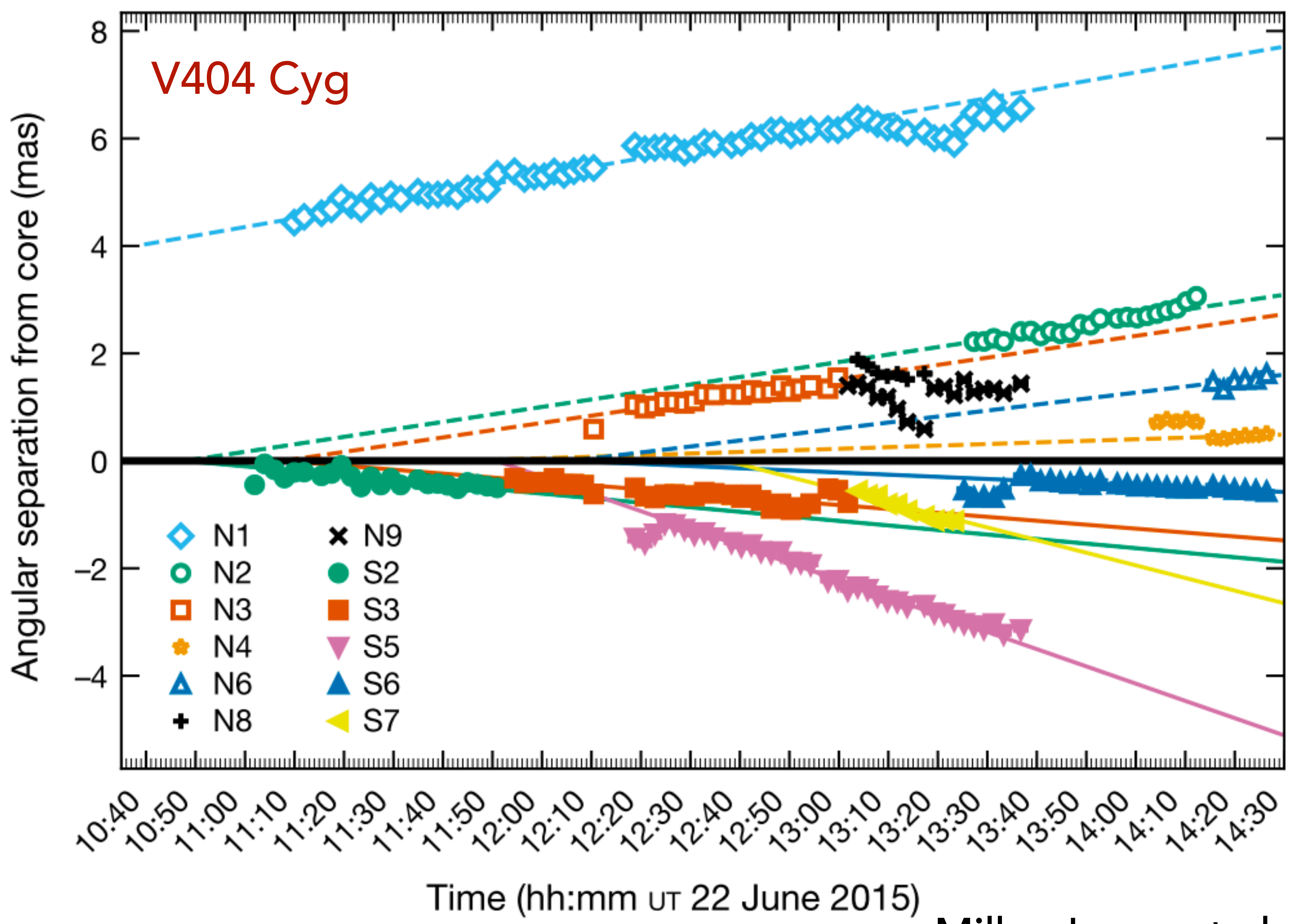
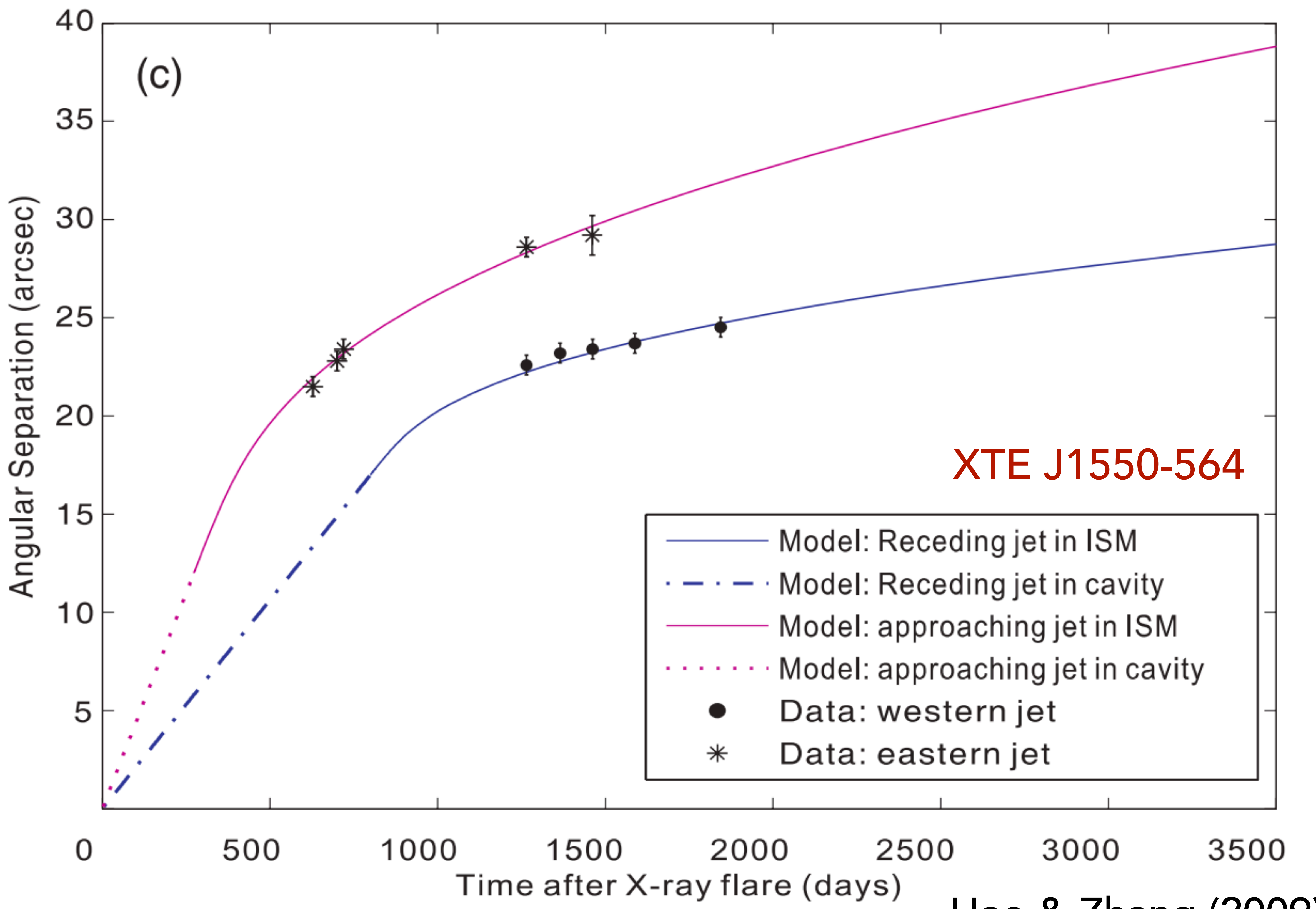


Miller-Jones et al. (2019)

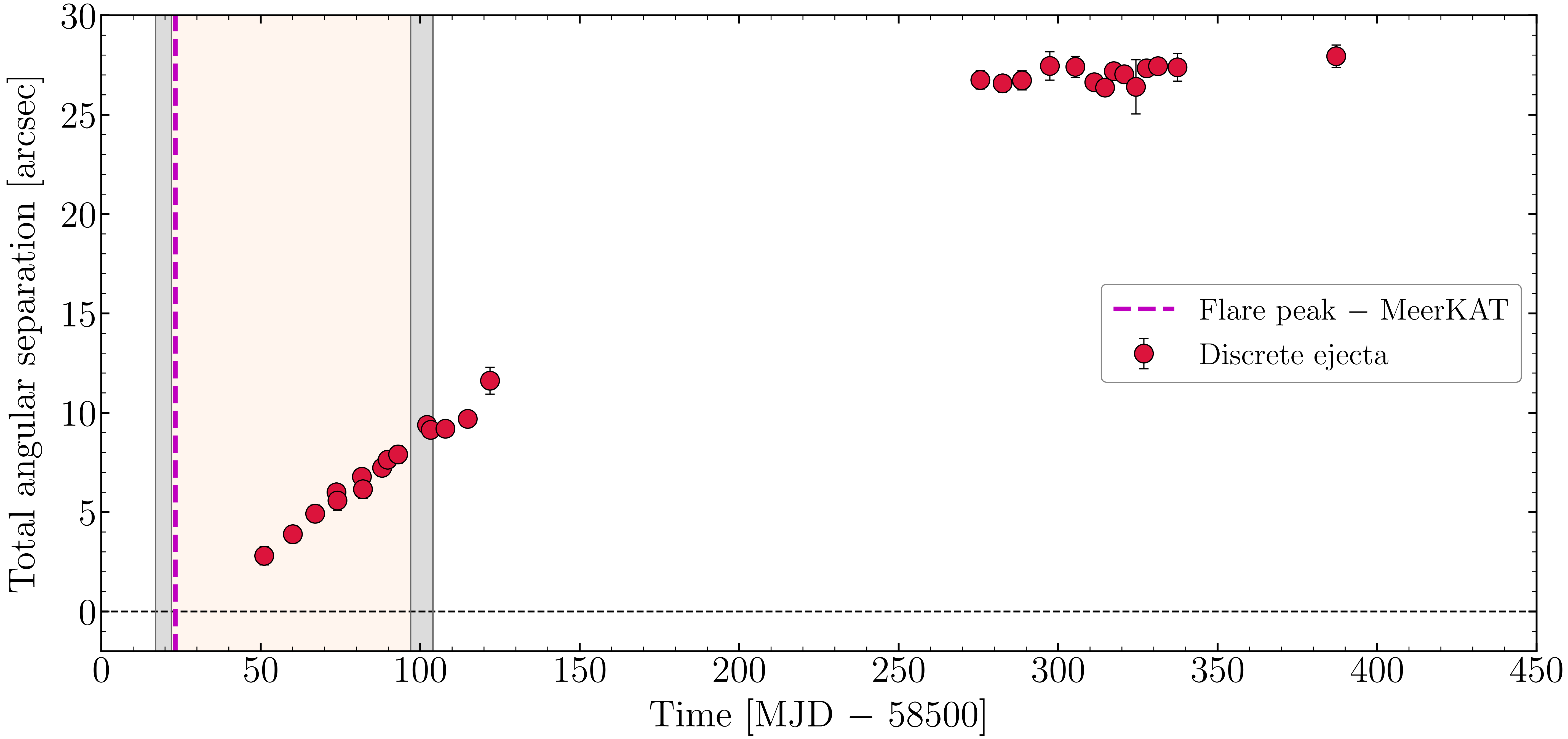
Evidences for late-time **deceleration** of the jets due to the **interaction with the ISM**



Hao & Zhang (2009)

The case of MAXI J1348-630

MeerKAT and ATCA observations
Carotenuto et al. (2021a)



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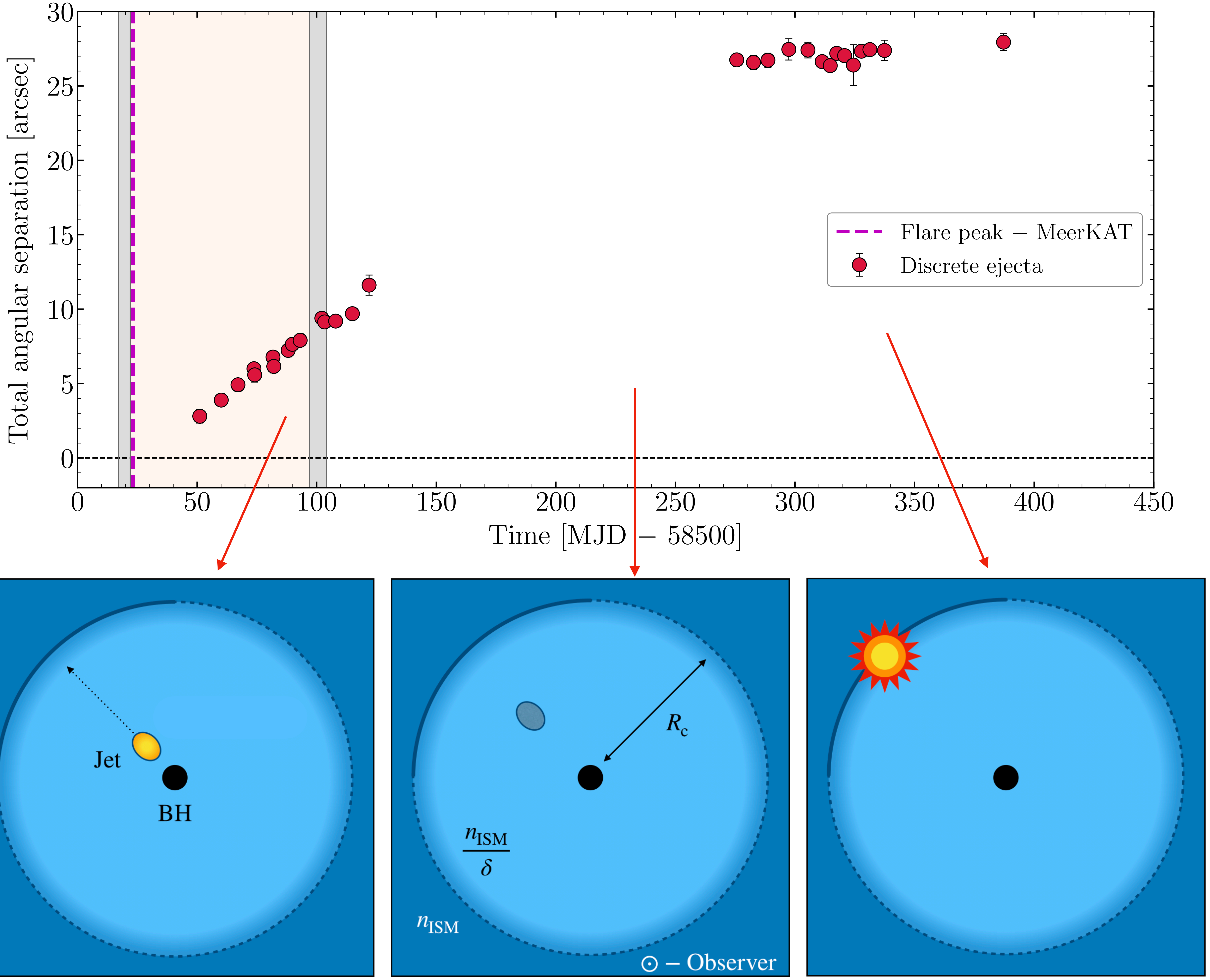

Carotenuto, Tetarenko, Corbel (2022)

The external shock model

- **Jet dynamical model** based on **plasmon adiabatic expansion** (Wang et al. 2003)

- Kinetic energy is transferred to the swept up material via **external shocks**, in analogy with GRB afterglows:

- Depends on many parameters of the jet and of the surrounding environment: $\Gamma_0, E_0, \theta, n_{\rm ISM}, \phi, t_{ej}$

- **Cavity with density:** $n = \frac{n_{\rm ISM}}{\delta}$

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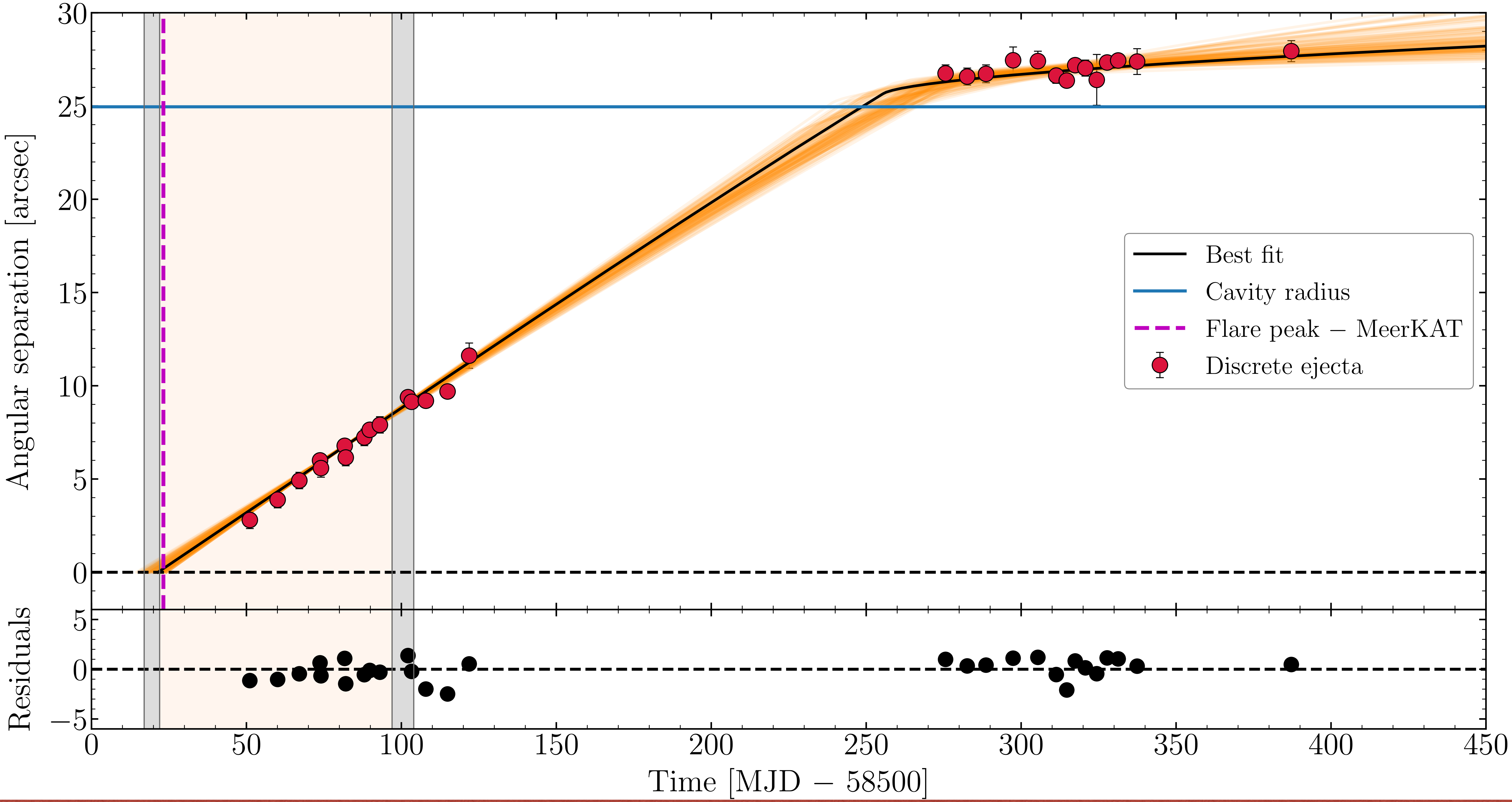
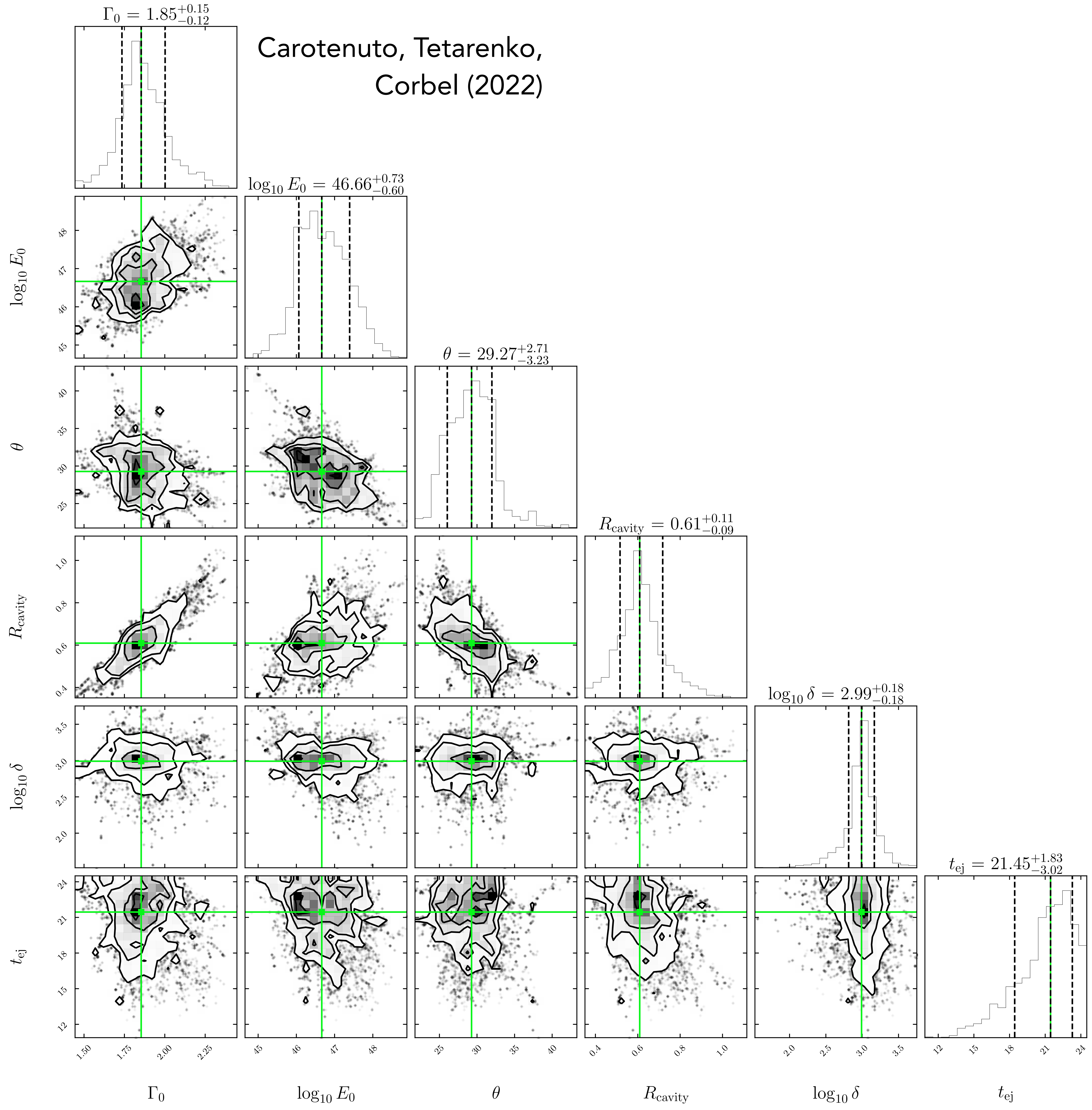


Carotenuto, Tetarenko, Corbel (2022)

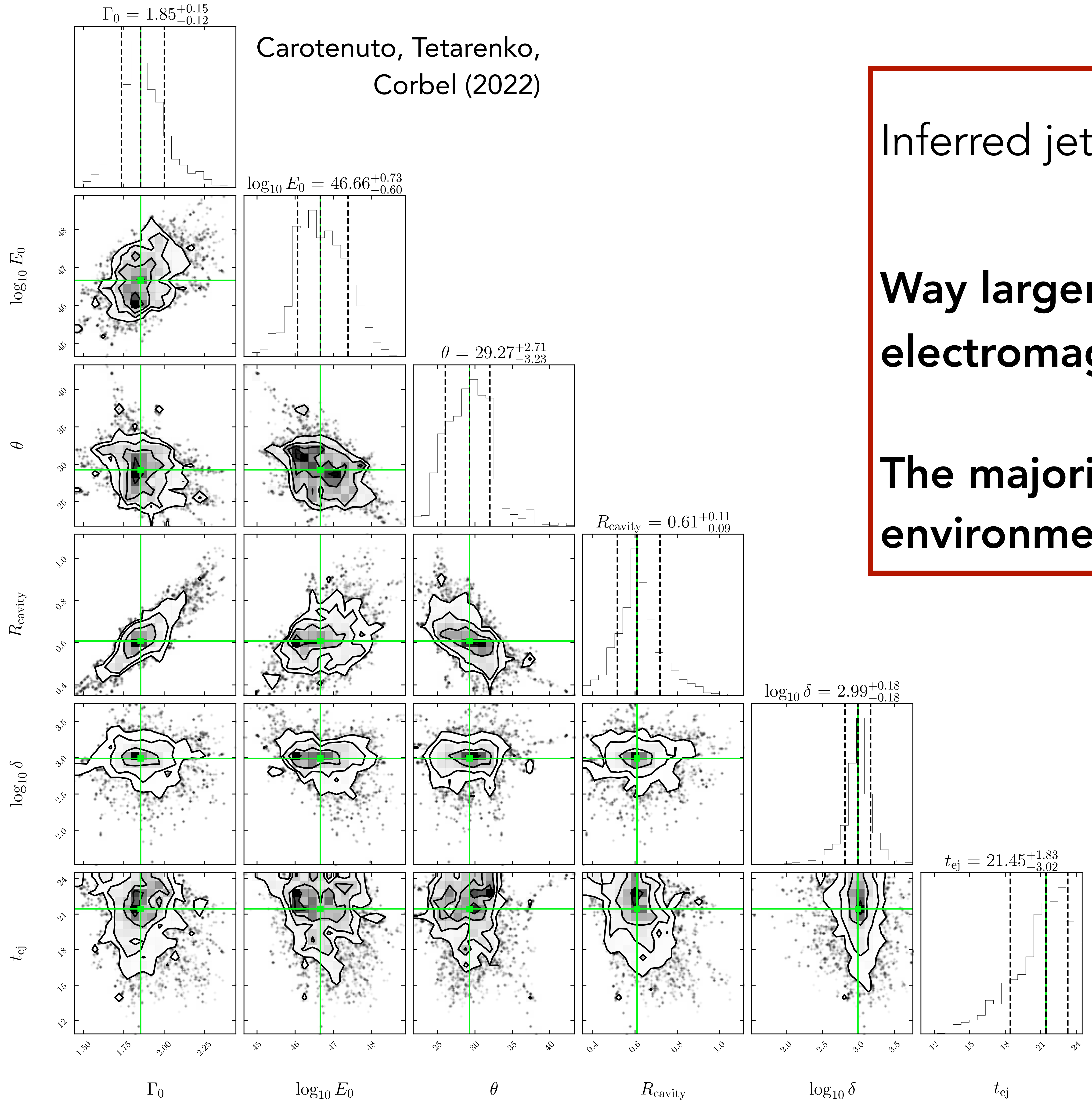
Jet physical parameters



Carotenuto, Tetarenko, Corbel (2022)

- Ejection time constrained with ~2 days precision
- $\Gamma_0 = 1.85^{+0.15}_{-0.12}$ - a mildly relativistic ejecta
- $\theta\ [^o] = 29.3^{+2.7}_{-3.2}$ - Consistent with results from X-rays (Anczarski et al. 2020, Jia et al. 2022)
- $R_{\rm cavity} = 0.61^{+0.11}_{-0.09}$ pc
- $n \simeq 10^{-3}$ cm^{-3} inside the cavity

Jet physical parameters



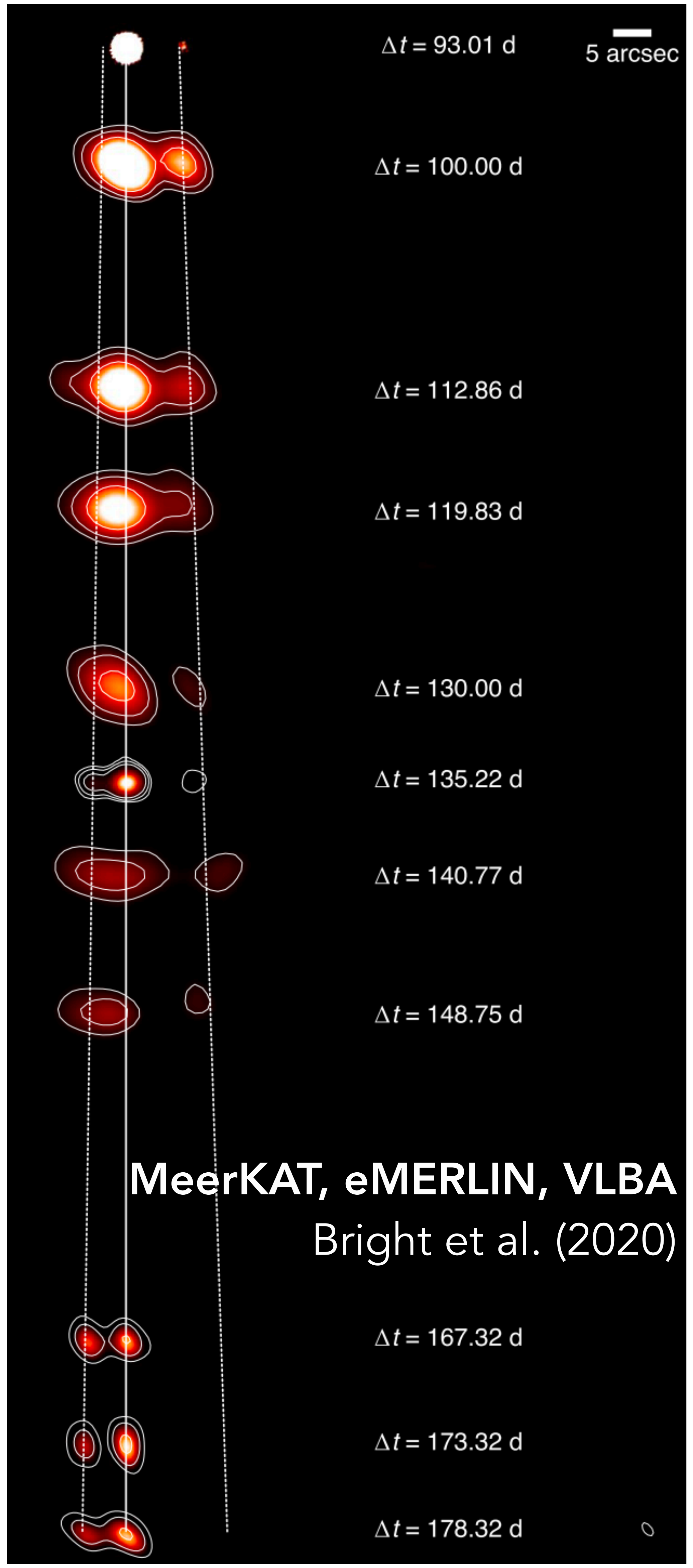
Carotenuto, Tetarenko, Corbel (2022)

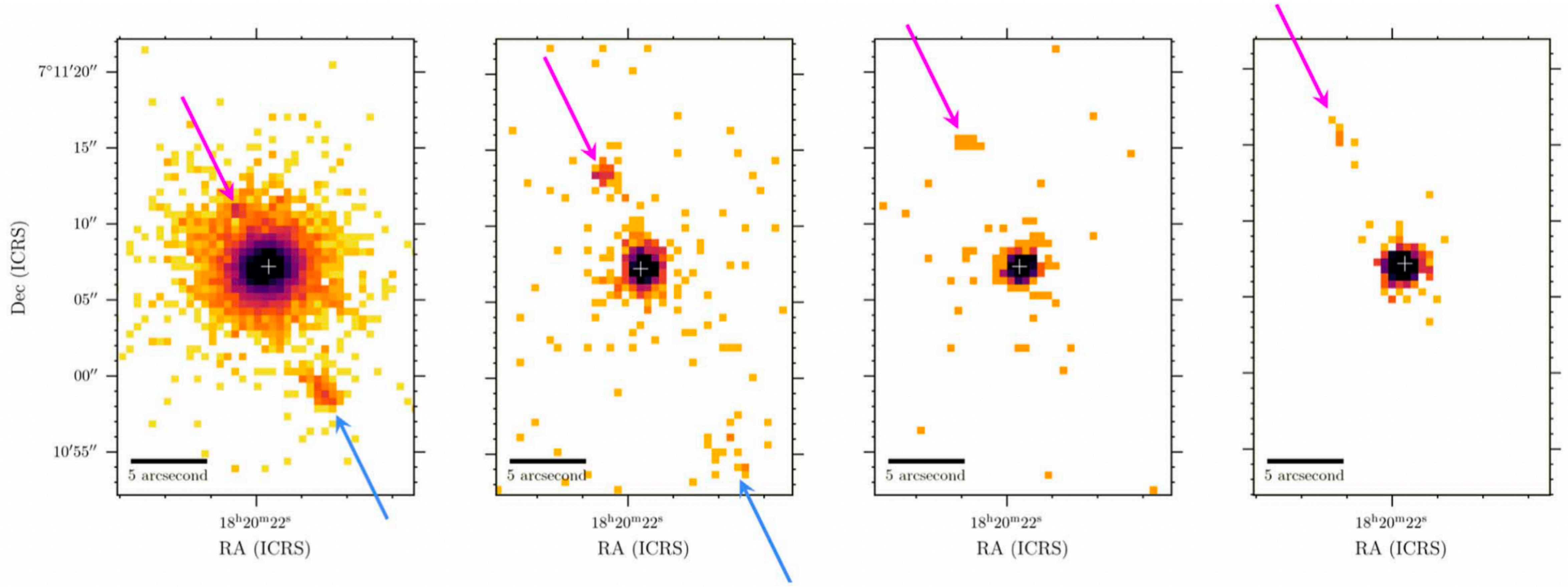
Inferred jet energy: $E_0 = 4.6^{+20.0}_{-3.4} \times 10^{46} \left(\frac{n_{ISM}}{1\ \mathrm{cm}^{-3}}\right)\left(\frac{\phi}{1^o}\right)^2$ erg

Way larger than the constraints obtained from the jet electromagnetic emission: $E_0 \gtrsim 10^{42}$ erg

The majority of the jet energy is transferred to the surrounding environment.

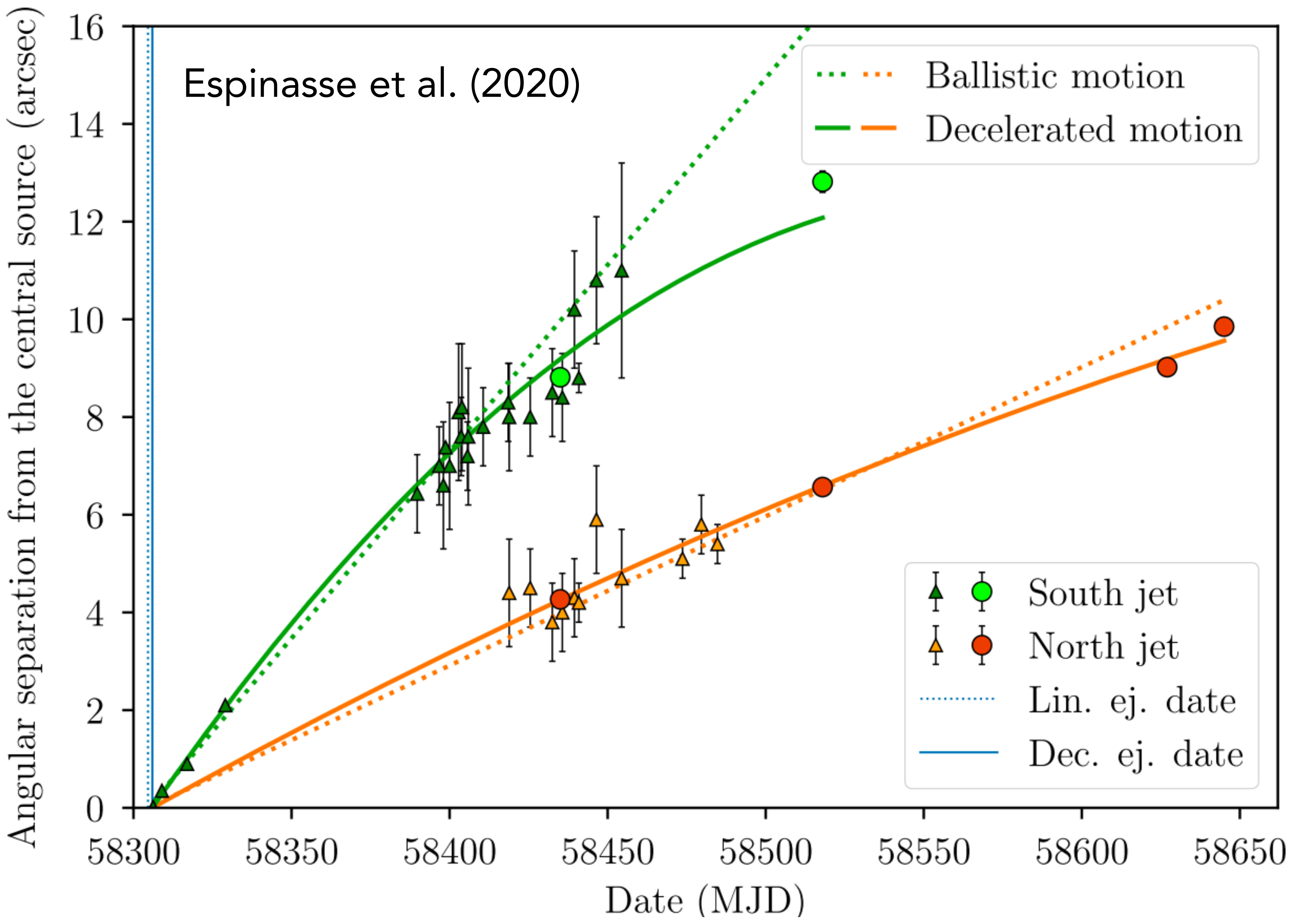
Bipolar jets from MAXI J1820+070





Chandra

Espinasse et al. (2020)



Uniform density ISM?

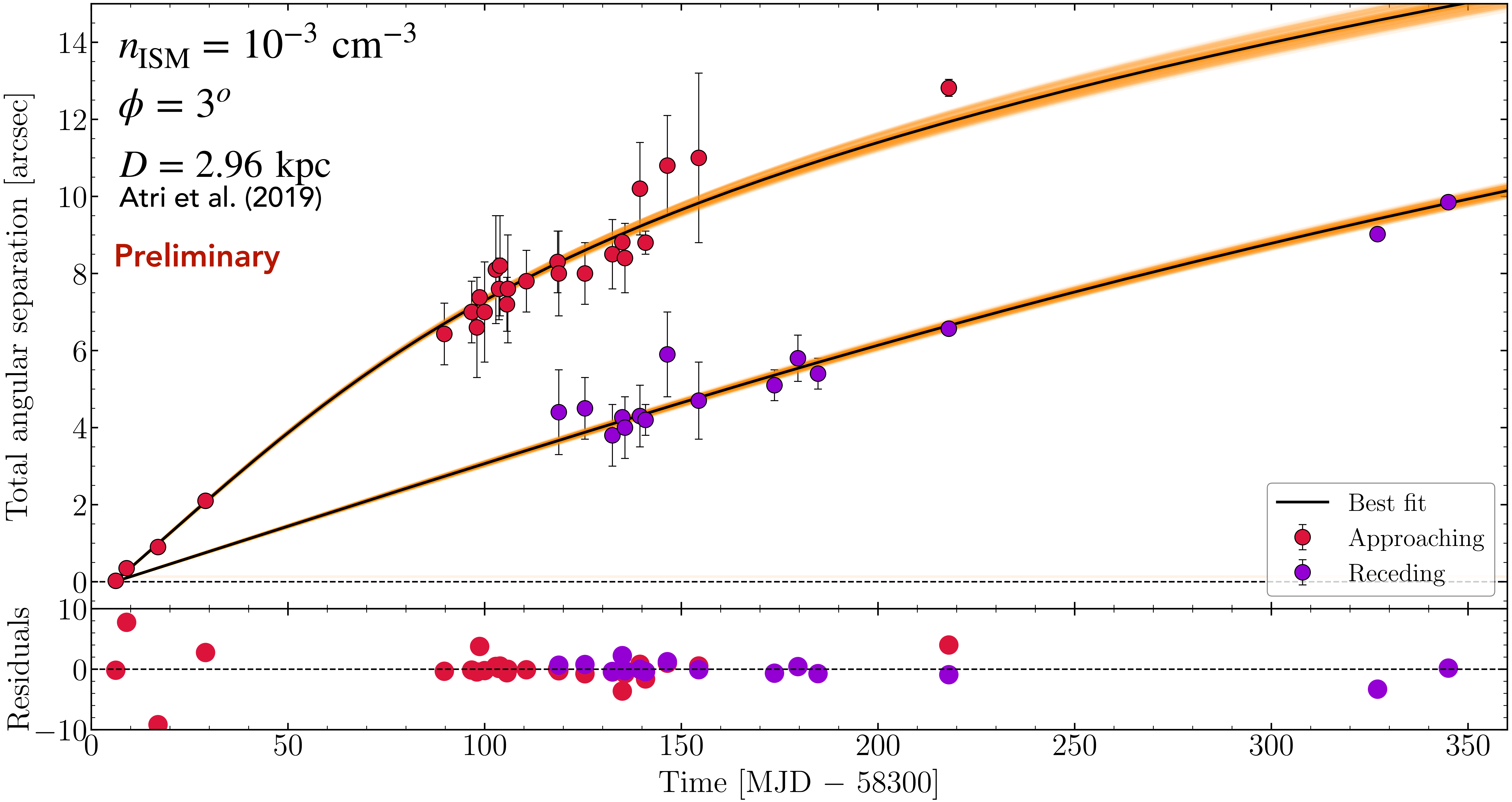
Fitting the jet motion

$n_{\mathrm{ISM}} = 10^{-3}\ \mathrm{cm}^{-3}$

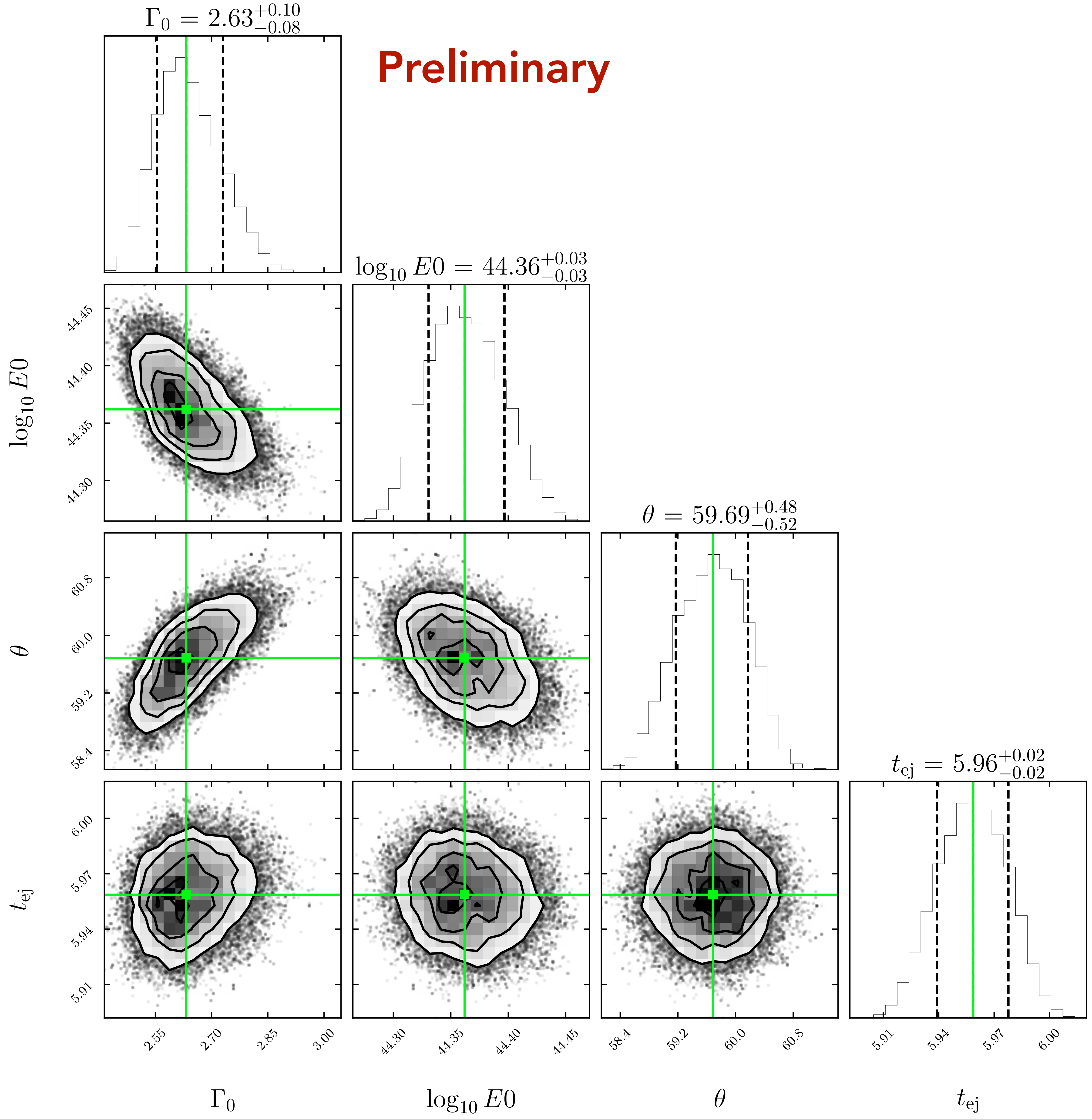
$\phi = 3^{o}$

$D = 2.96\ \mathrm{kpc}$
Atri et al. (2019)

Fitting the jet motion



Kinetic energy



$$\Gamma_0 = 2.63^{+0.10}_{-0.08}$$

Consistent with Bright et al. (2020) and Wood et al. (2021)

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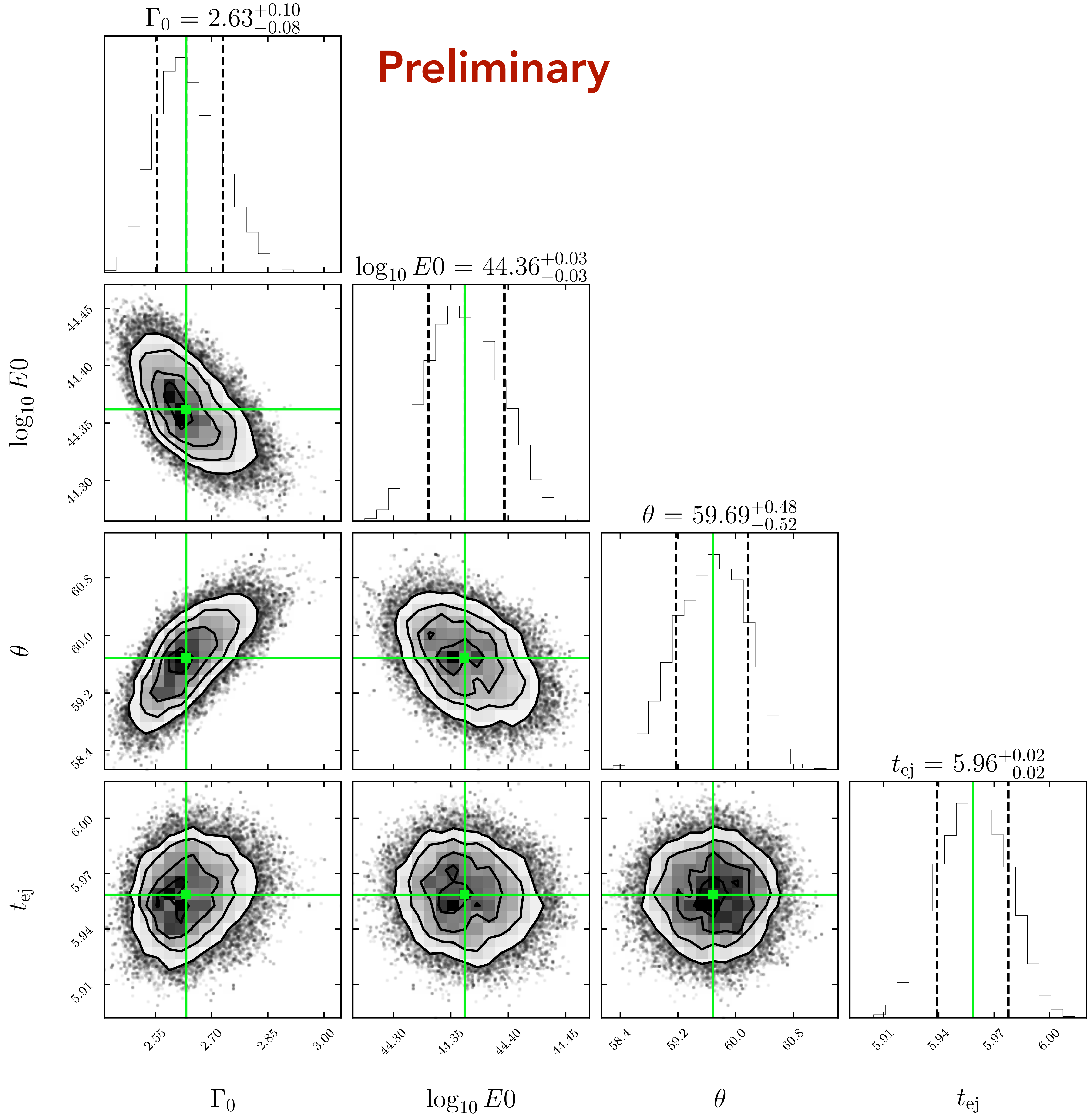

Preliminary

$$\Gamma_0 = 2.63^{+0.10}_{-0.08}$$

Consistent with Bright et al. (2020) and Wood et al. (2021)

$$E_0 = 2.3^{+0.2}_{-0.2} \times 10^{44} \left(\frac{n_{\rm ISM}}{10^{-3}\ {\rm cm}^{-3}}\right)\left(\frac{\phi}{3^o}\right)^2 \ {\rm erg}$$

$\sim 10^5$ times the energy obtained from the radio flare (Bright et al. 2020)

$\sim 10^2$ times the energy from equipartition (measured jet size, Bright et al. 2020, Espinasse et al. 2020)

~ 0.05 times the kinetic energy of the jets from MAXI J1348-630 (Carotenuto et al. 2022)


Thanks for the attention!
MAXI J1348-630
MeerKAT