Probing the dynamics of AGN jets with advanced semi-analytical modelling

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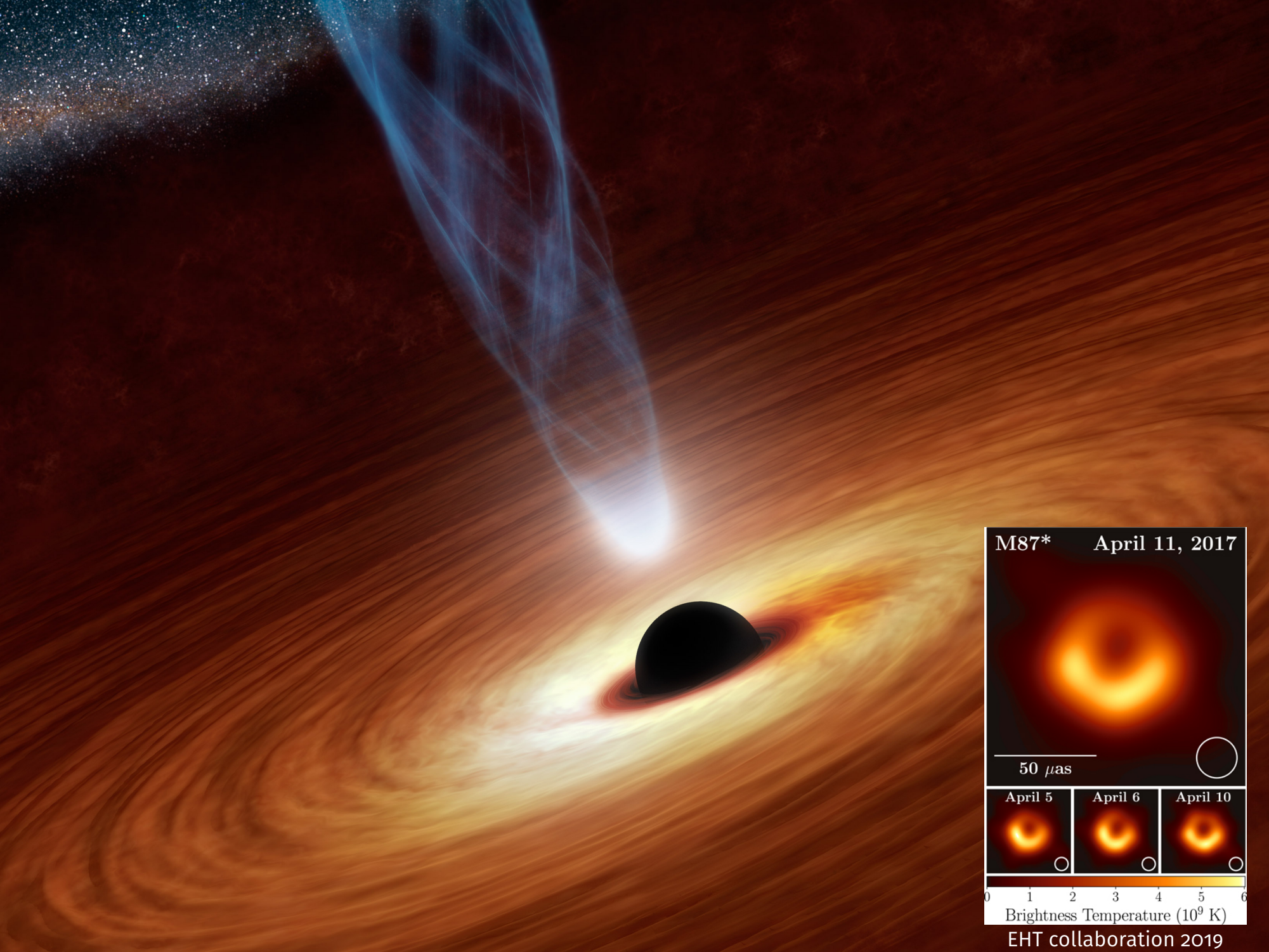
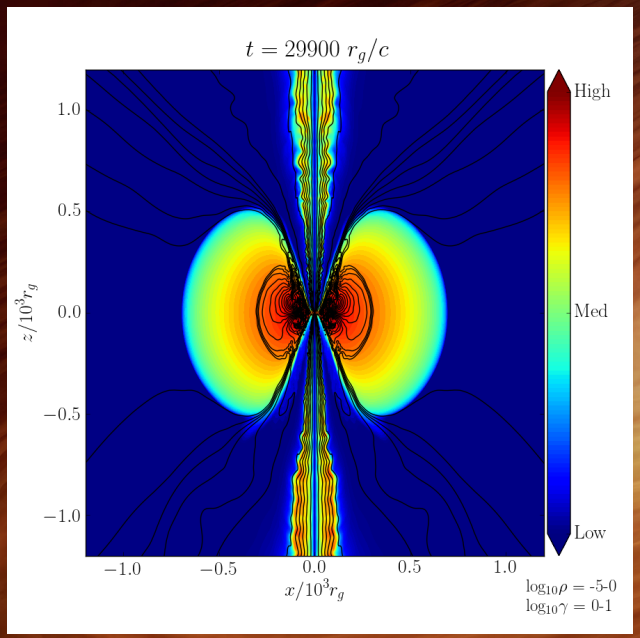


EHT collaboration 2019



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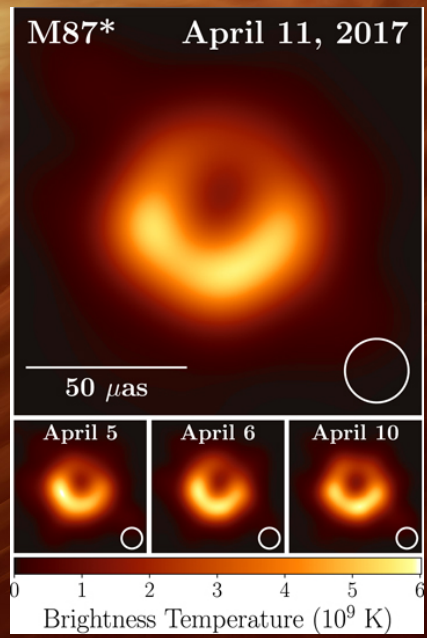

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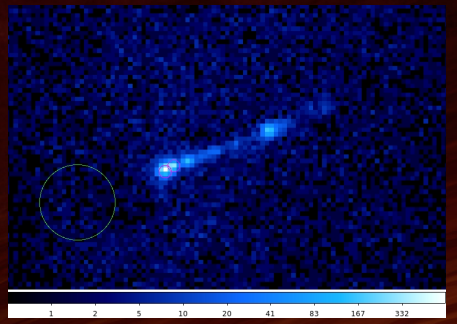

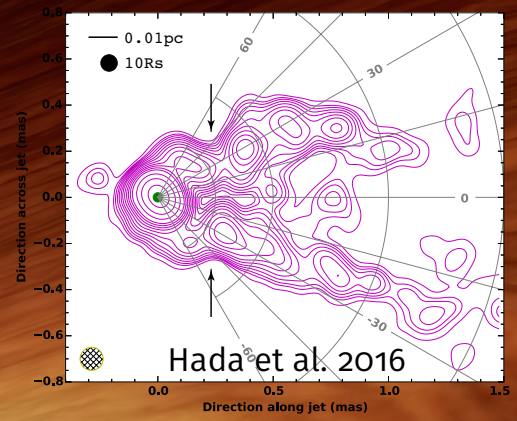

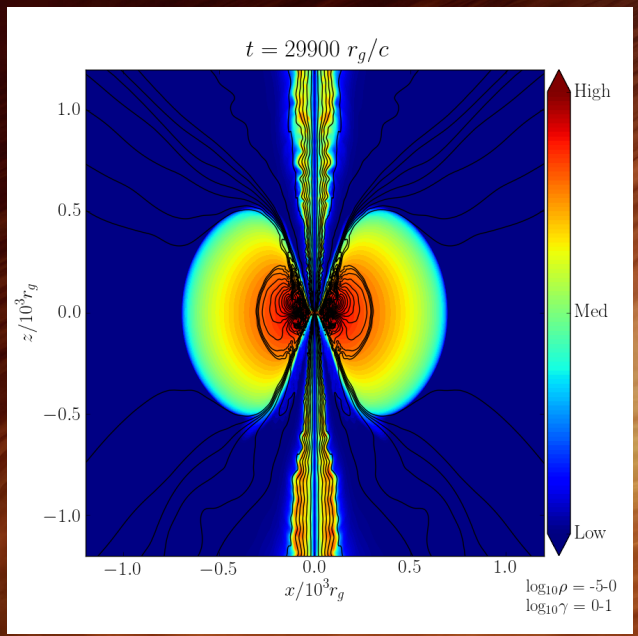

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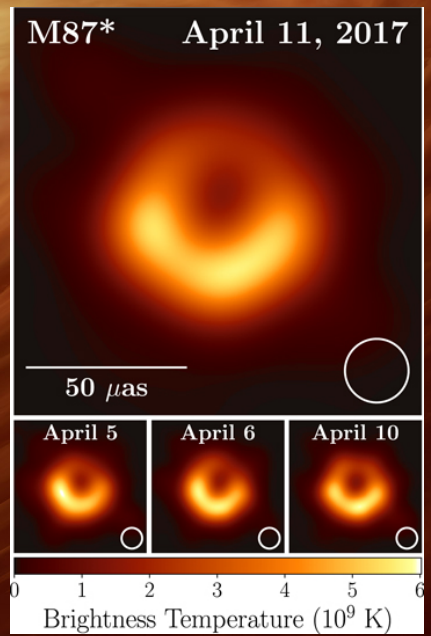
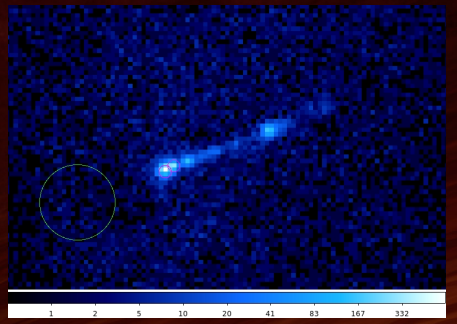
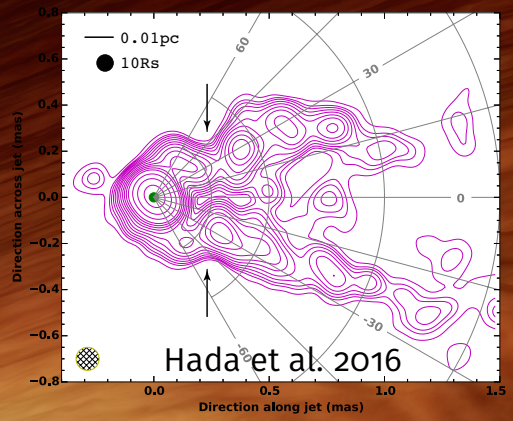
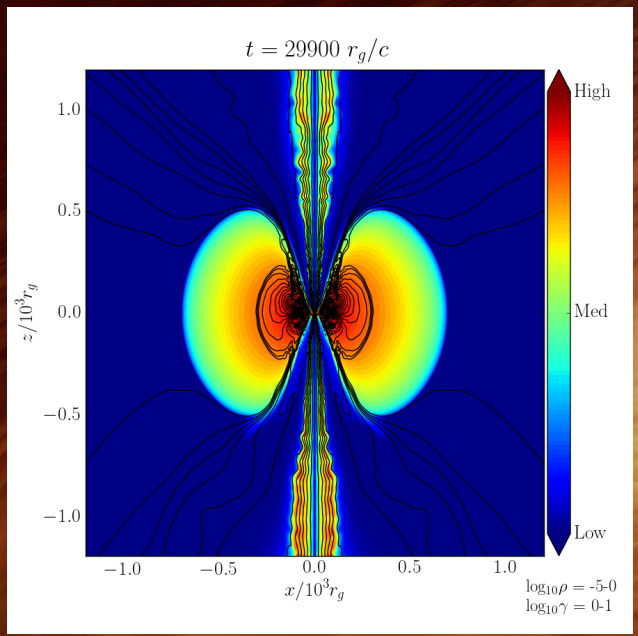


EHT collaboration 2019

How can we use semi-analytical models to guide simulations?







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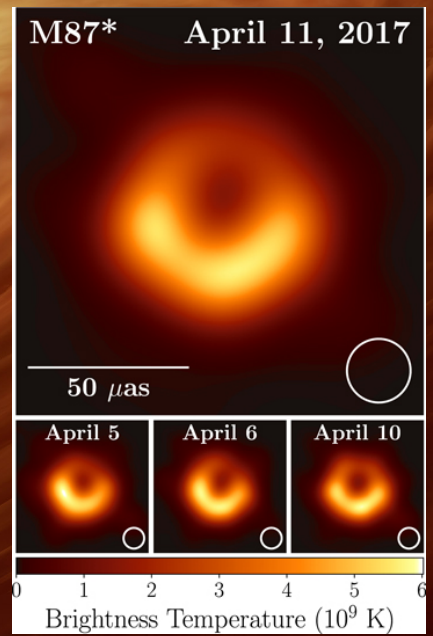
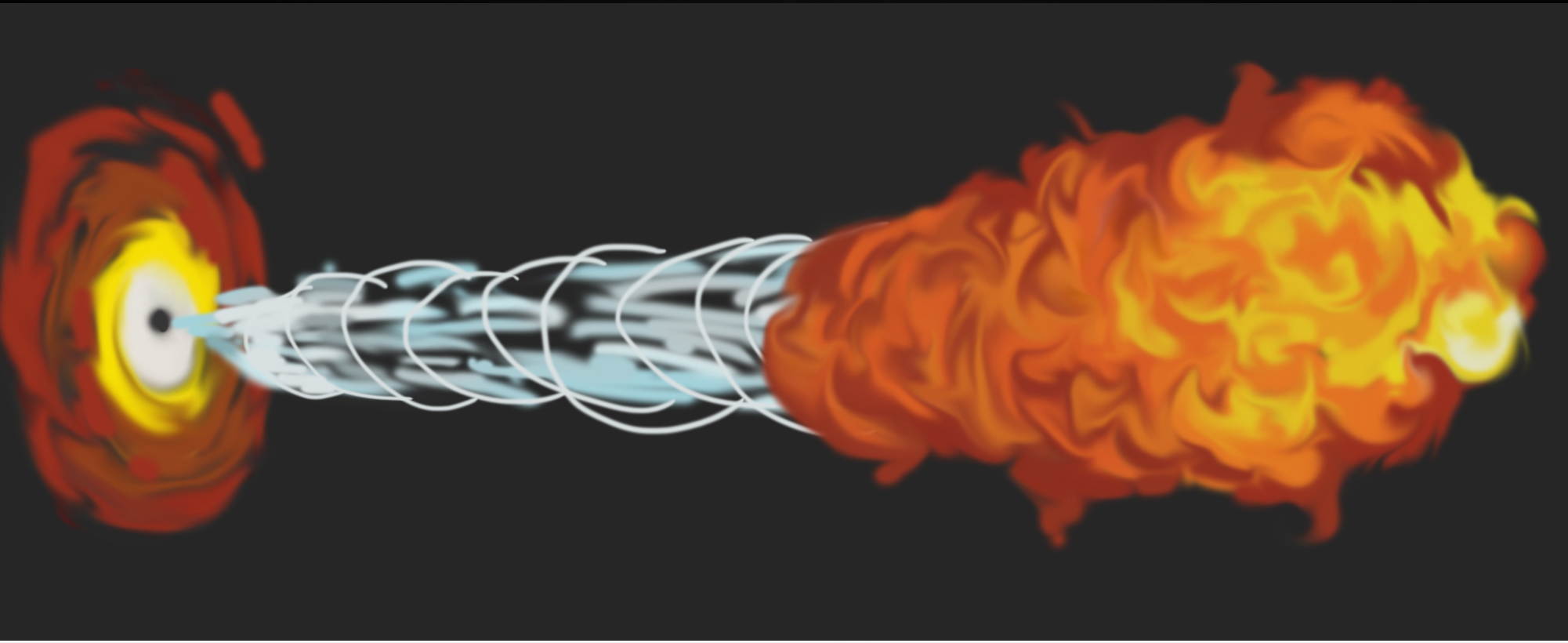


EHT collaboration 2019

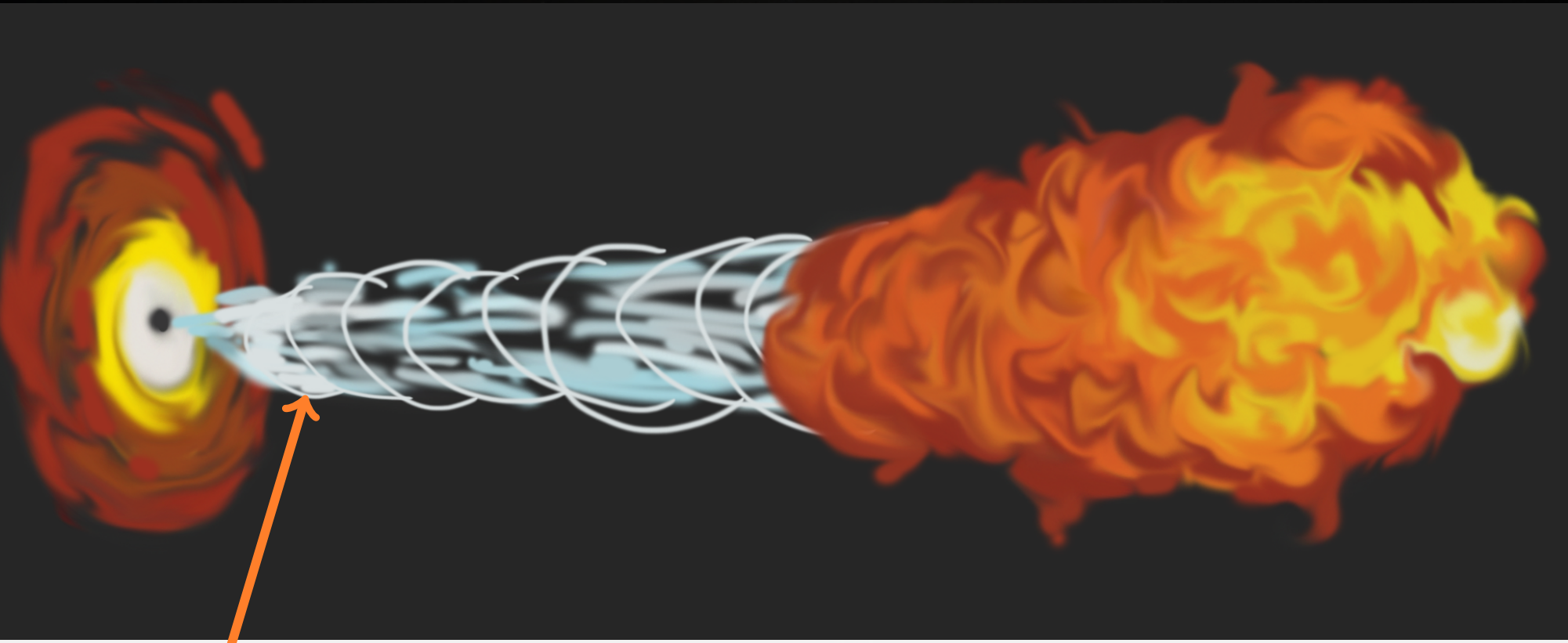
`BLJet`: a new all-zone model



Extension of `agnjet` (e.g. Markoff and Nowak 2001)

- Focus on jet dynamics and energetics
- Account for entire outflow

`BLJet`: a new all-zone model



Jet nozzle/corona:
power U_j, temperature T,
magnetization $\sigma_0 \gg 1$,
radius R_0

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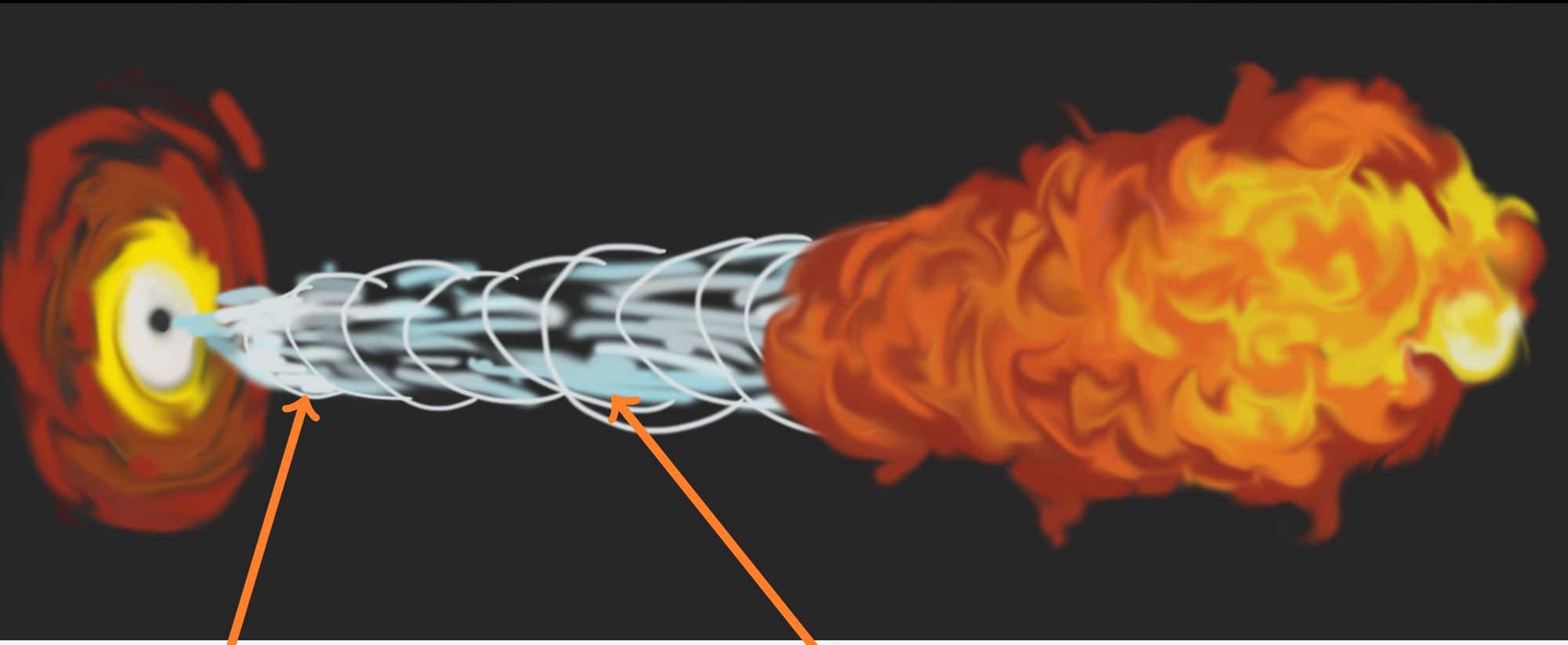

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distance Z_{diss},
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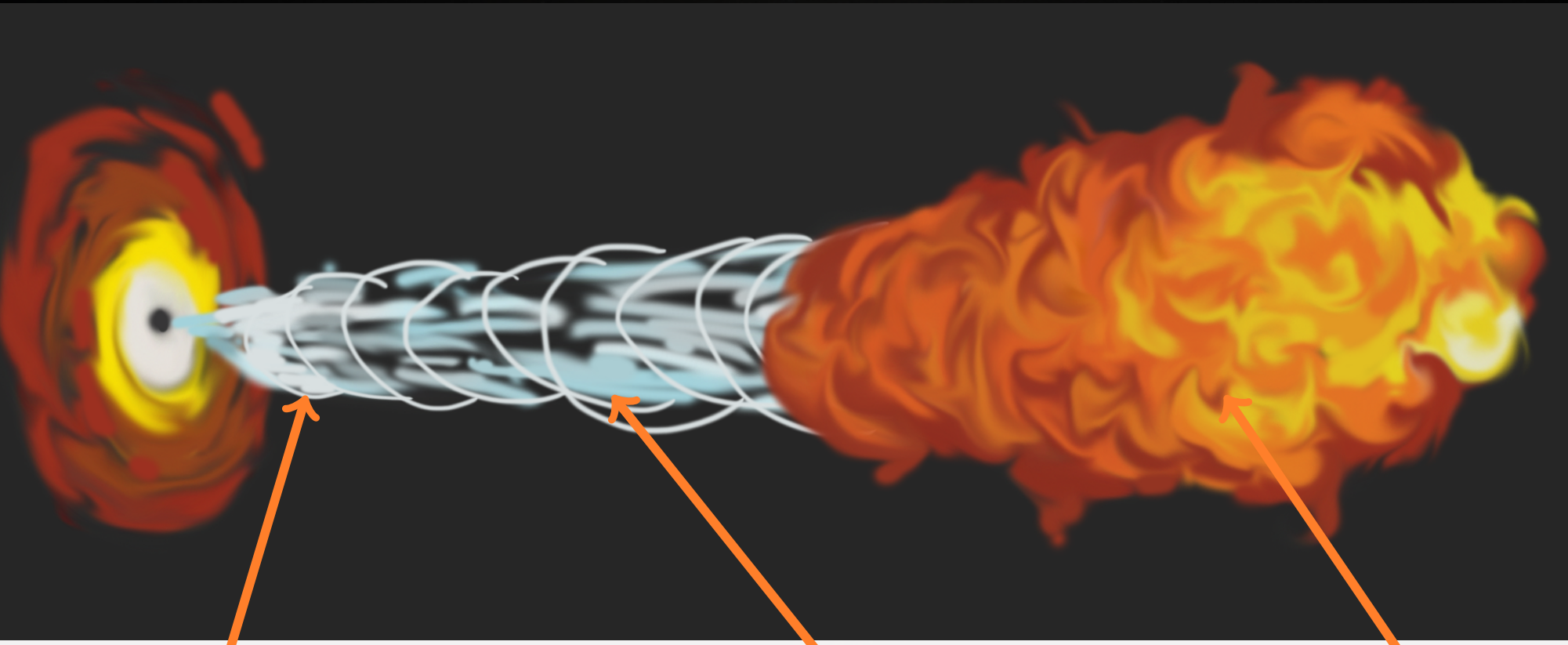

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power U_j, temperature T,
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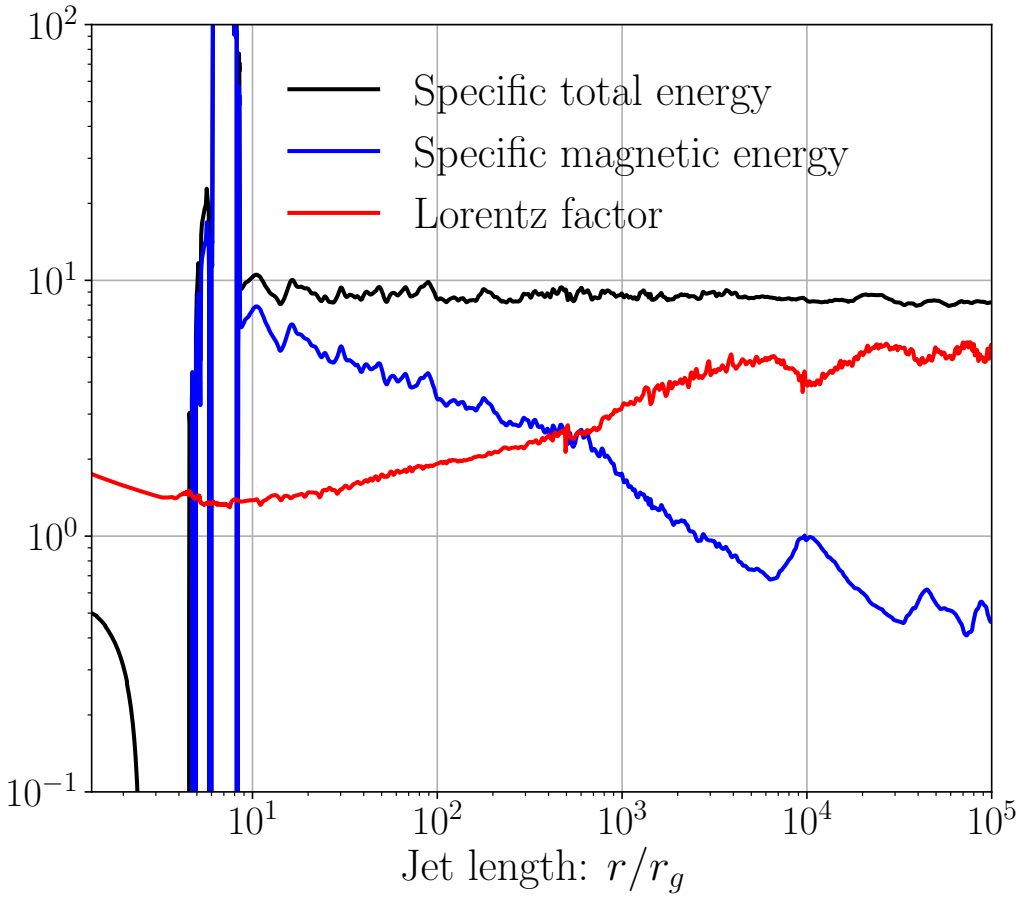
Magnetic acceleration region:
distance Z_{diss},
magnetization $\sigma_f \leq 1$,

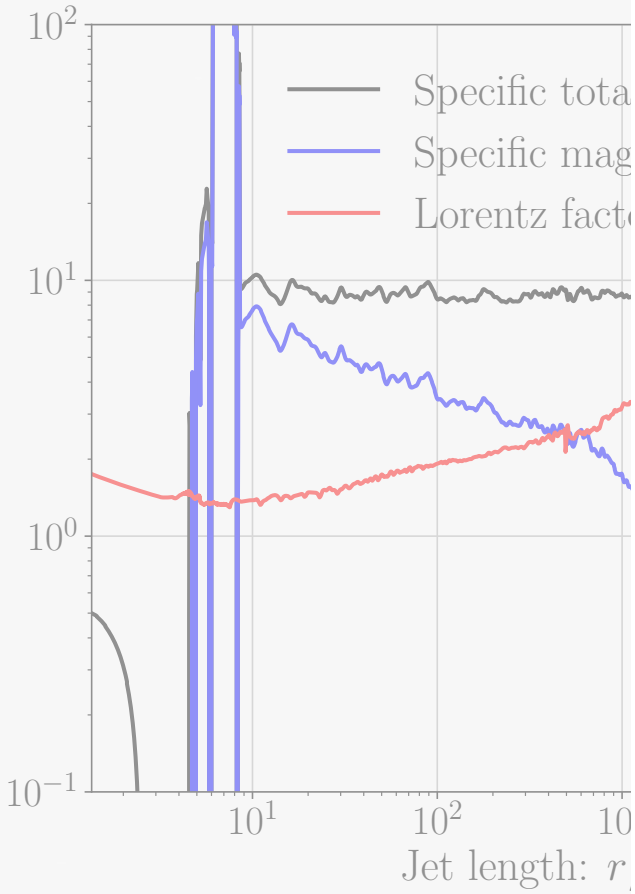
Outer jet:
non-thermal tail
$N(\gamma) \propto \gamma^{-p}$

Magnetically accelerated jets



Chatterjee et al. 2019

Magnetically accelerated jets



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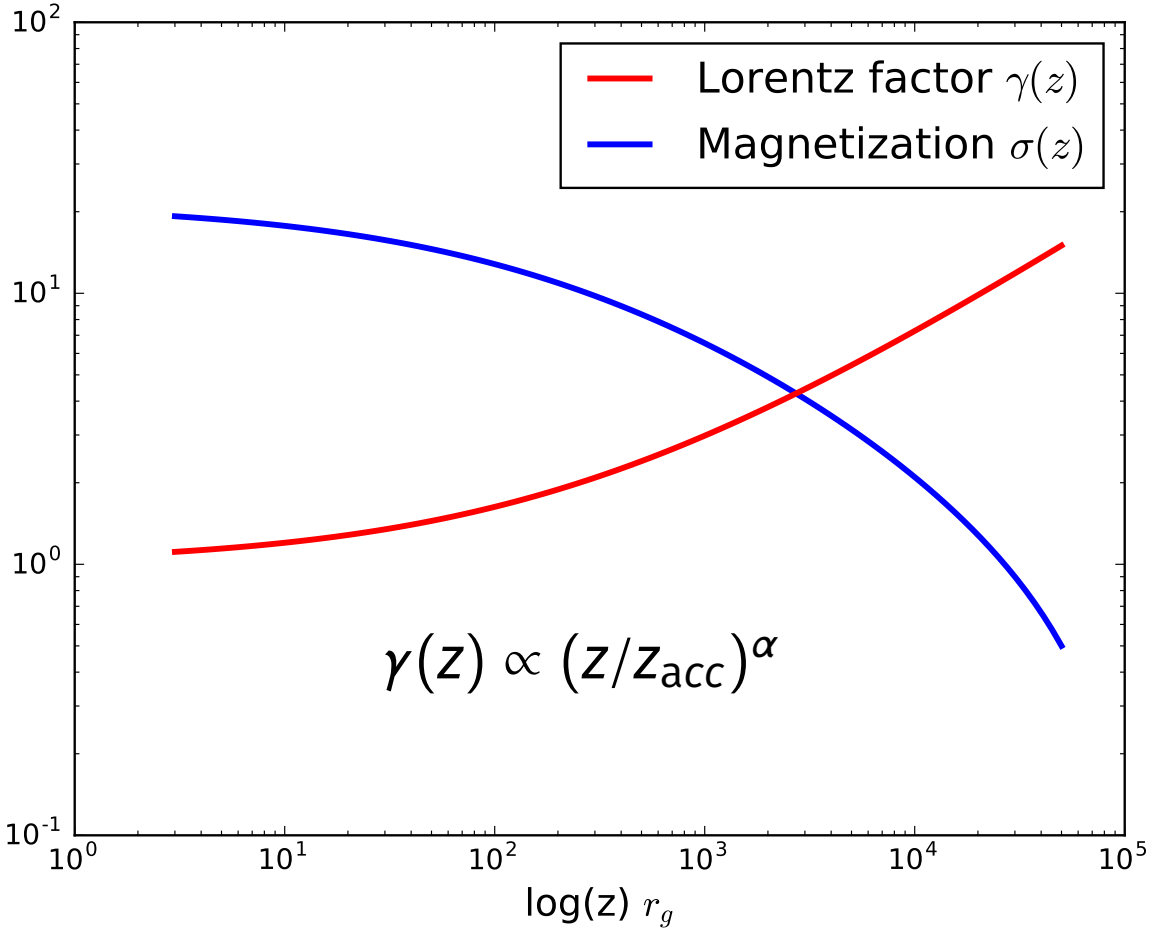

Lucchini et al. 2019

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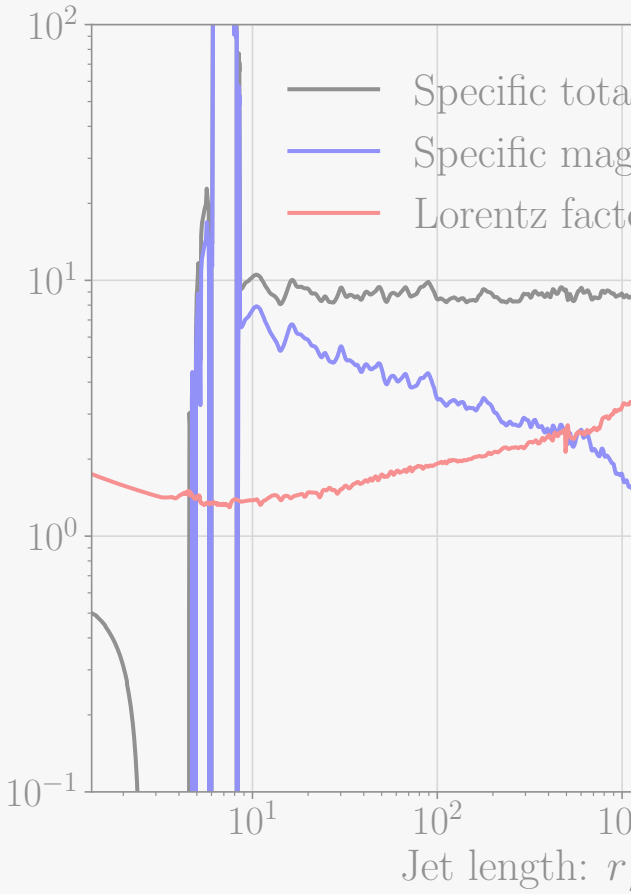
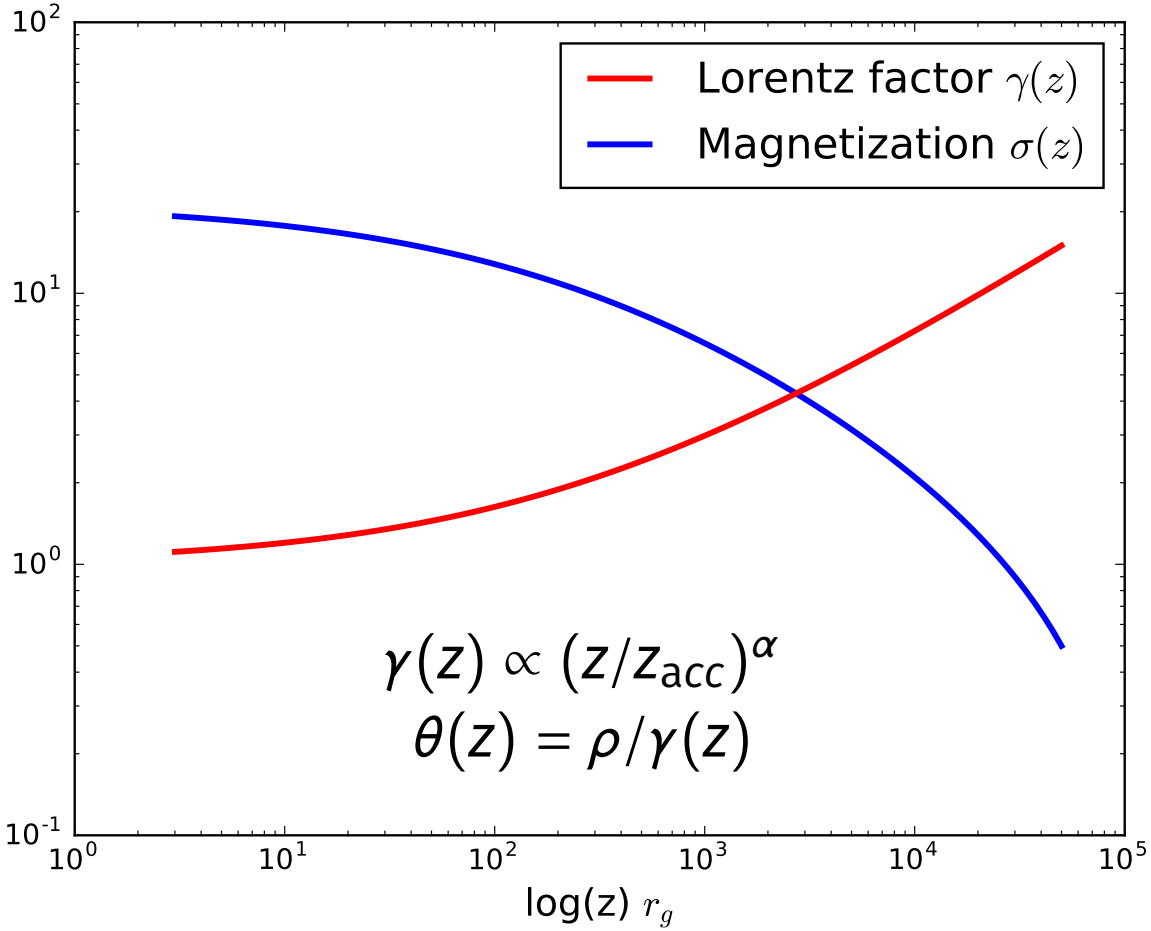
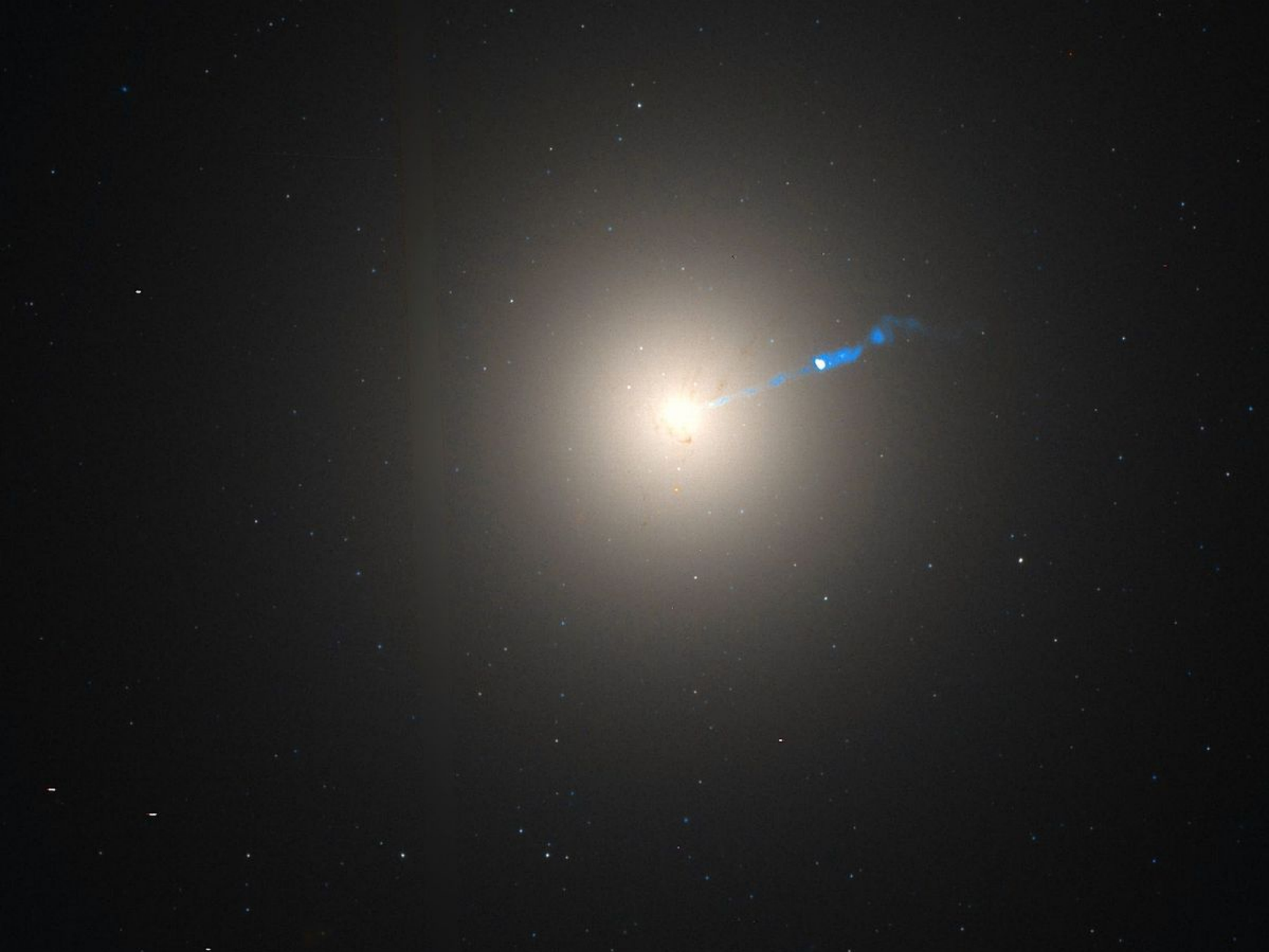


Chatterjee et al. 2019

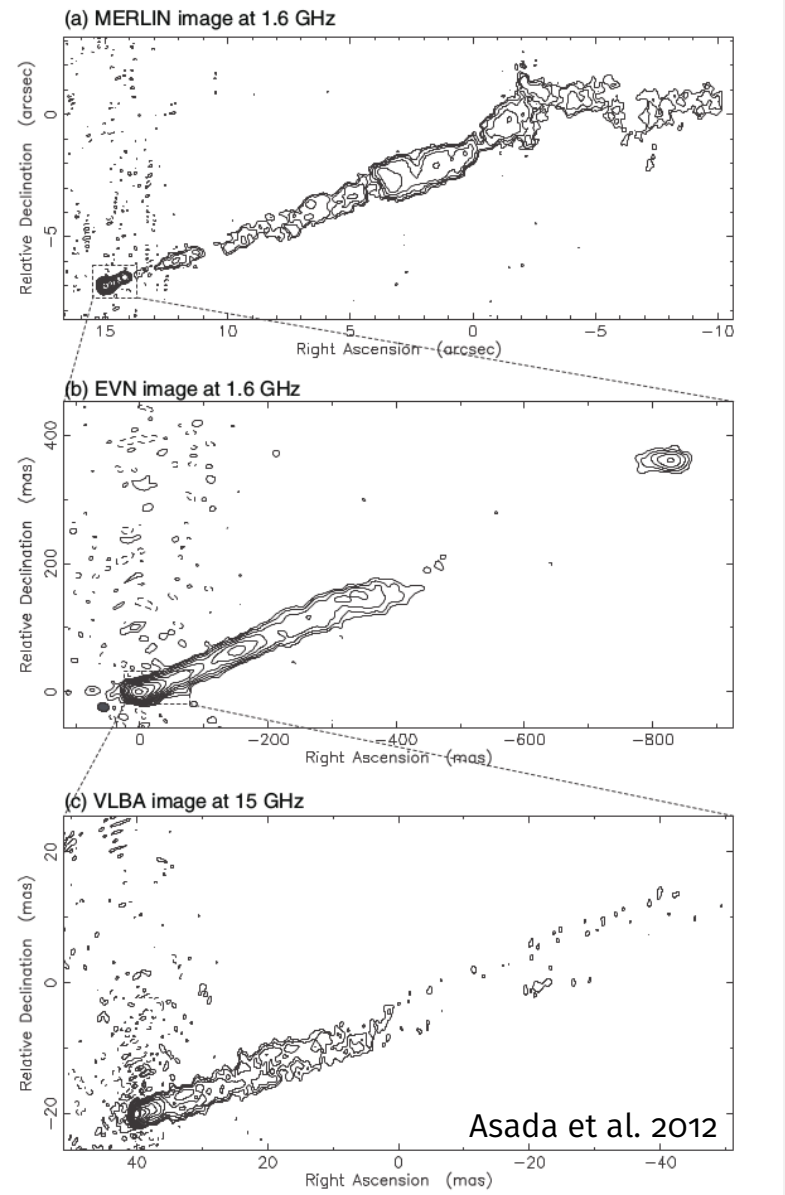


Lucchini et al. 2019



Modelling M87

- Large BH mass + vicinity → Event Horizon Telescope target
- VLBI mapping of jet profile



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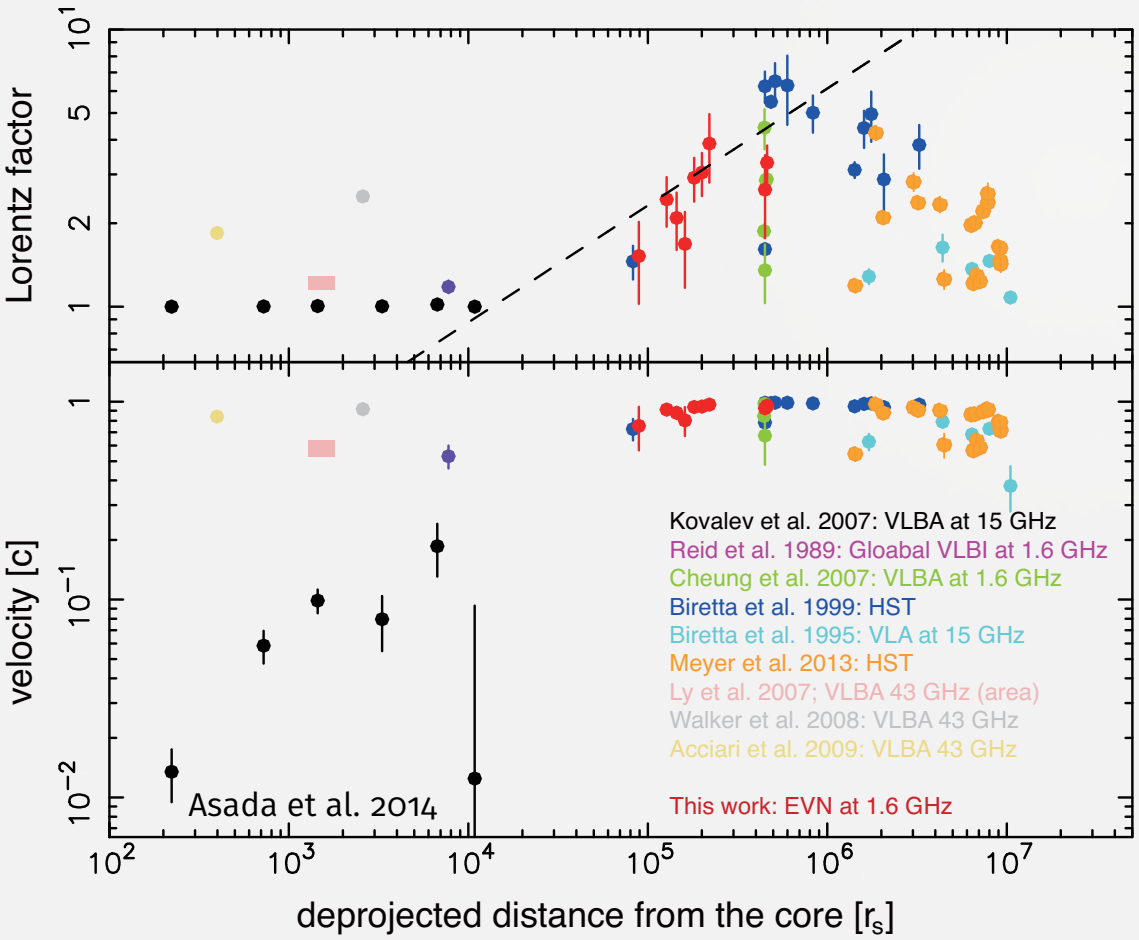
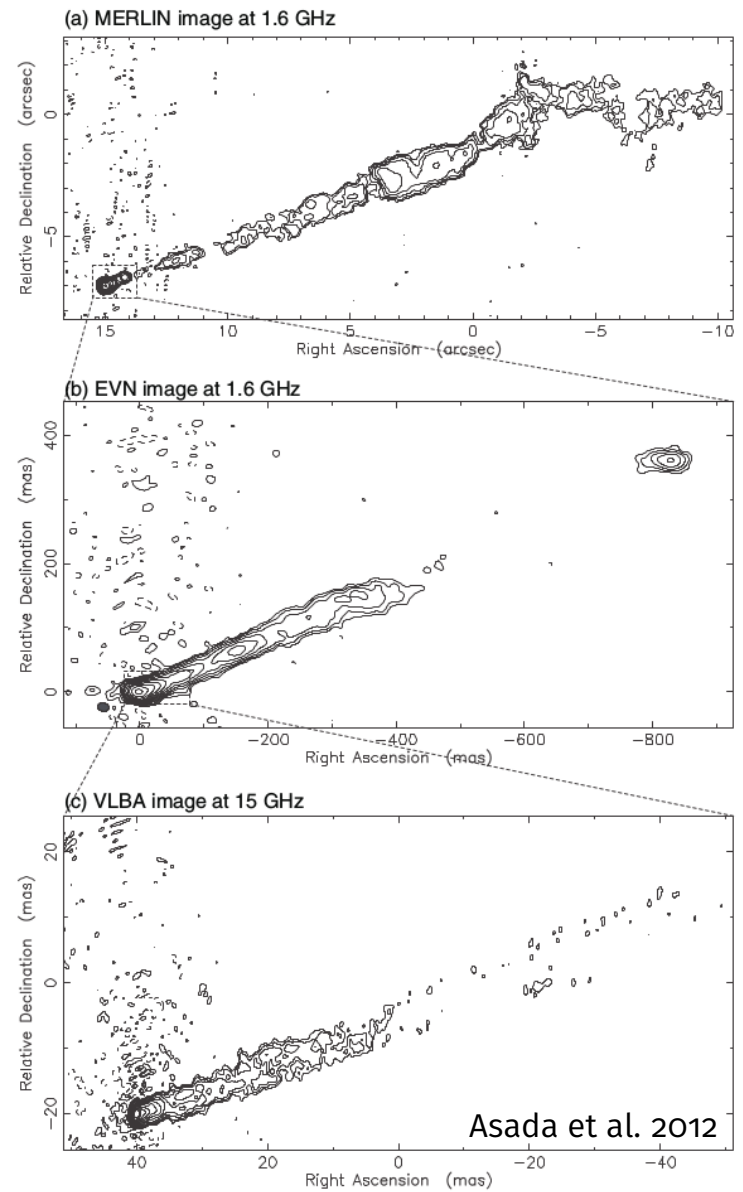
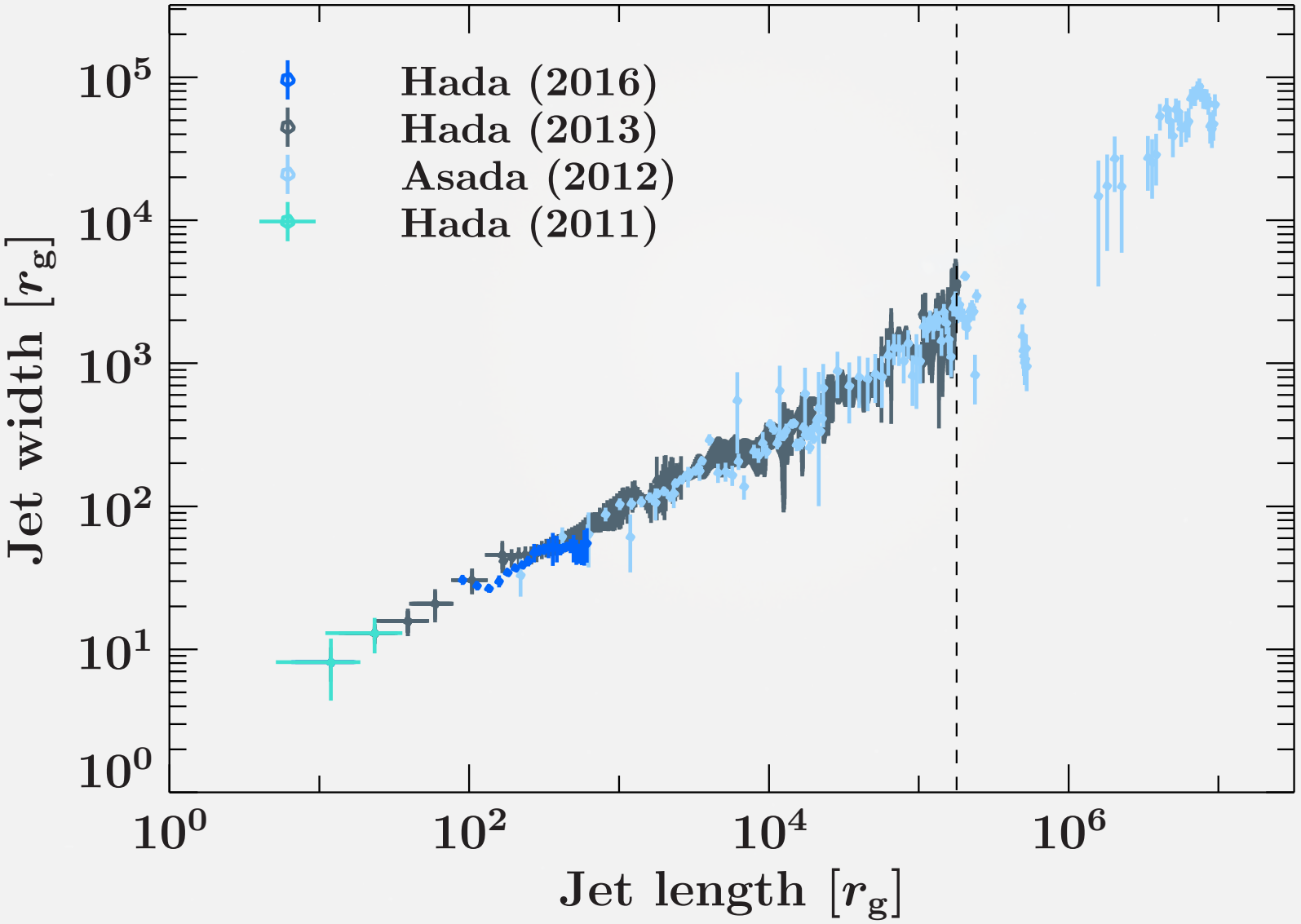




Modelling M87: collimation profile



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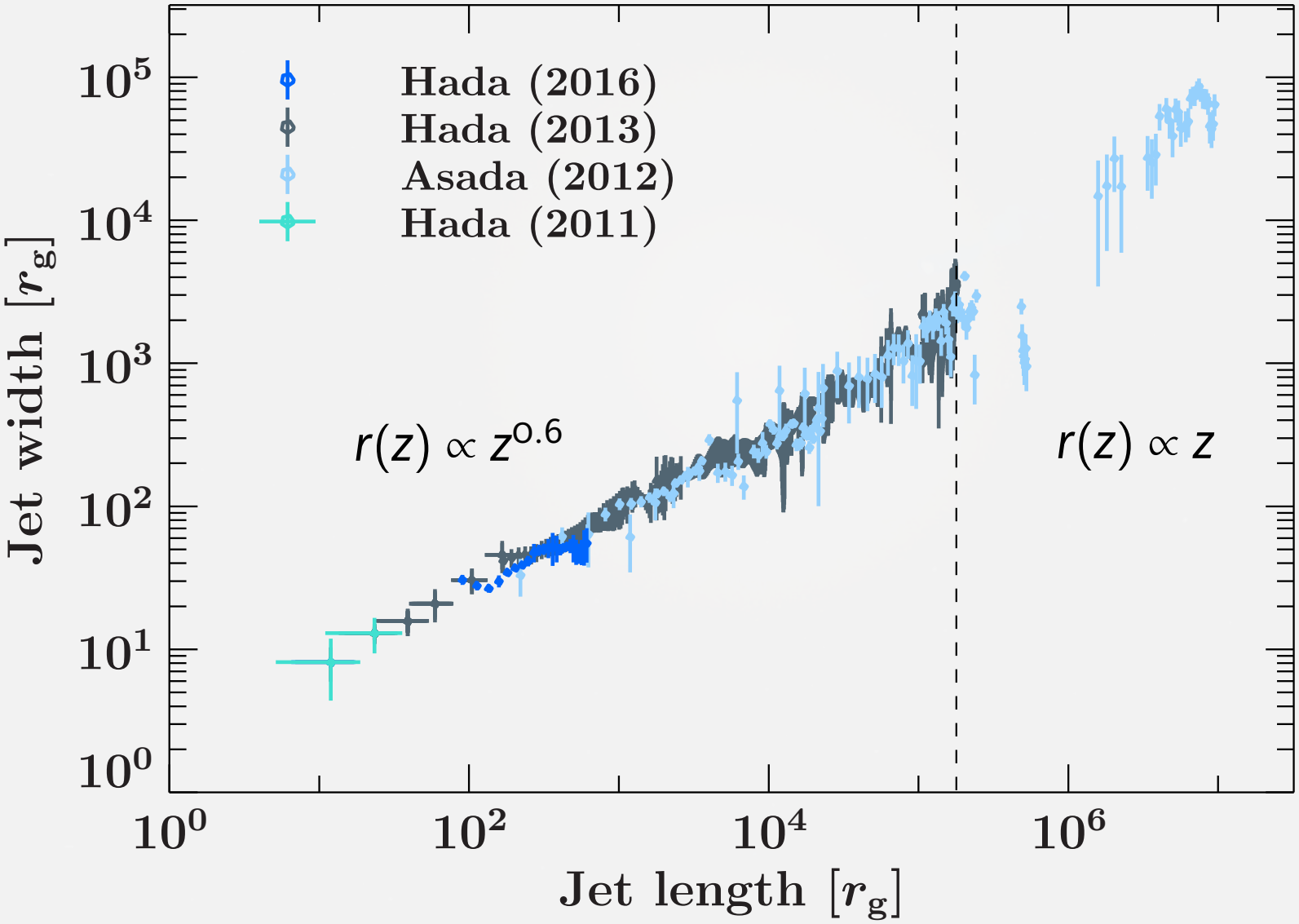

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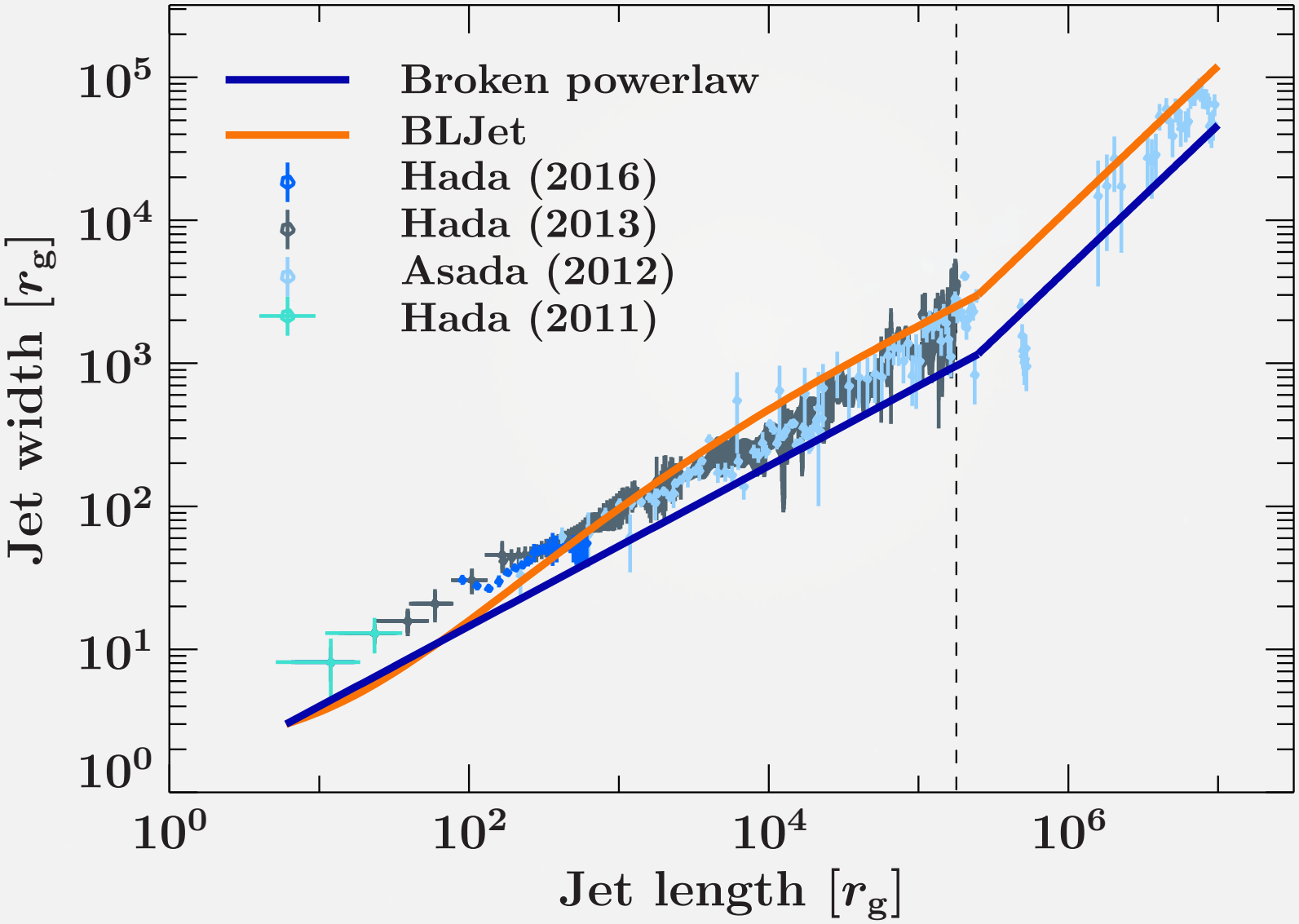

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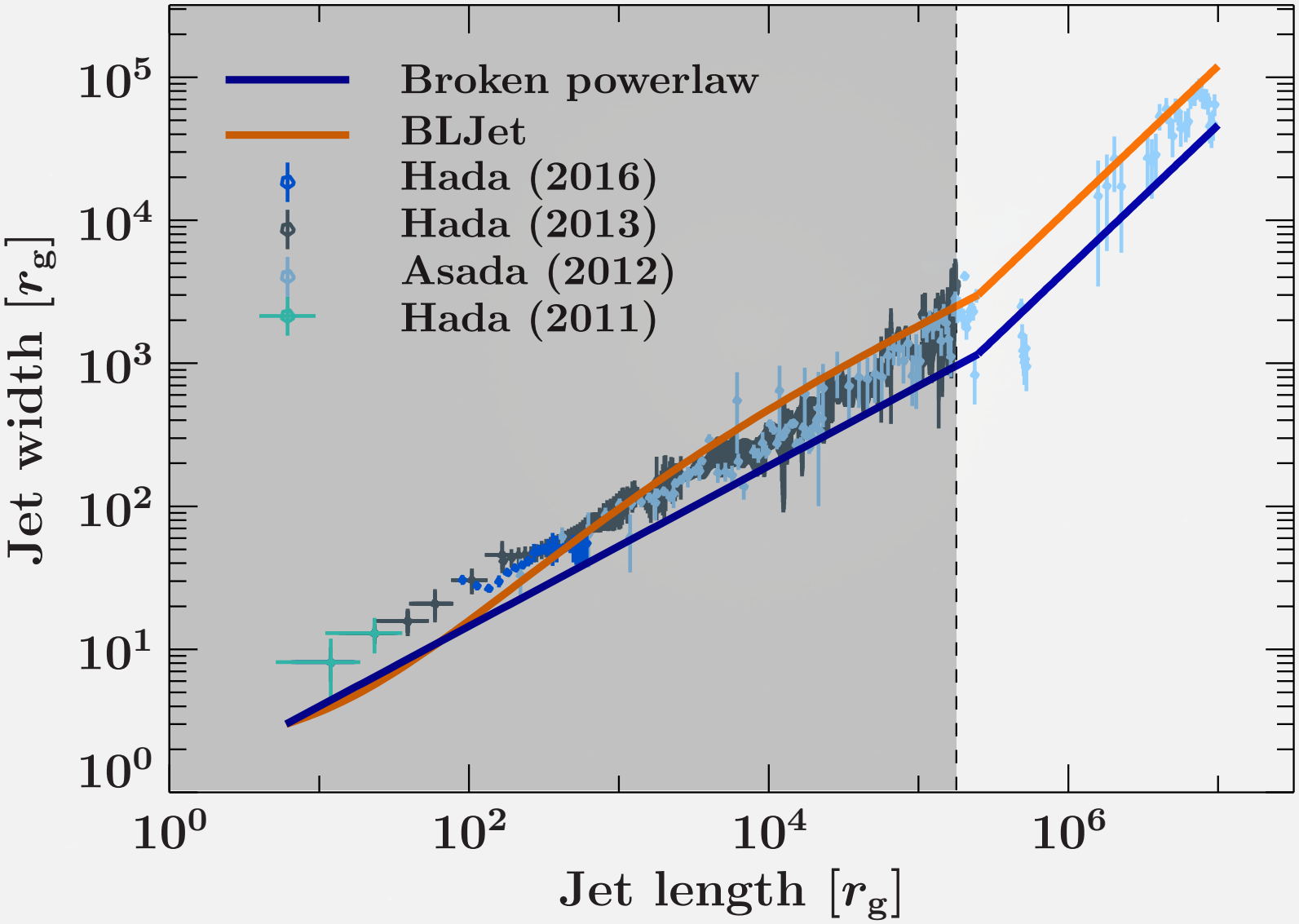
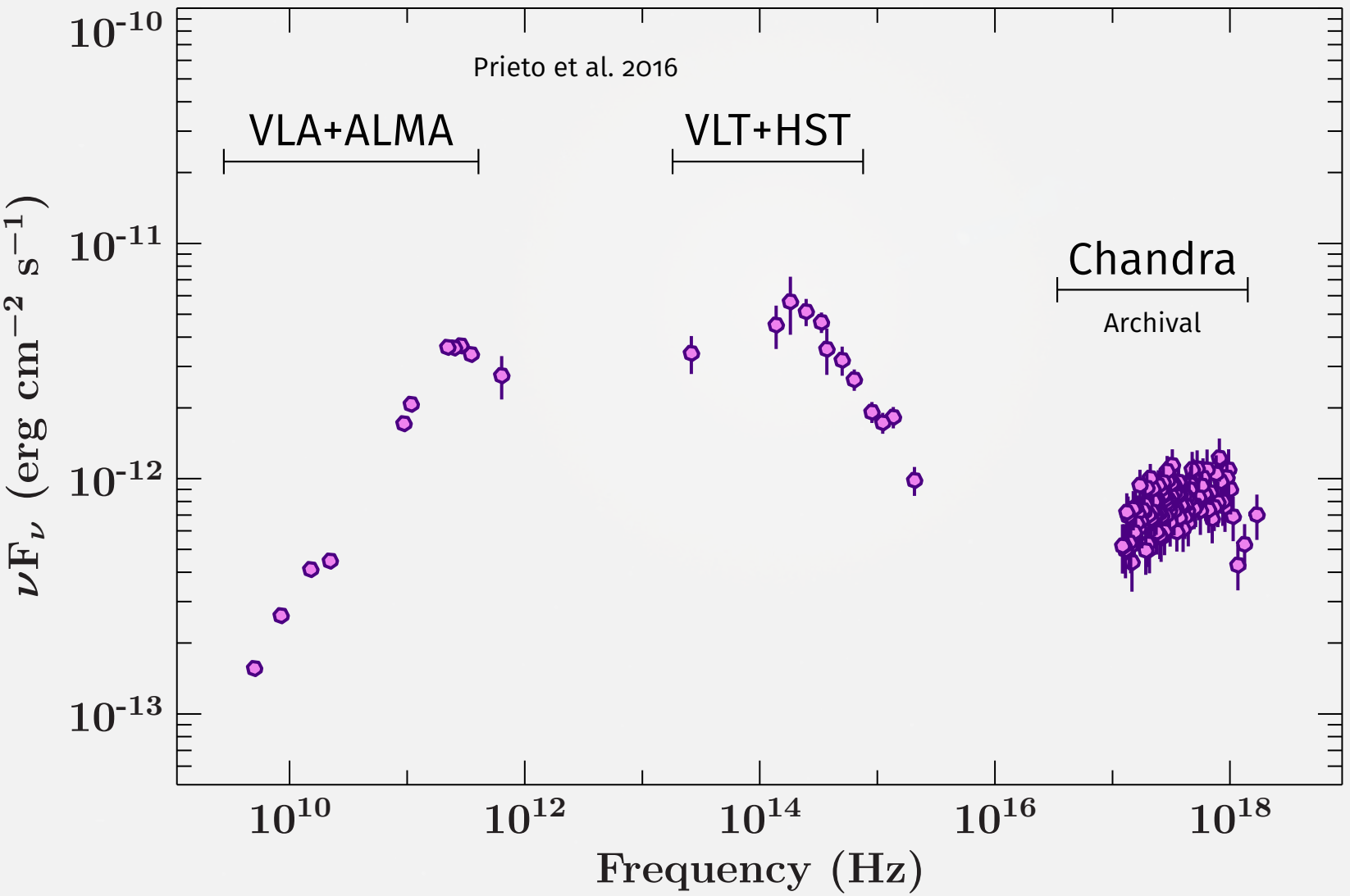
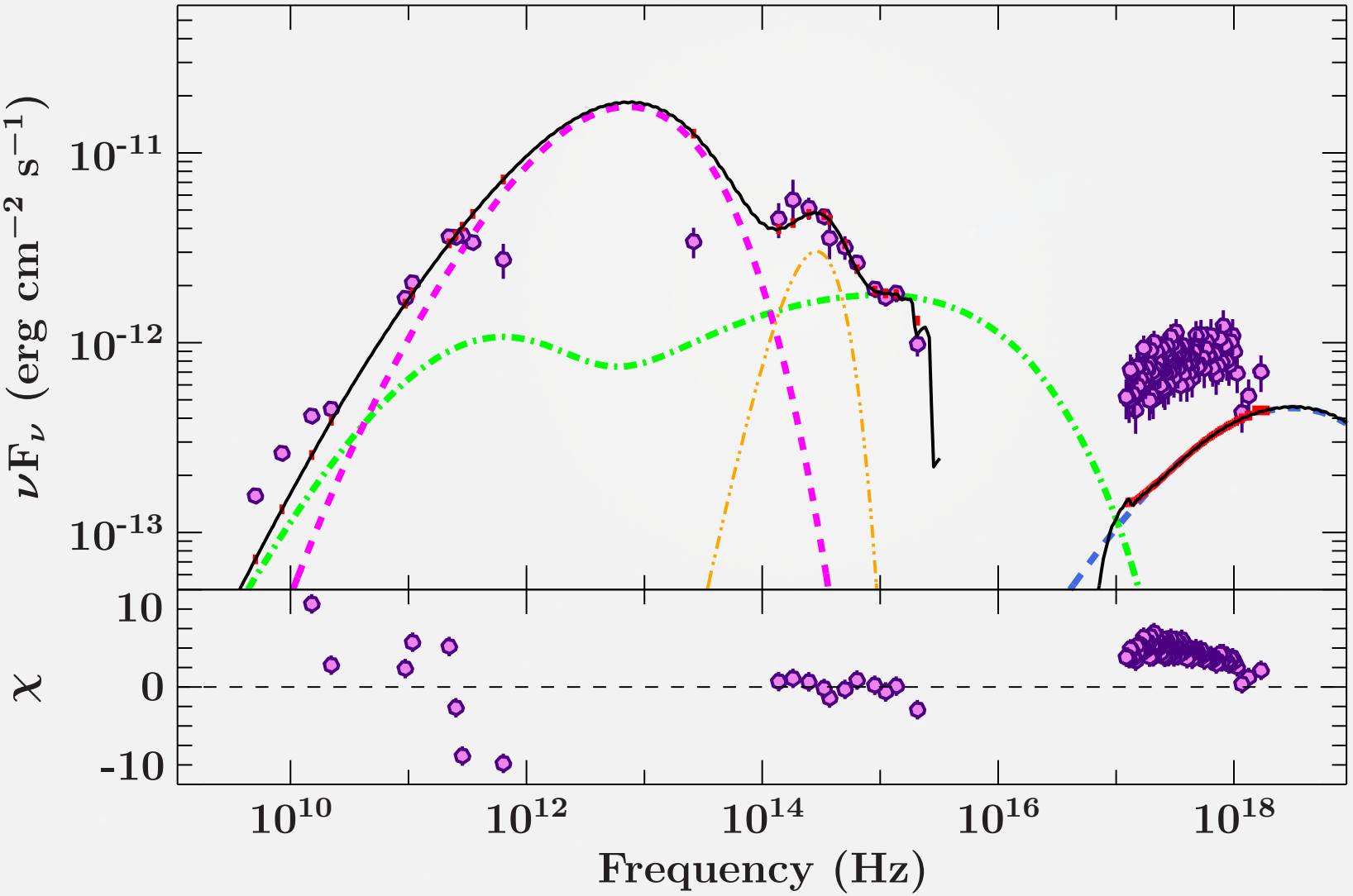


Modelling M87: pc-scale core SED



Modelling M87: SSC-dominated core



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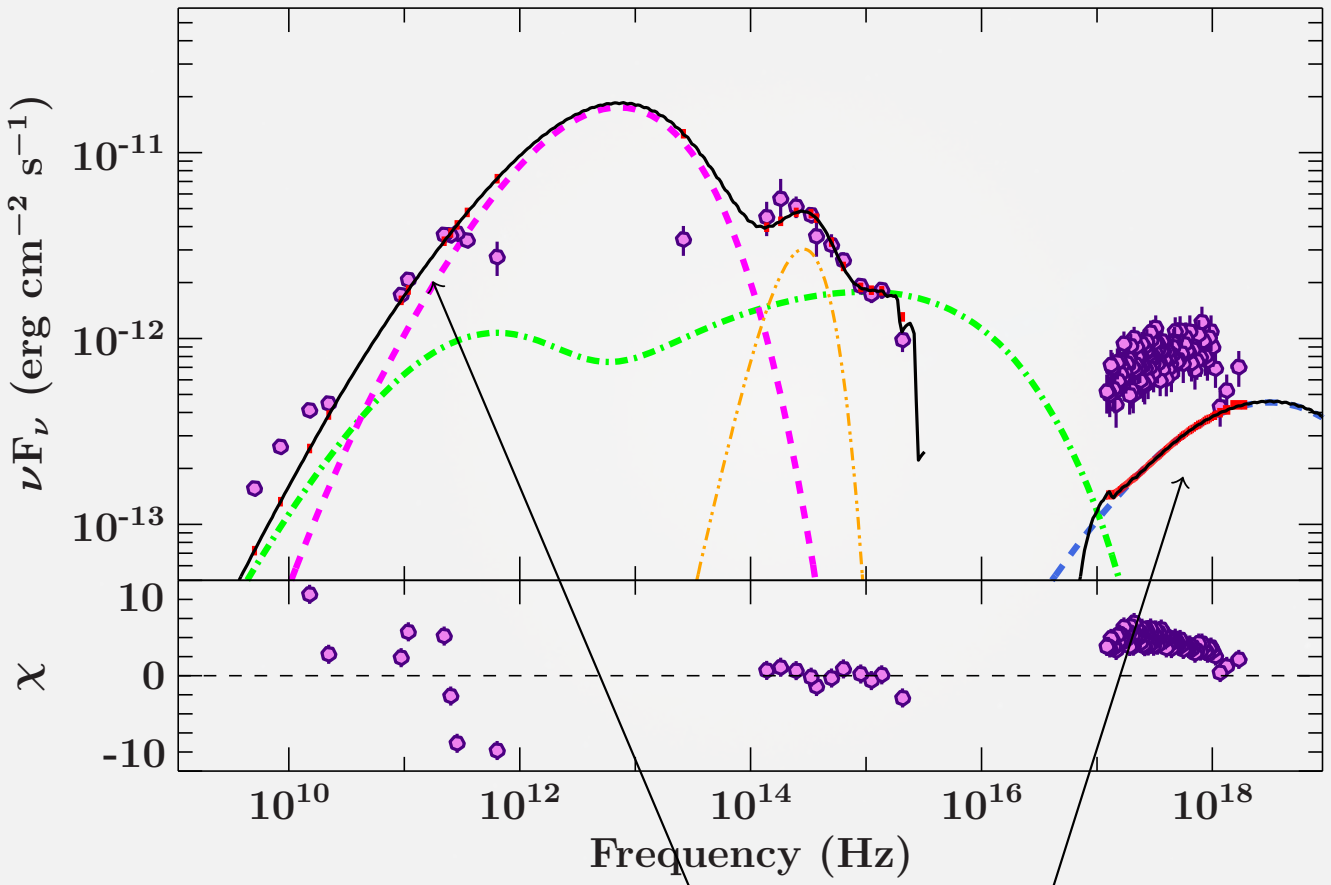
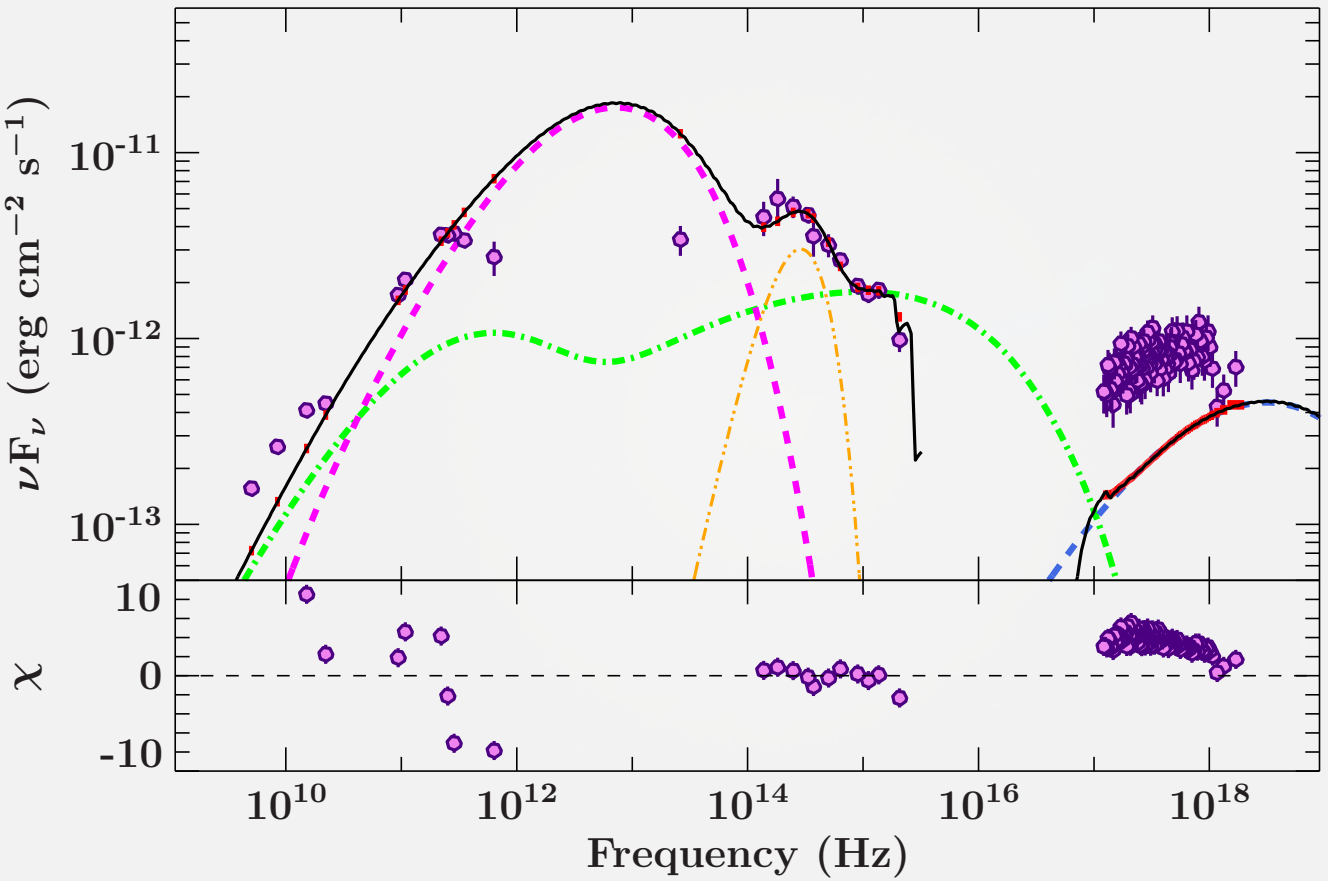


Can’t match X-rays with SSC from the jet base!

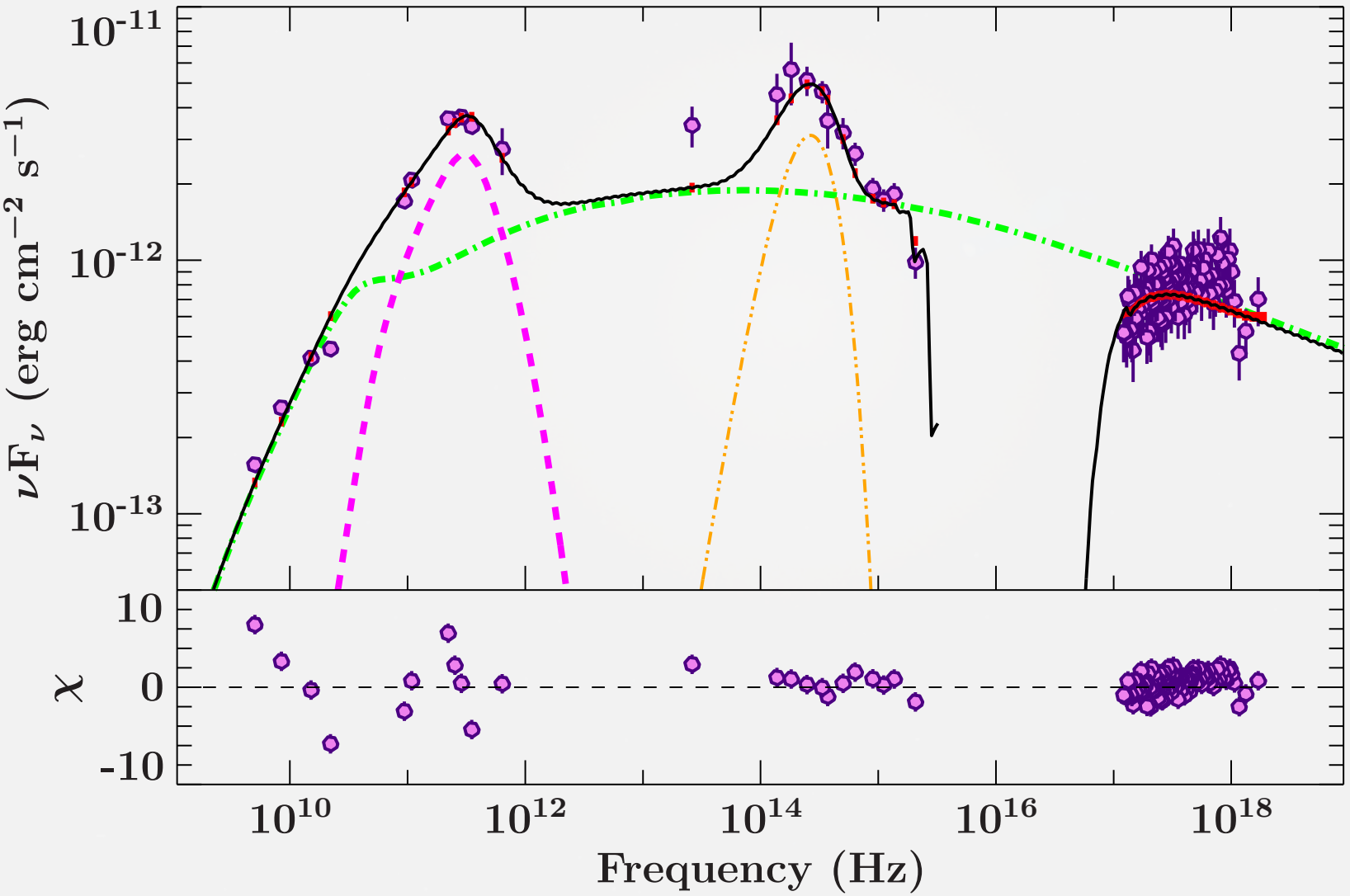
Modelling M87: SSC-dominated core



Can’t match X-rays with SSC from the jet base!

High σ and high T_e → high synchrotron luminosity

Modelling M87: synchrotron-dominated core



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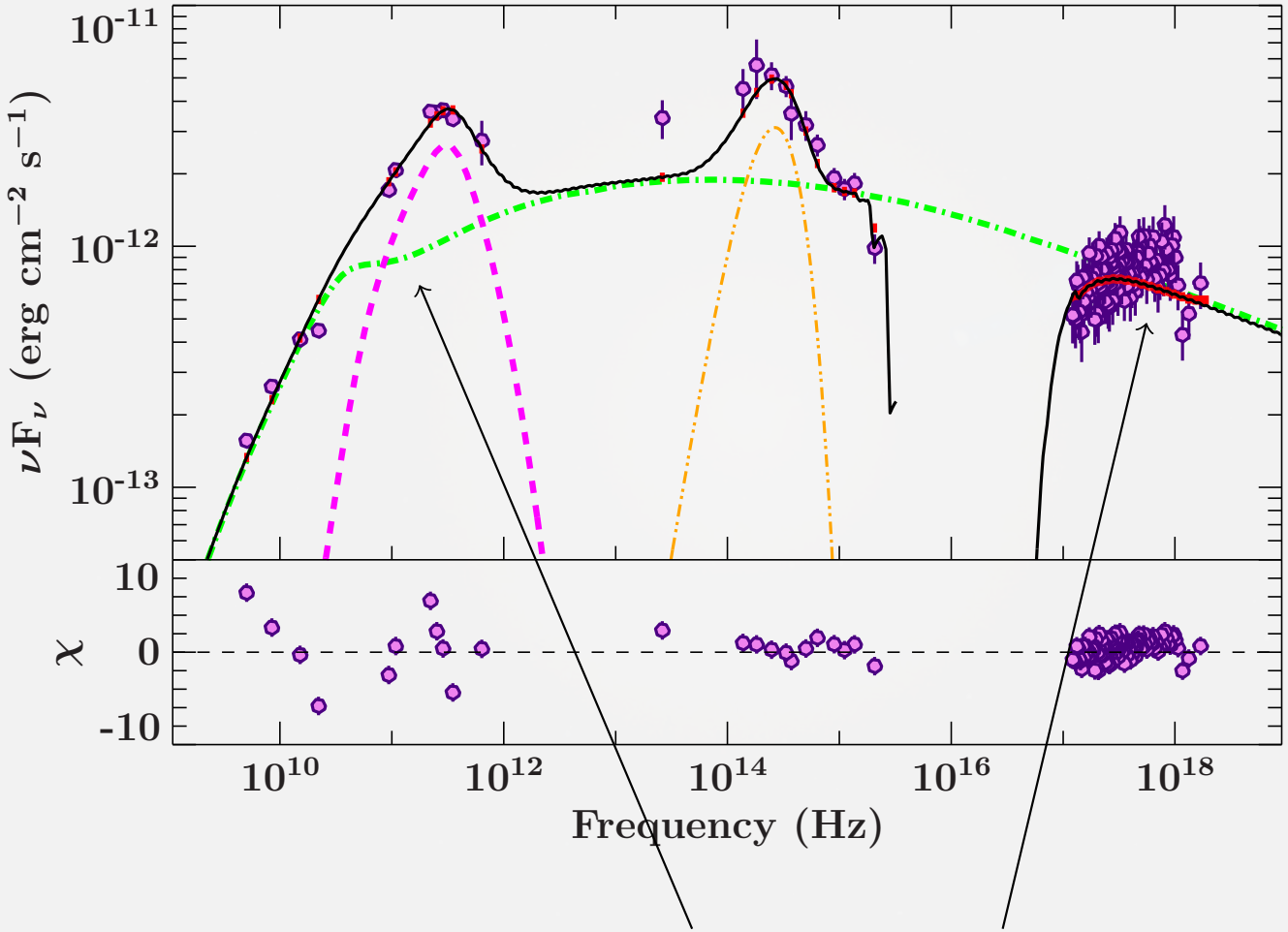
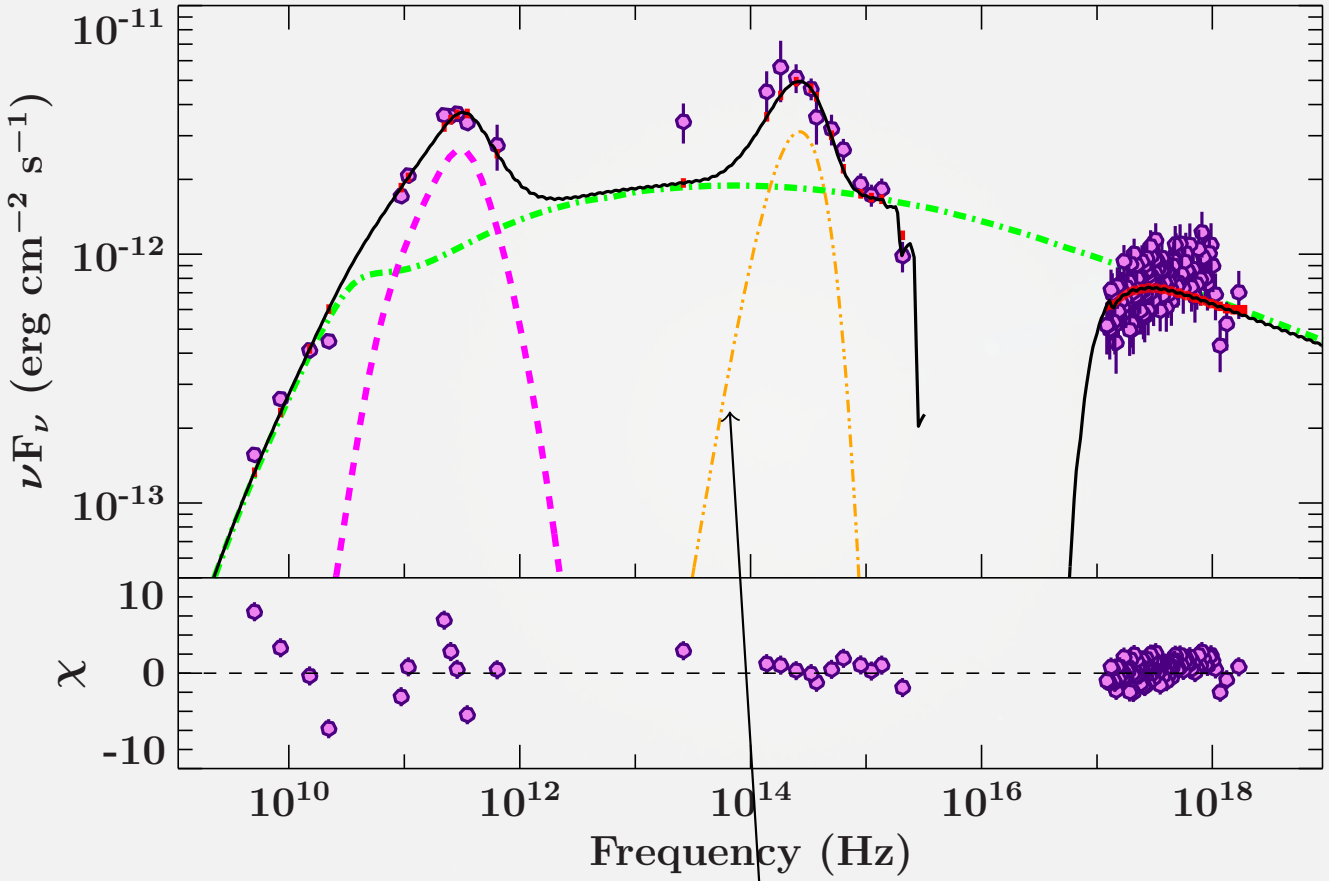


Radio/X-ray emission fit by thermal+non-thermal synchrotron

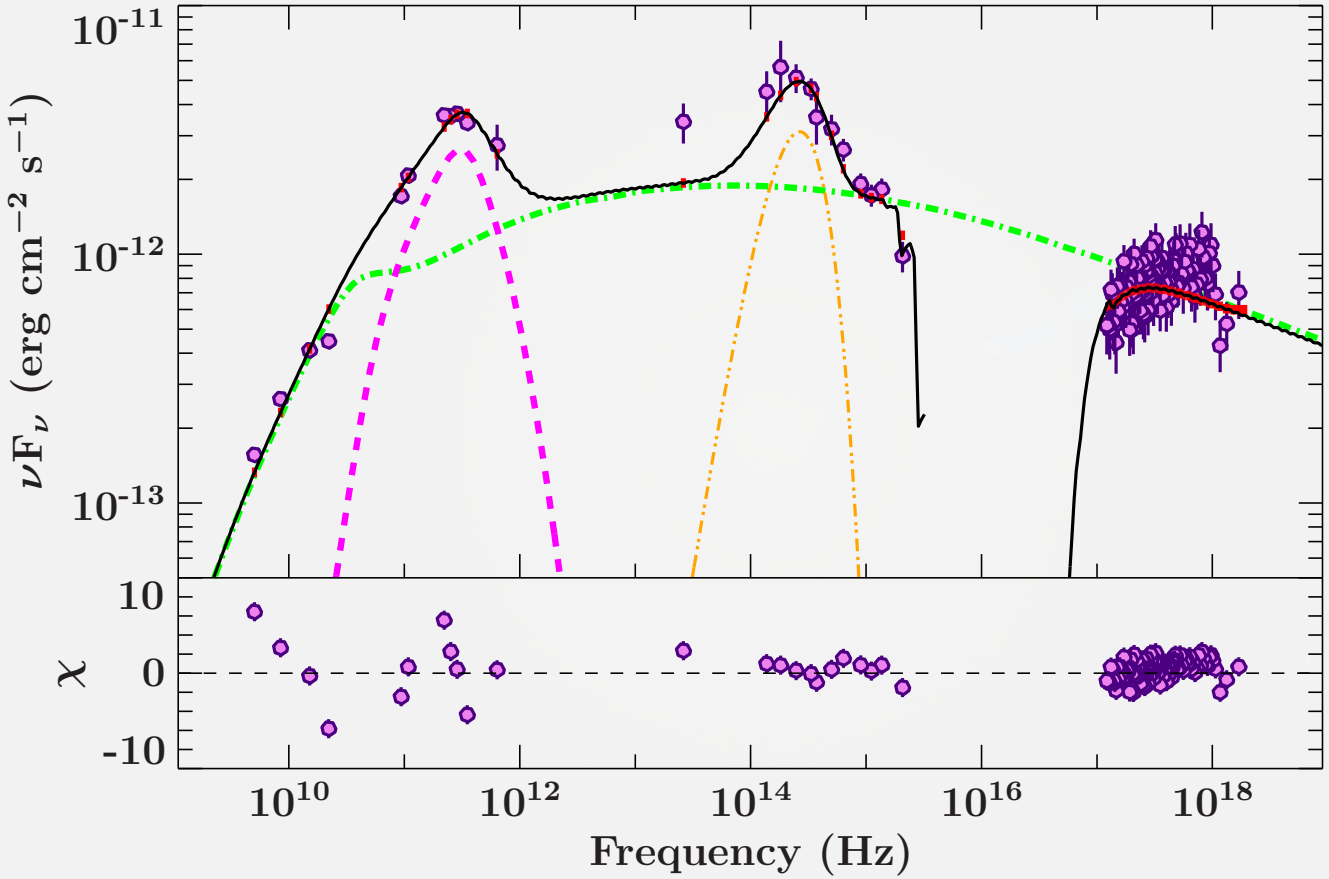
Modelling M87: synchrotron-dominated core



Radio/X-ray emission fit by thermal+non-thermal synchrotron

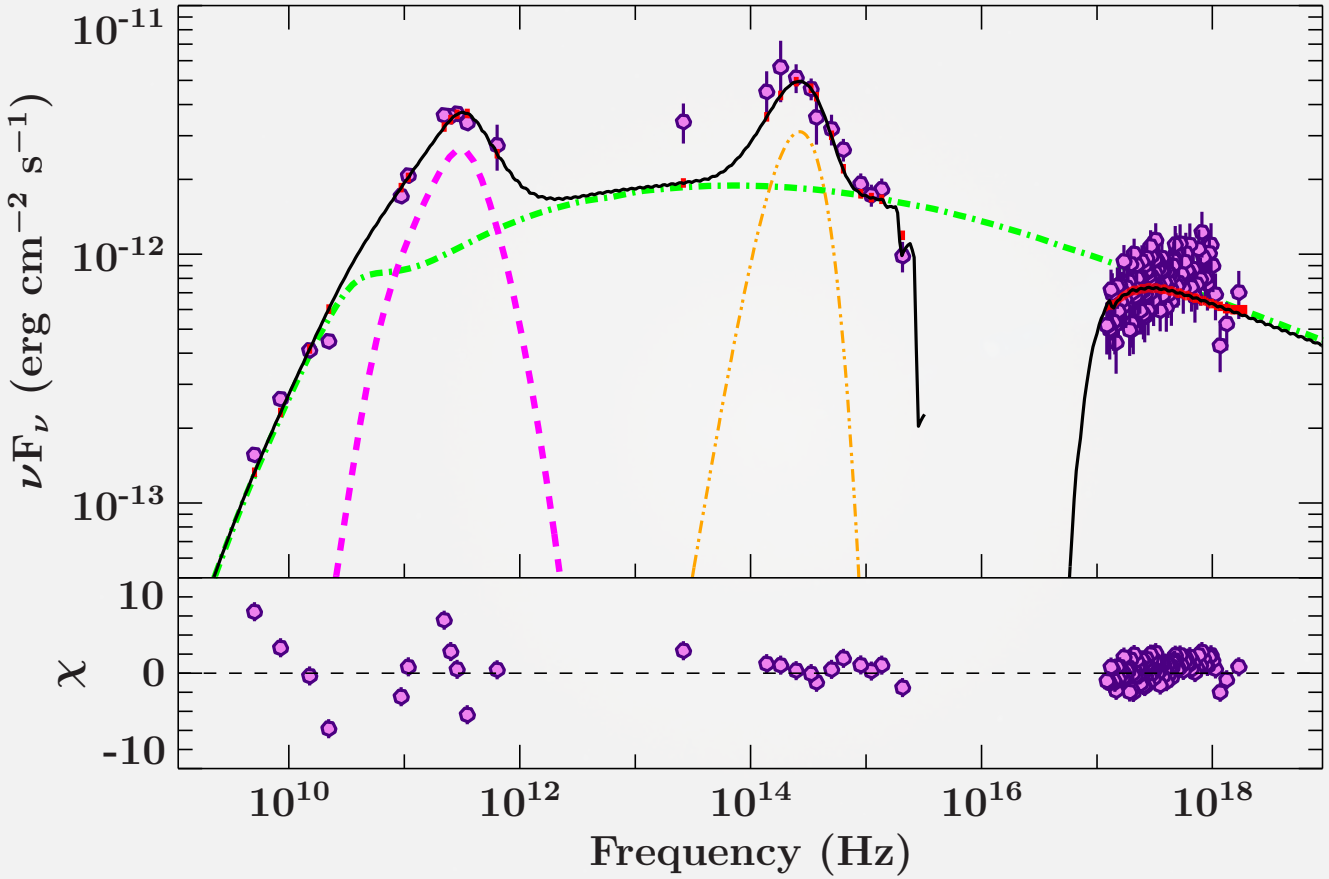
Black body (host galaxy?) dominates optical/IR

Modelling M87: synchrotron-dominated core



Low jet power: $P_{jet} \approx 10^{43}$ erg s^{-1}

Modelling M87: synchrotron-dominated core



Low jet power: $P_{jet} \approx 10^{43}\,\mathrm{erg\,s^{-1}}$

Particle acceleration close to BH: $z_{diss} \approx 100\,R_g$, $\sigma \gg 1$

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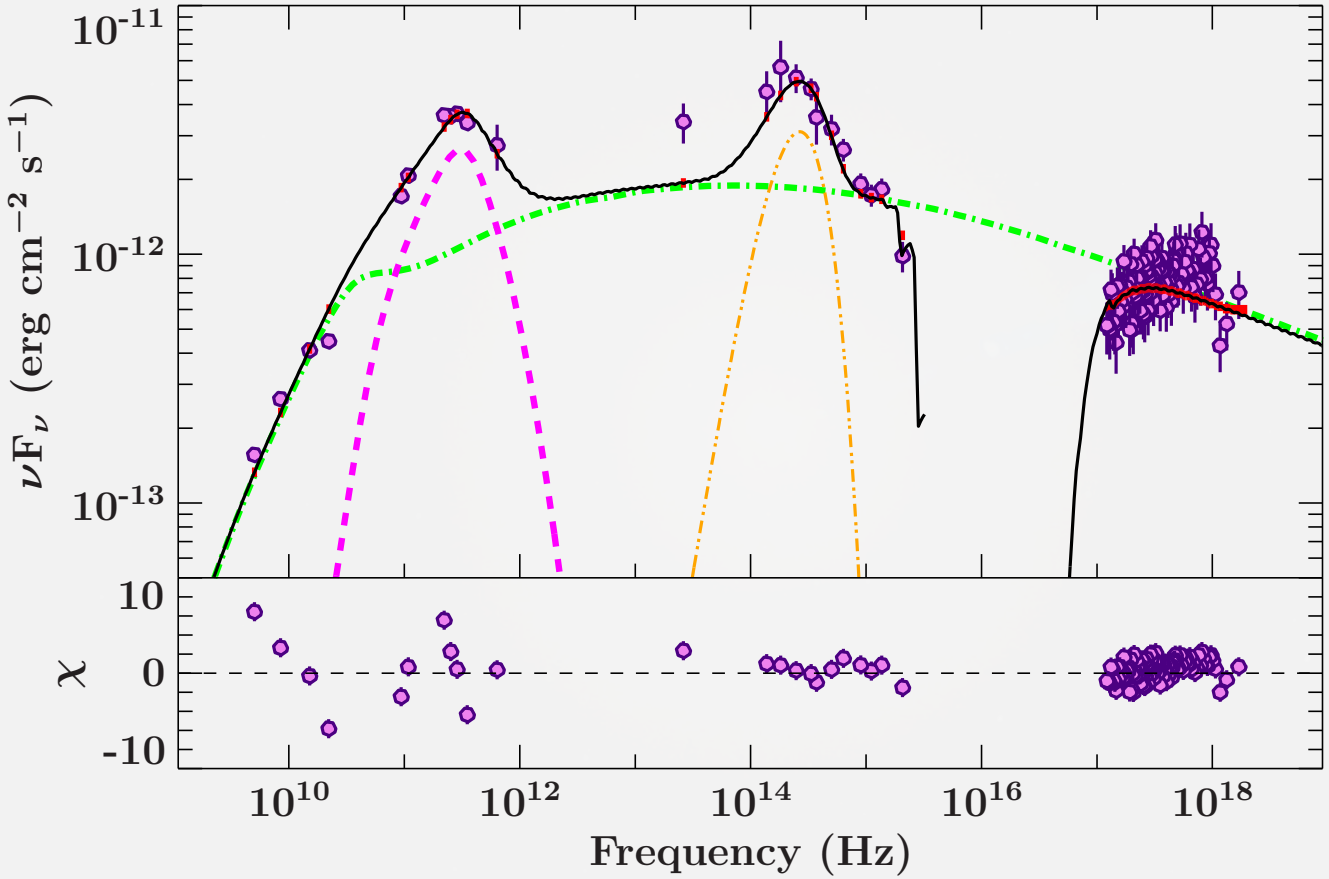
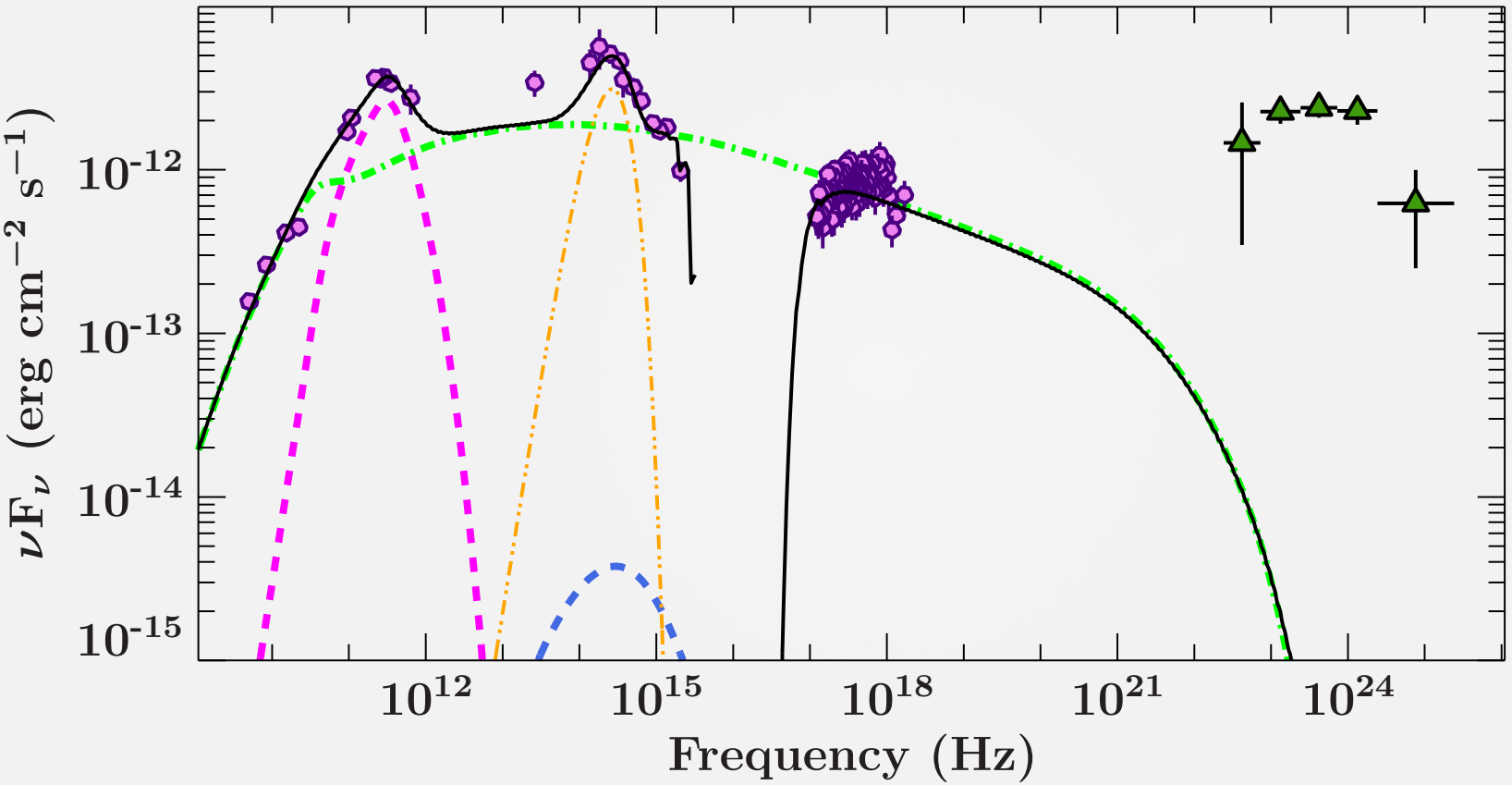


Low jet power: $P_{jet} \approx 10^{43}\,\mathrm{erg\,s^{-1}}$

Particle acceleration close to BH: $z_{diss} \approx 100\,R_g$, $\sigma \gg 1$

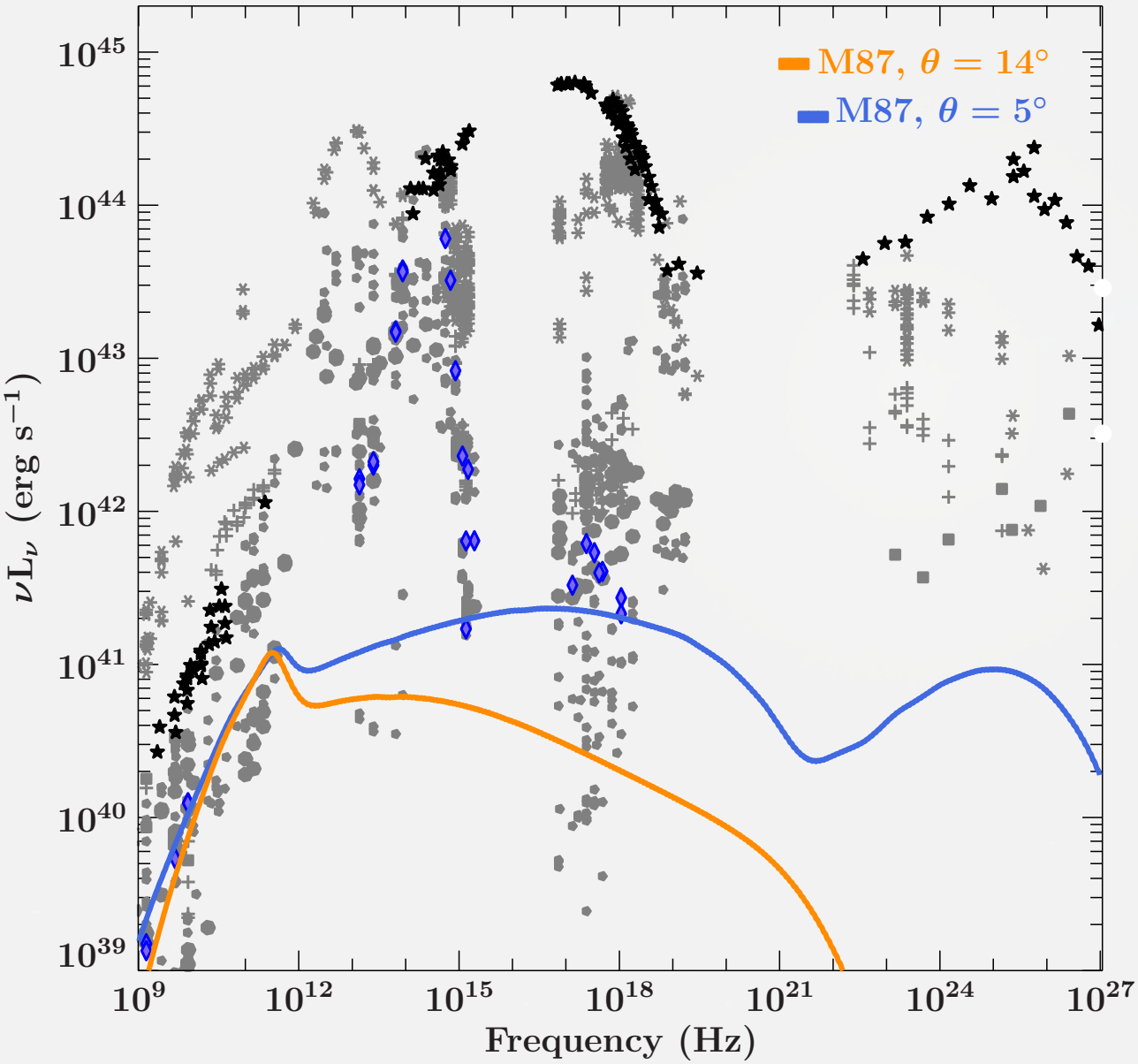
Compared to EHT simulations: "high" P_j, low L_X models favoured

Modelling M87: pc-scale SED+3FGL



IC from the core far below 3FGL!
Suggests different origin of γ-ray emission
e.g. spine/sheath, hadronic, kpc-scale...

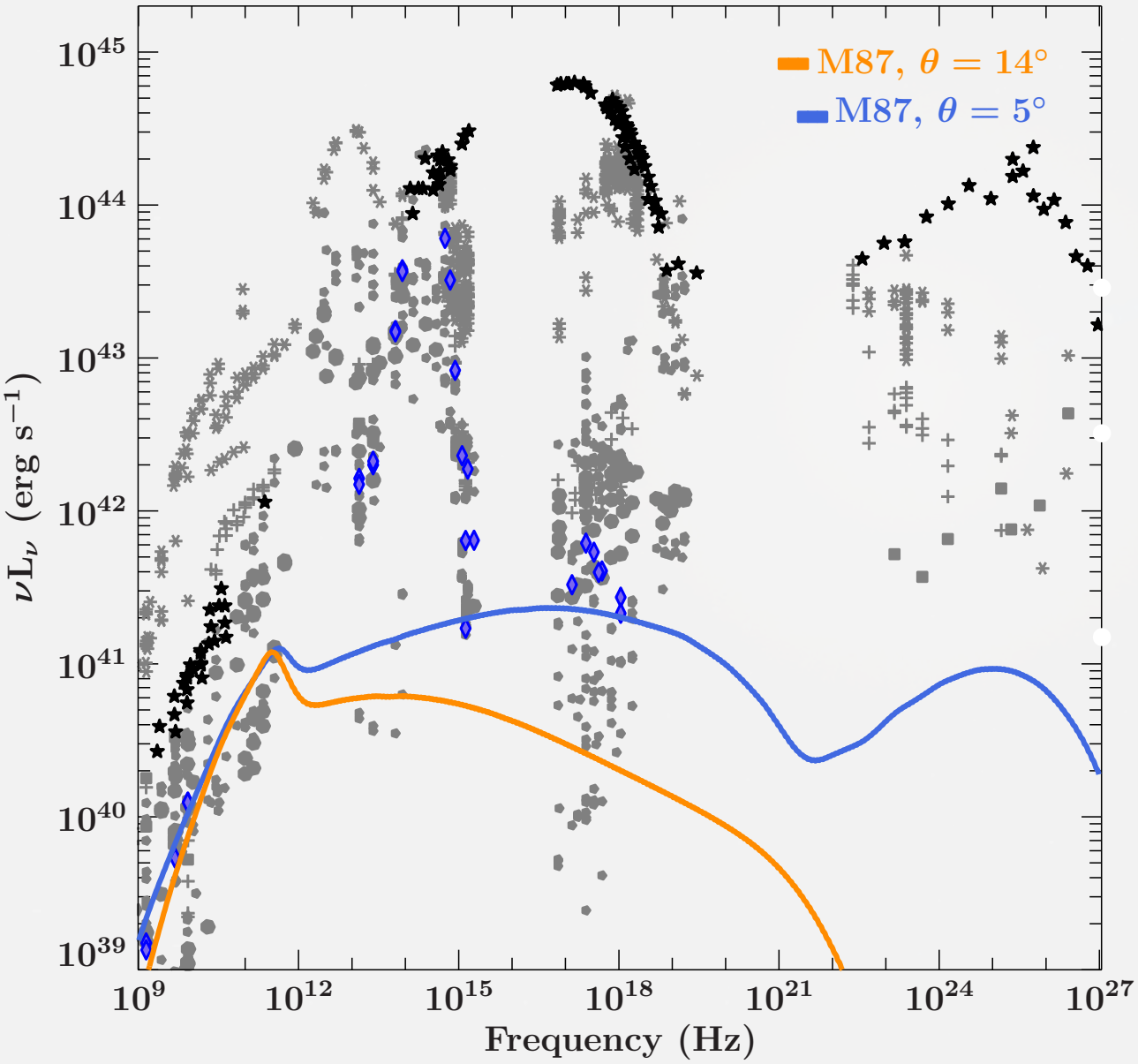
M87 vs nearby blazars



M87 is not a typical *Fermi* HBL, low power!

Beamed luminosity ≈1-4 orders of magnitude lower than *Fermi* sources

M87 vs nearby blazars



M87 is not a typical *Fermi* HBL, low power!

Beamed luminosity ≈1-4 orders of magnitude lower than *Fermi* sources

Consistent with power estimate from SED modelling

Conclusions

- M87: synchrotron-dominated X-rays, low jet power, particle acceleration close to BH

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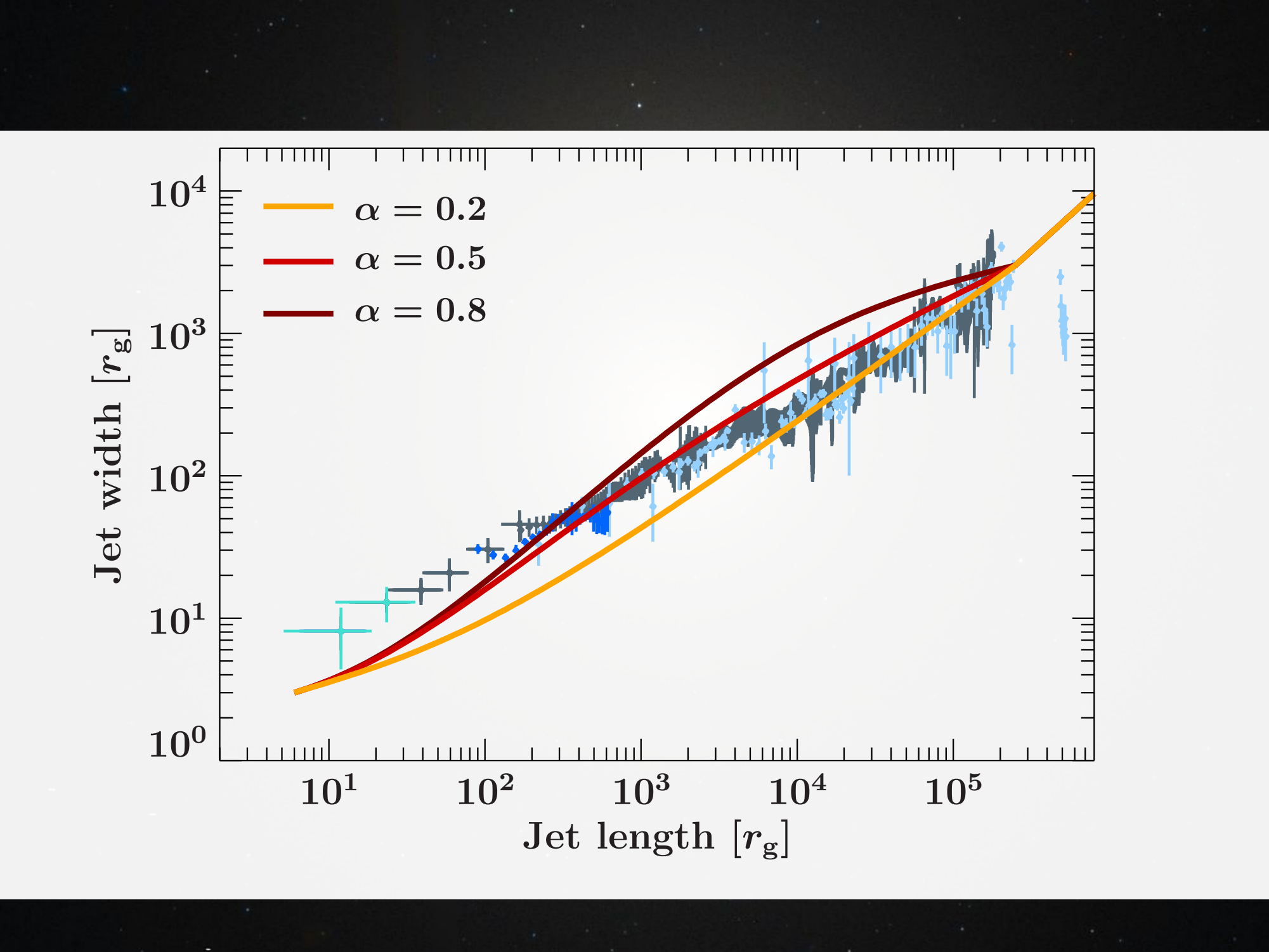
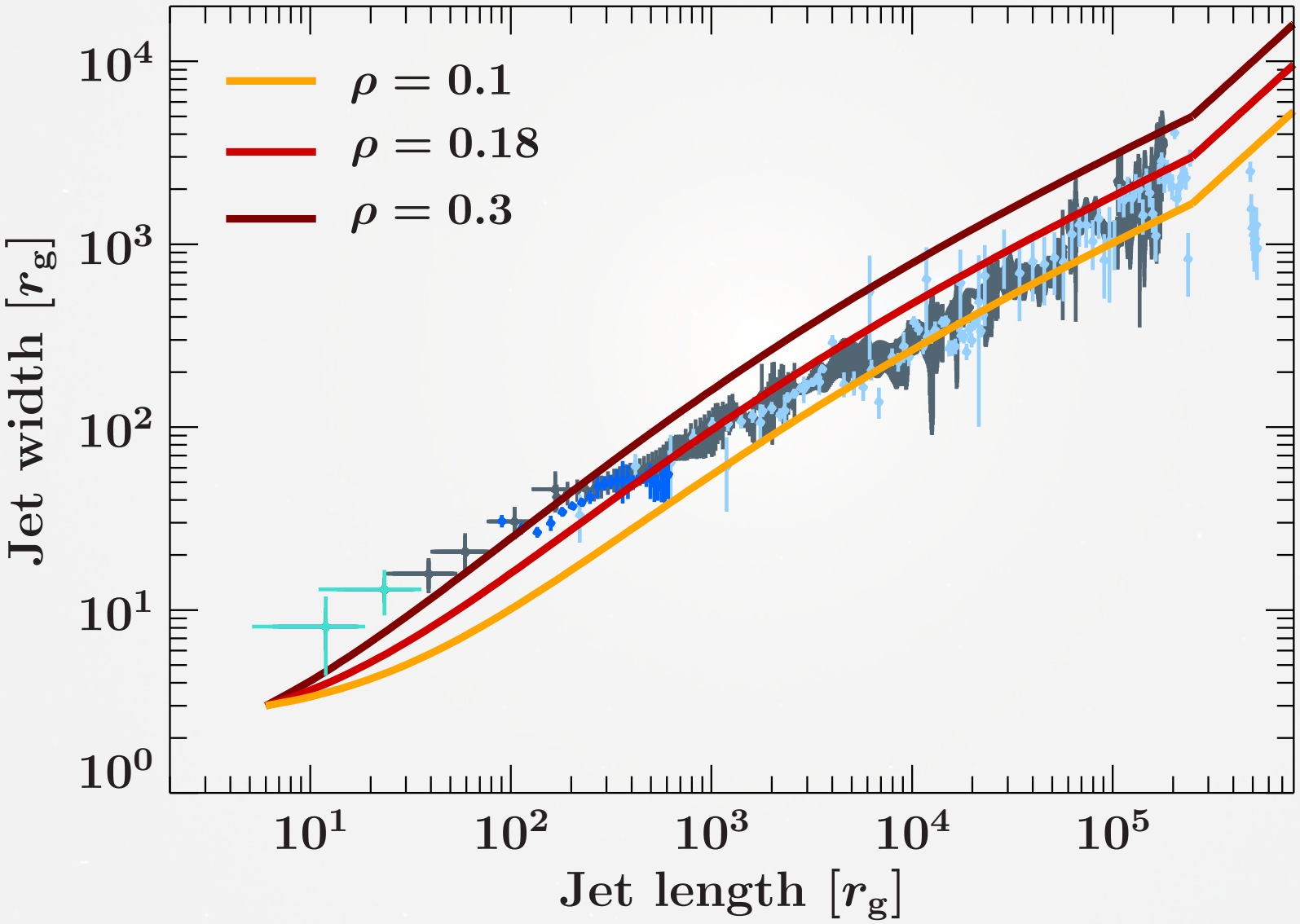
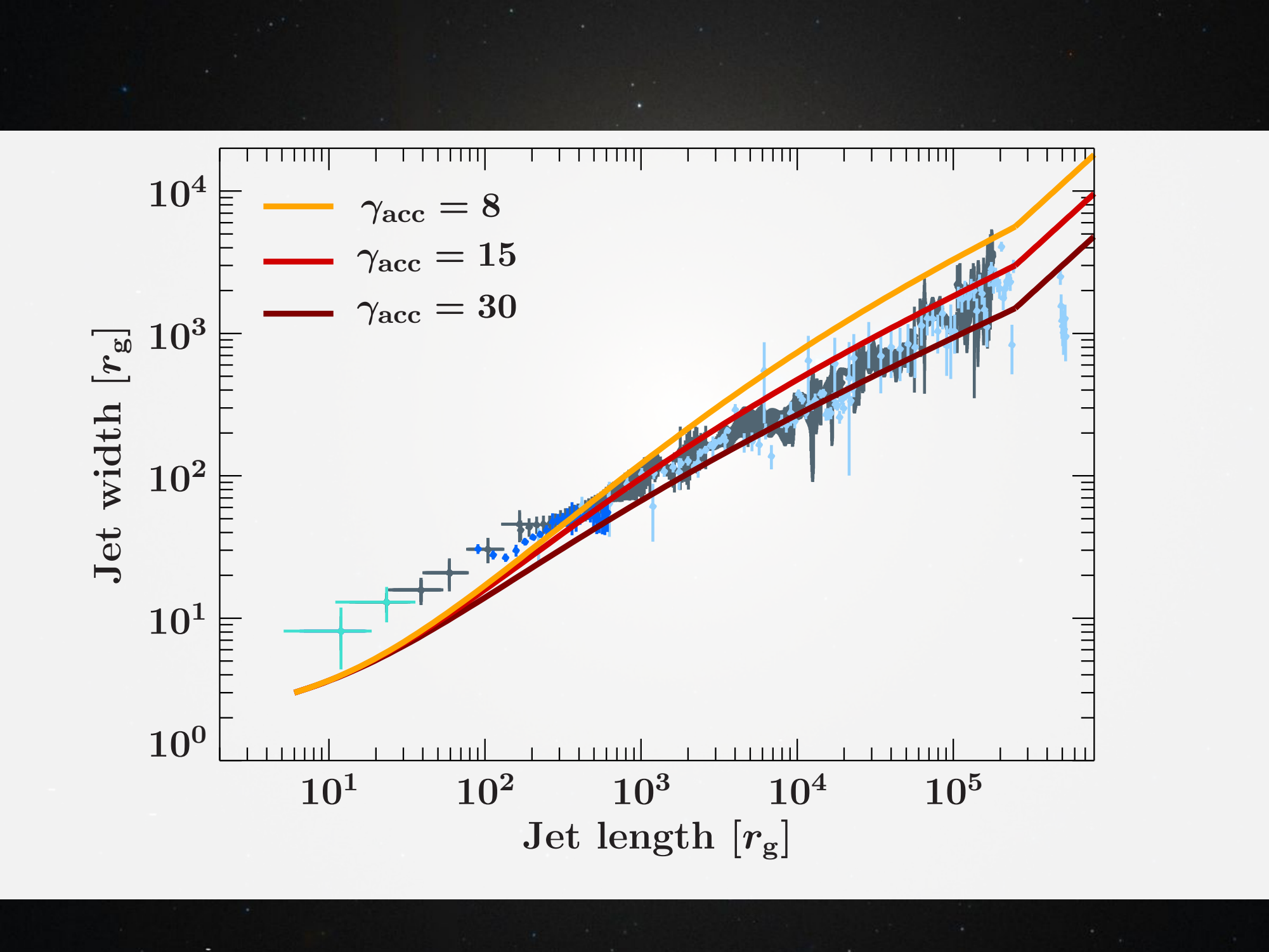
- M87 not misaligned counterpart of a regular γ-ray HBL!

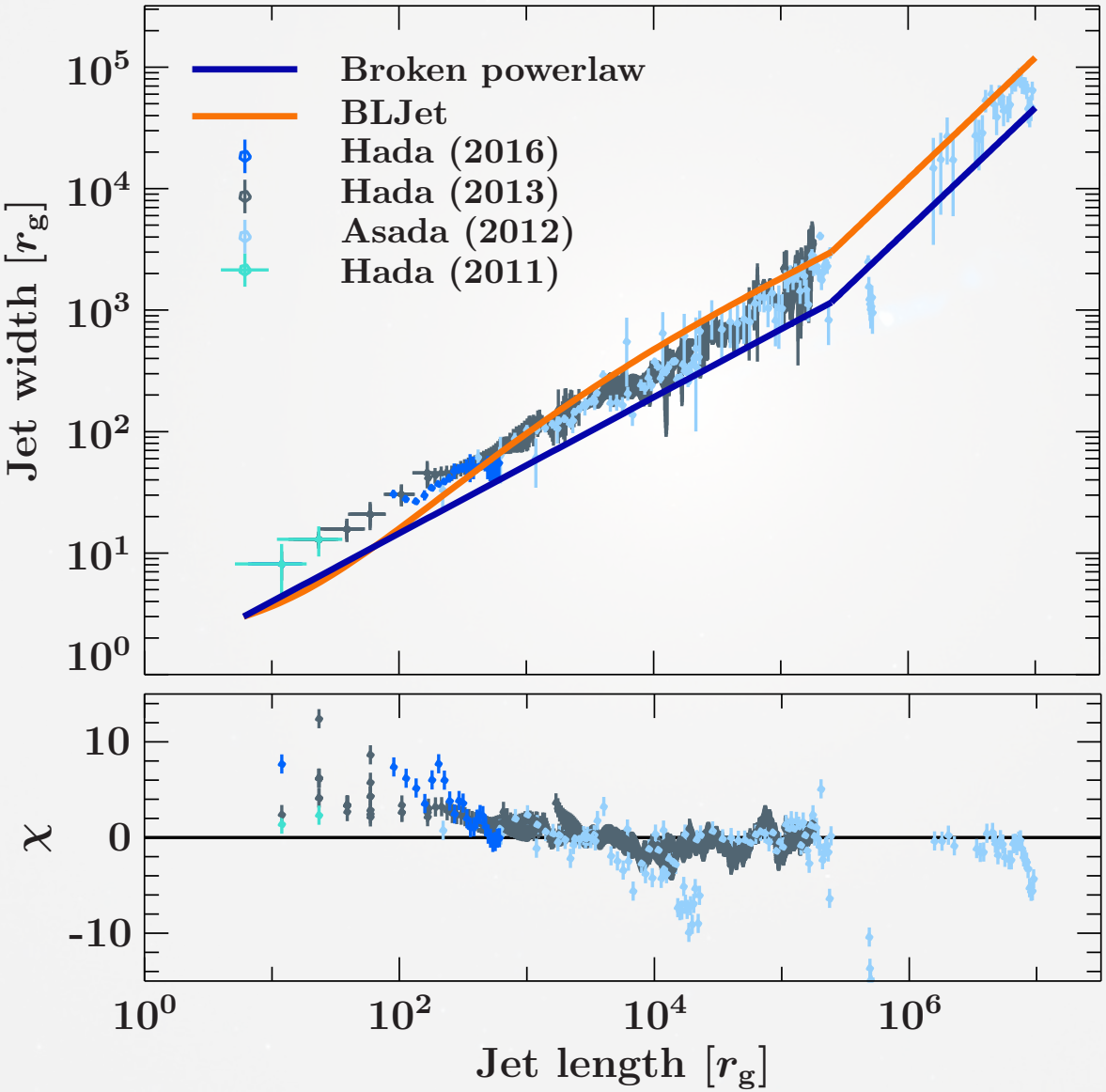
Conclusions

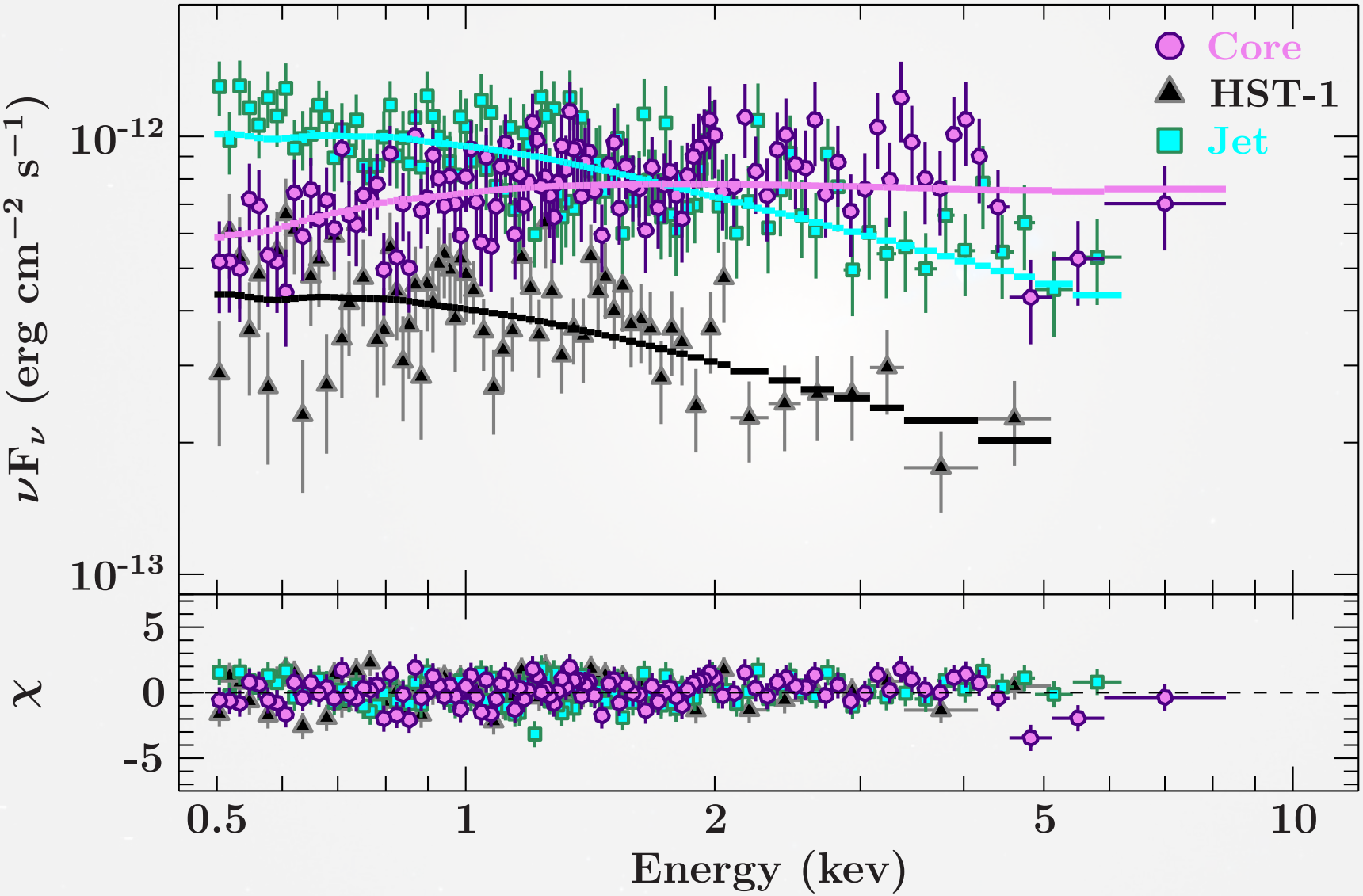
- M87: synchrotron-dominated X-rays, low jet power, particle acceleration close to BH
- M87 not misaligned counterpart of a regular γ-ray HBL!
- Future work: high power sources e.g. EHT calibrators


$\alpha = 0.2$
$\alpha = 0.5$
$\alpha = 0.8$
Jet width $[r_g]$
Jet length $[r_g]$
10^0
10^1
10^2
10^3
10^4
10^5


$\rho = 0.1$
$\rho = 0.18$
$\rho = 0.3$
Jet width [r_g]
Jet length [r_g]
10^0
10^1
10^2
10^3
10^4
10^5


$\gamma_{\rm acc} = 8$
$\gamma_{\rm acc} = 15$
$\gamma_{\rm acc} = 30$
Jet width $[r_{\rm g}]$
Jet length $[r_{\rm g}]$
10^0
10^1
10^2
10^3
10^4
10^5


Broken powerlaw
BLJet
Hada (2016)
Hada (2013)
Asada (2012)
Hada (2011)
Jet width [r_g]
10^5
10^4
10^3
10^2
10^1
10^0
χ
10
0
-10
10^0
10^2
10^4
10^6
Jet length [r_g]


Core
HST-1
Jet
10^{-12}
10^{-13}
νF_ν (erg cm^{-2} s^{-1})
χ
5
0
-5
0.5
1
2
5
10
Energy (kev)