

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

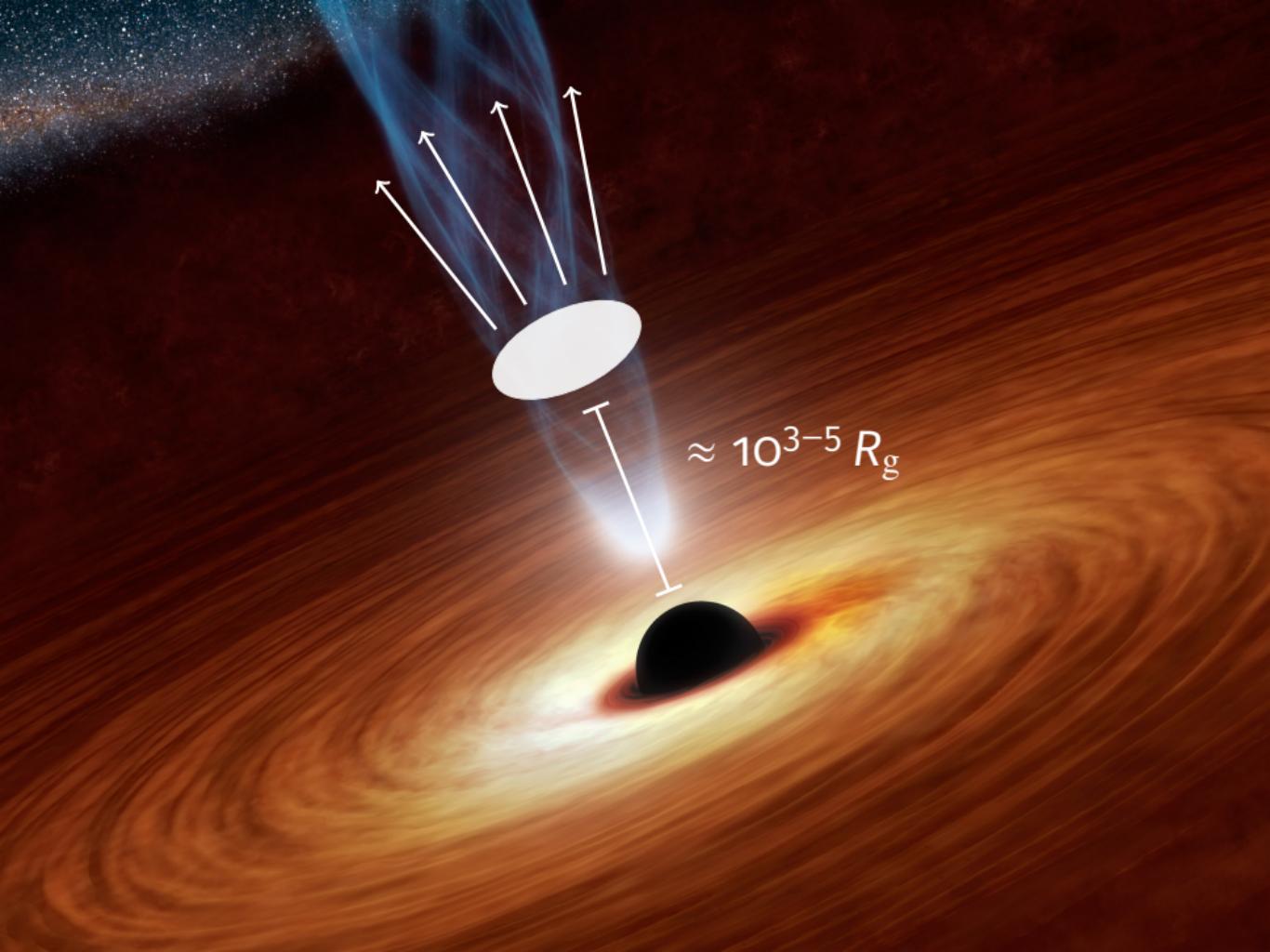
Matteo Lucchini, S. Markoff, F. Krauß, P. Crumley, R. M. T. Connors



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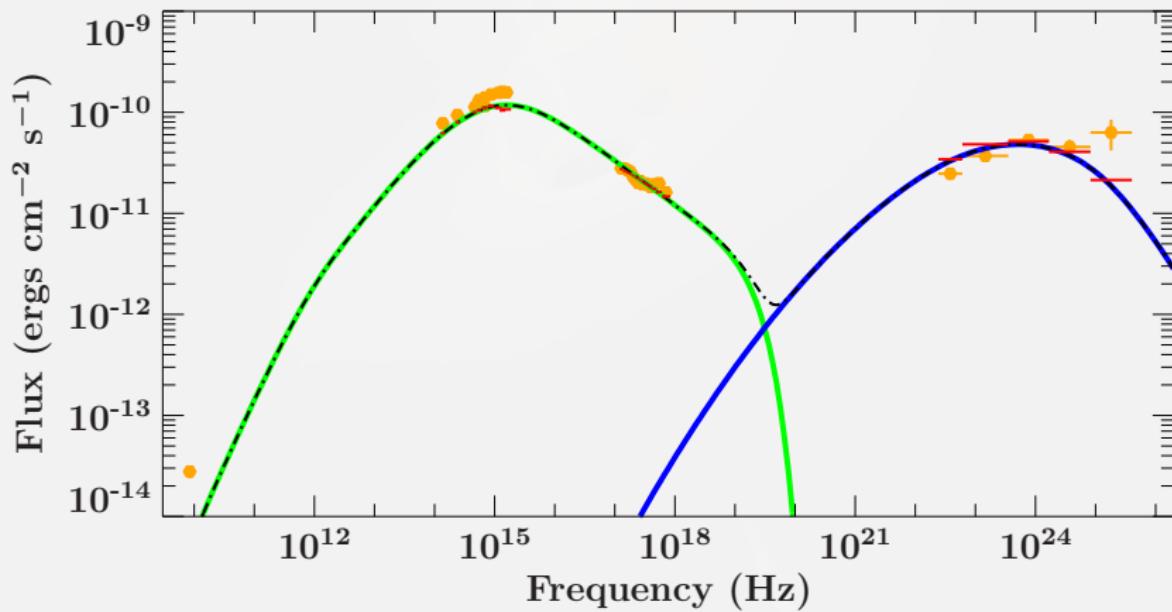




$$\approx 10^{3-5} R_g$$

Jetted AGN spectral energy distributions

Typical model: single zone (e.g. Böttcher et al 2013, Ghisellini et al 2014)

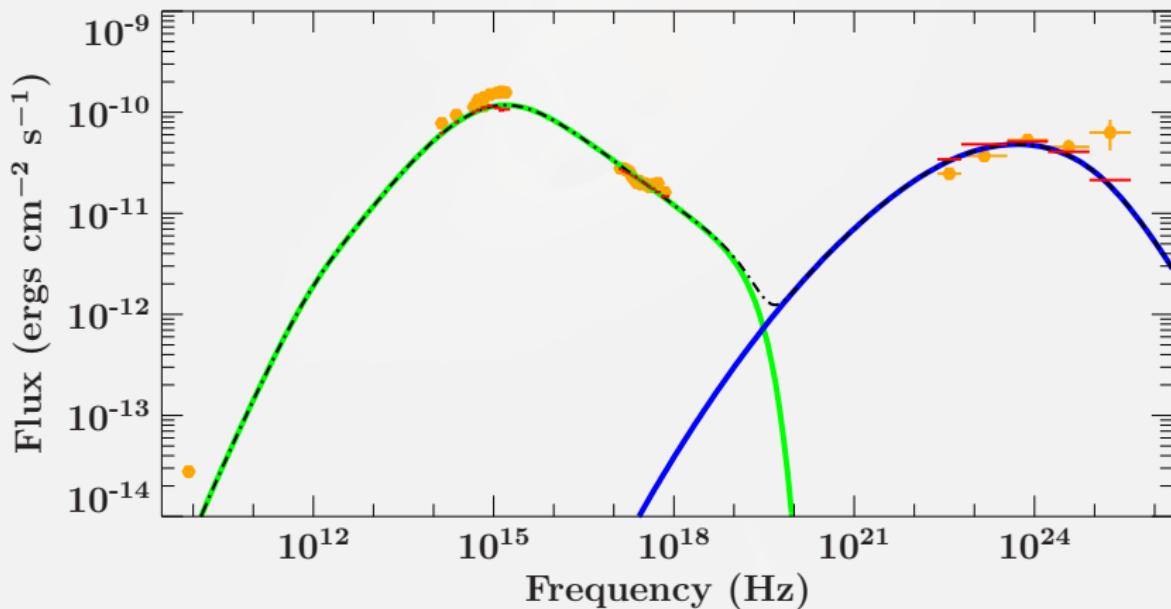


Jetted AGN spectral energy distributions

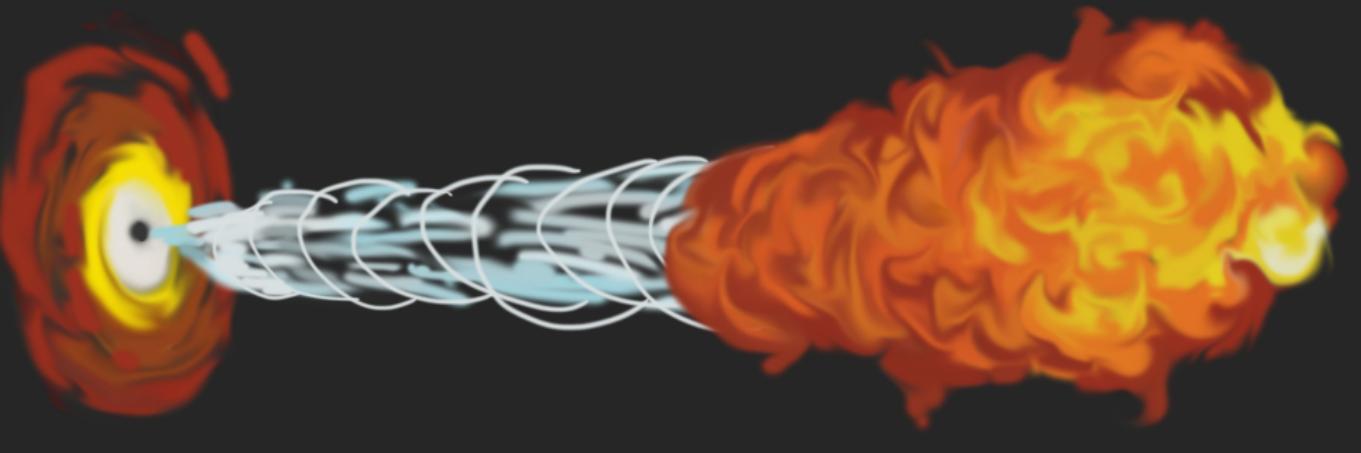
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Pros: very simple, quite successful

Cons: “too” simple, can’t reproduce radio data/extreme sources

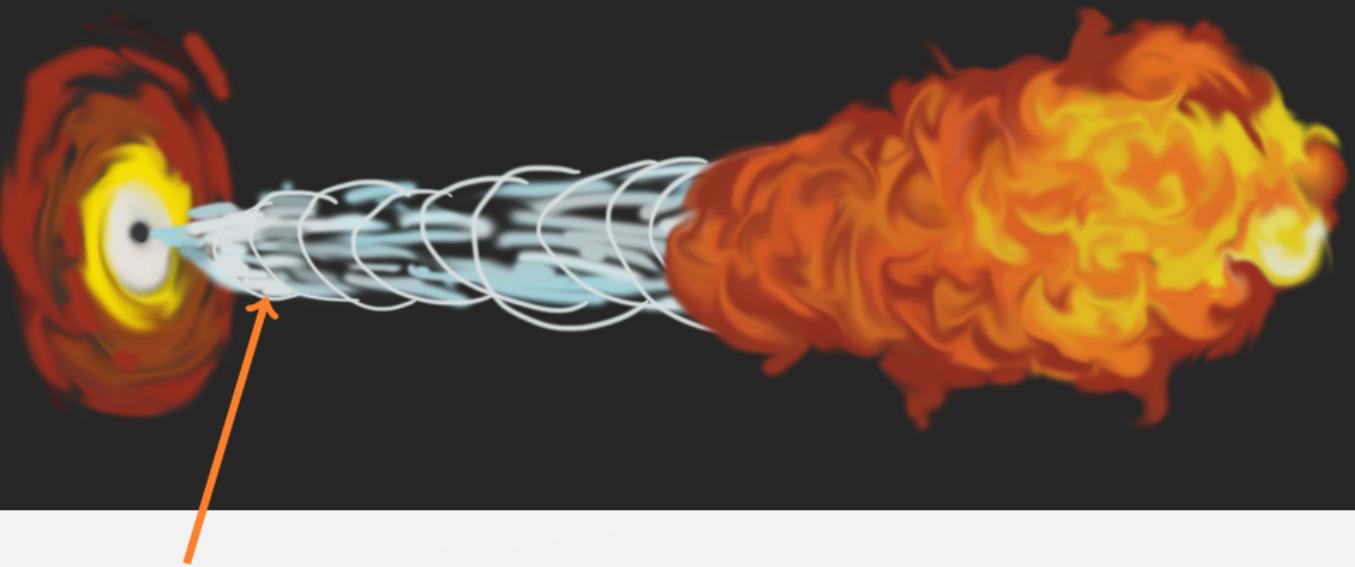


BLJet: a new multi-zone model



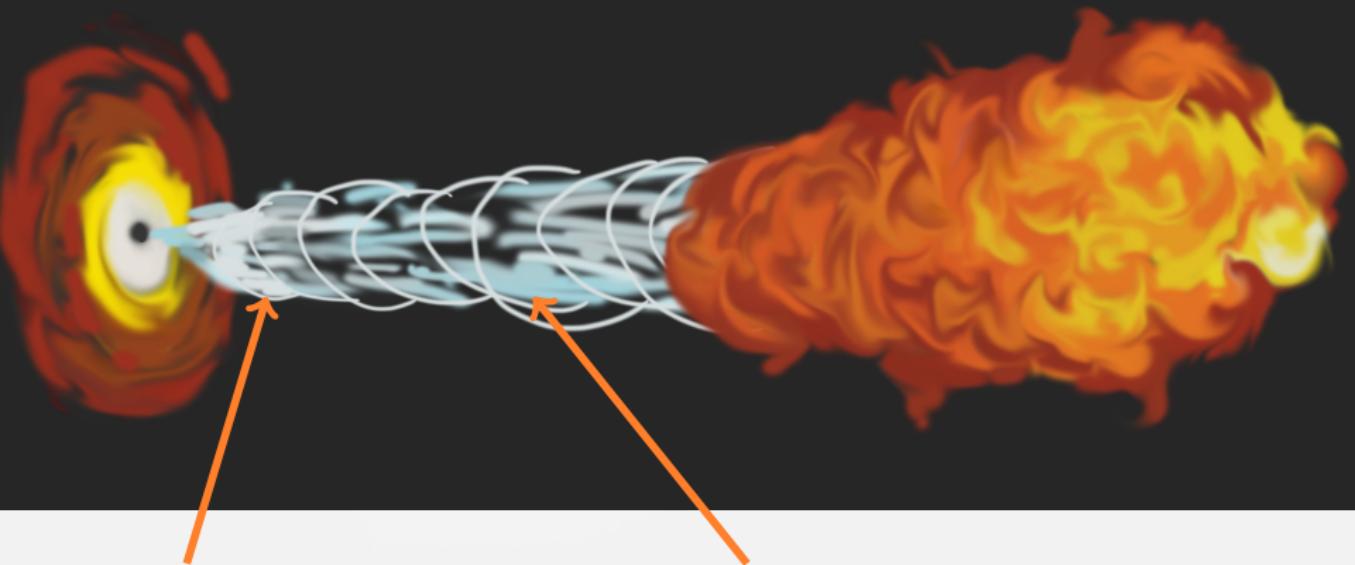
Extension of agnjet used for BHs/LLAGN (Markoff and Nowak 2001, Markoff et al 2005, Maitra et al 2009) to powerful blazar jets

BLJet: a new multi-zone model



Jet nozzle/corona:
power U_j , temperature T ,
magnetization σ_0
radius R_0

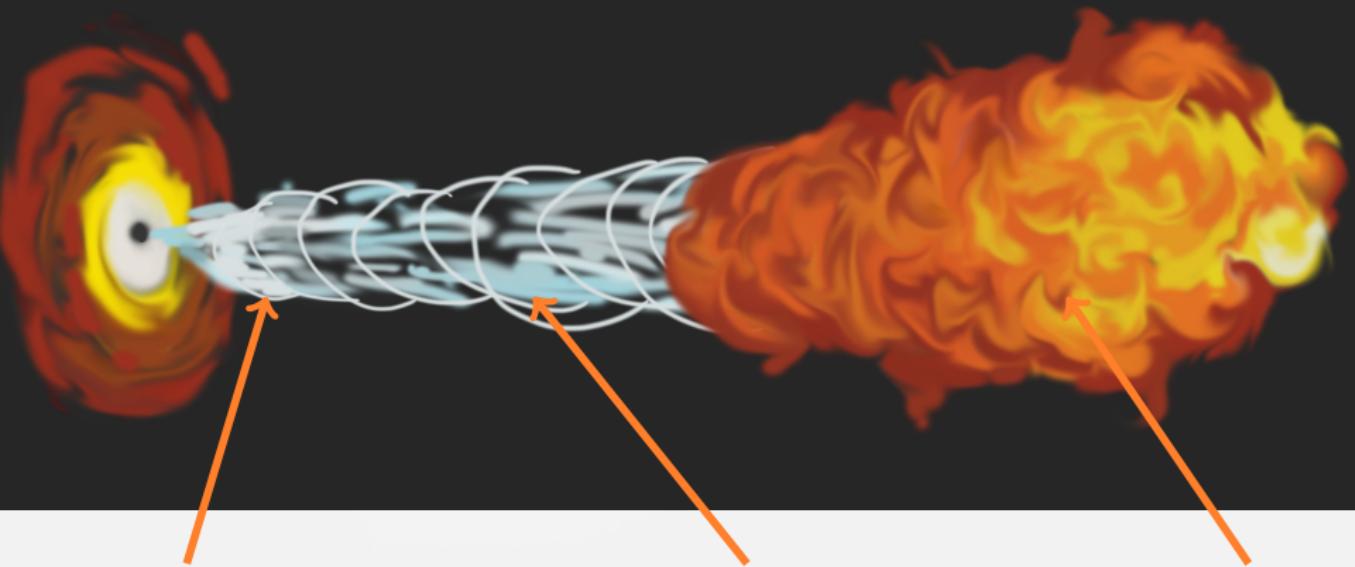
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acceleration region:
distance Z_{diss}
magnetization σ_{diss}

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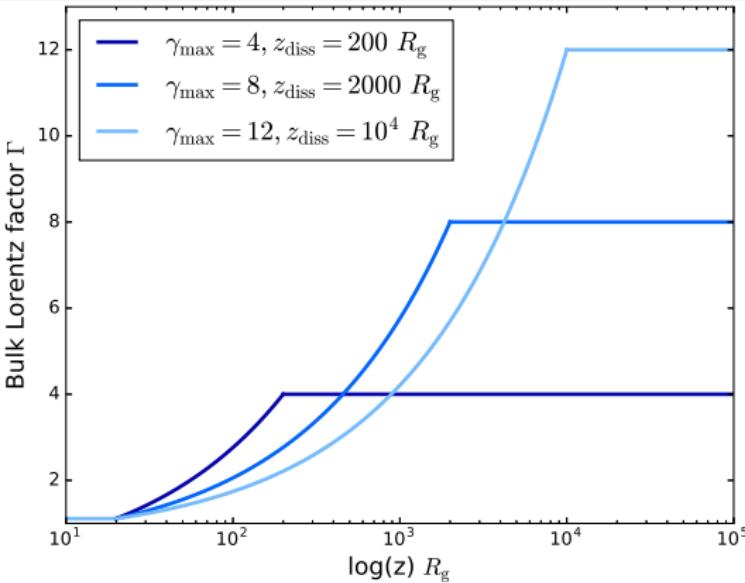


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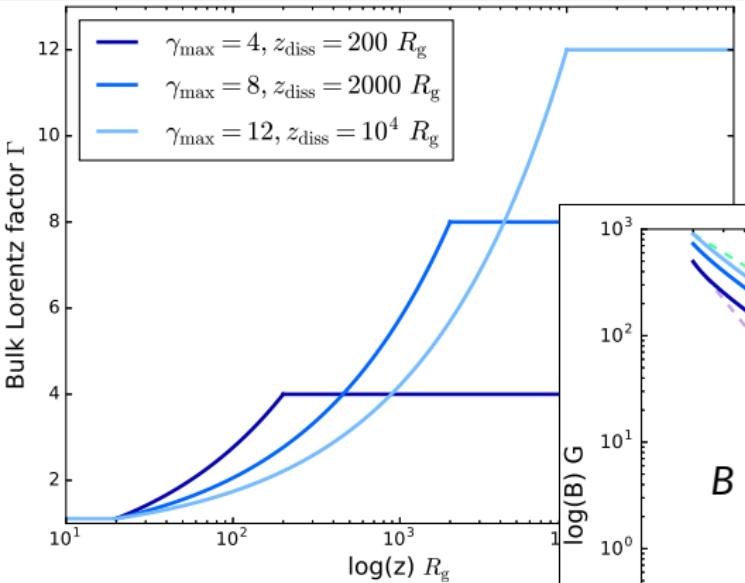
Outer jet:
non-thermal
tail: $f_{\text{heat}}, \gamma_{\text{brk}}, \gamma_{\text{max}}$

Magnetically-accelerated jets

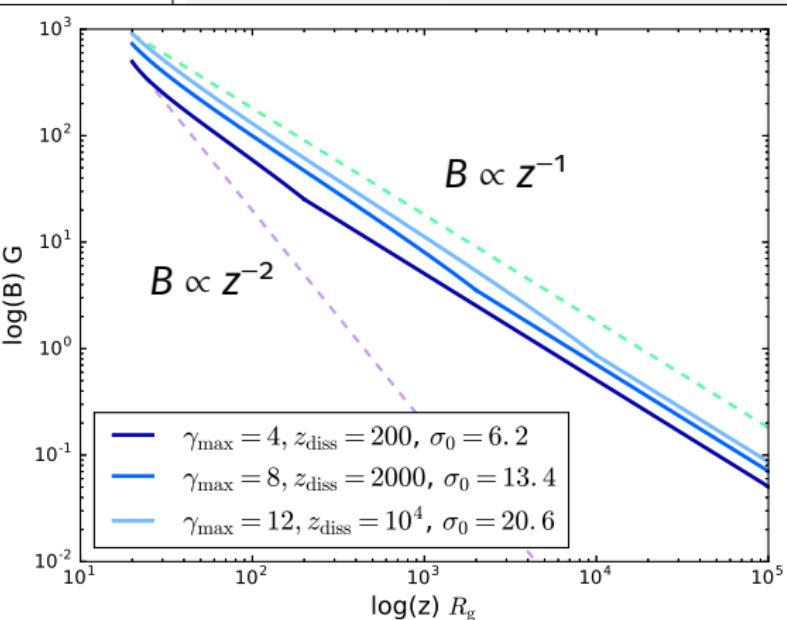


During acceleration $\gamma \propto z^{1/2}$
(Beskin and Nokhrina 2006,
Potter and Cotter 2012,13,14)

Magnetically-accelerated jets



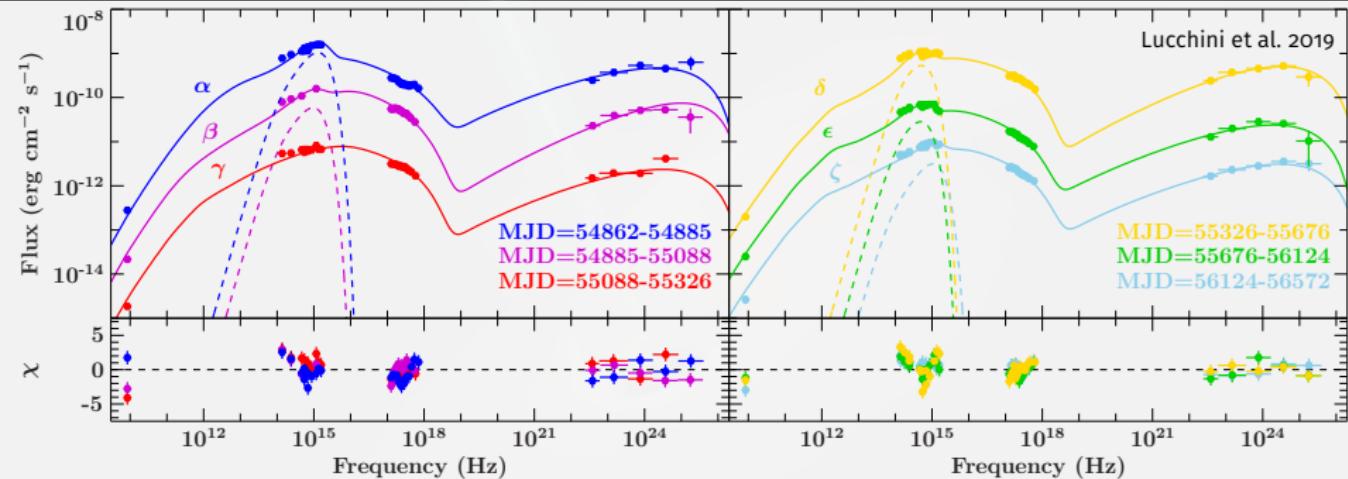
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Energy conserved:

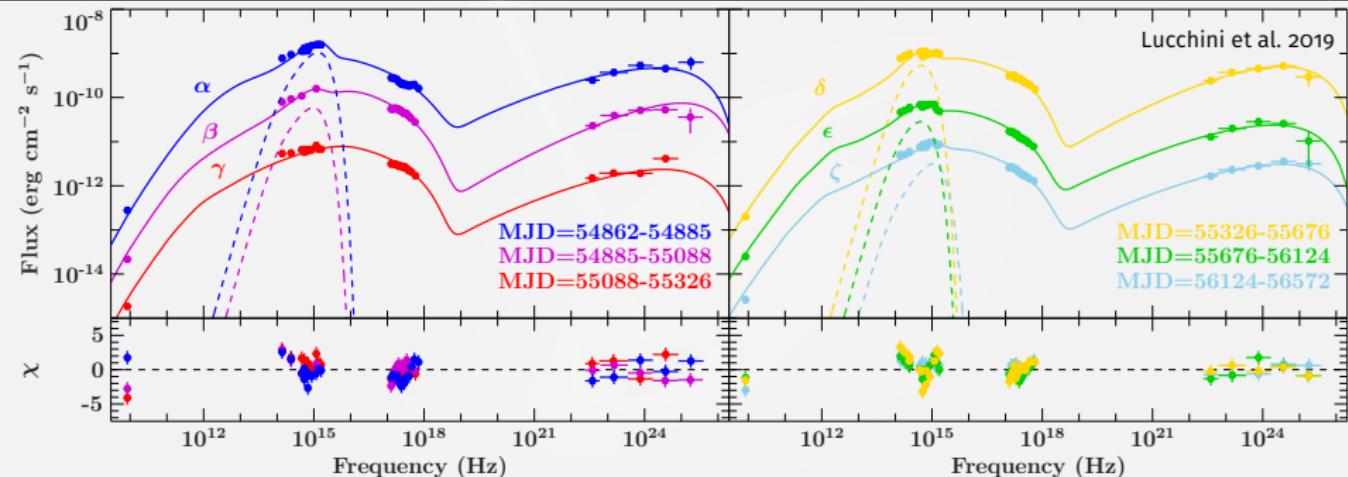
$$B = B(\gamma(z))$$

First application: BL Lac PKS2155-304



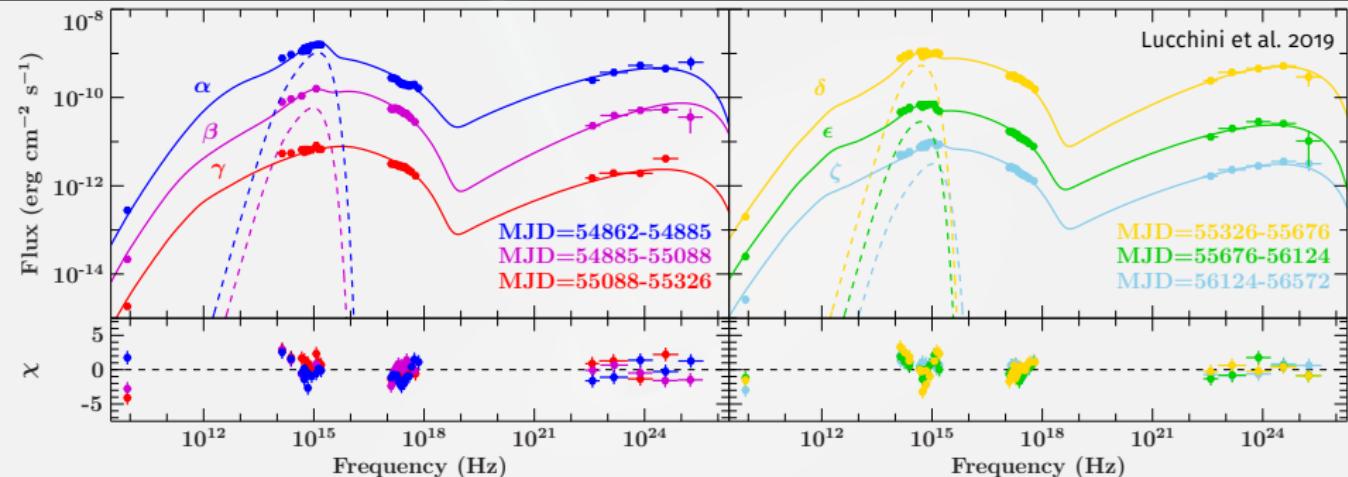
- Six quasi-simultaneous SEDs (Krauß et al. 2016), model long-term variability

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- Excellent data: I can use statistics instead of “fitting by eye”!
- Radio to γ -ray data reproduced with reasonable parameters, however

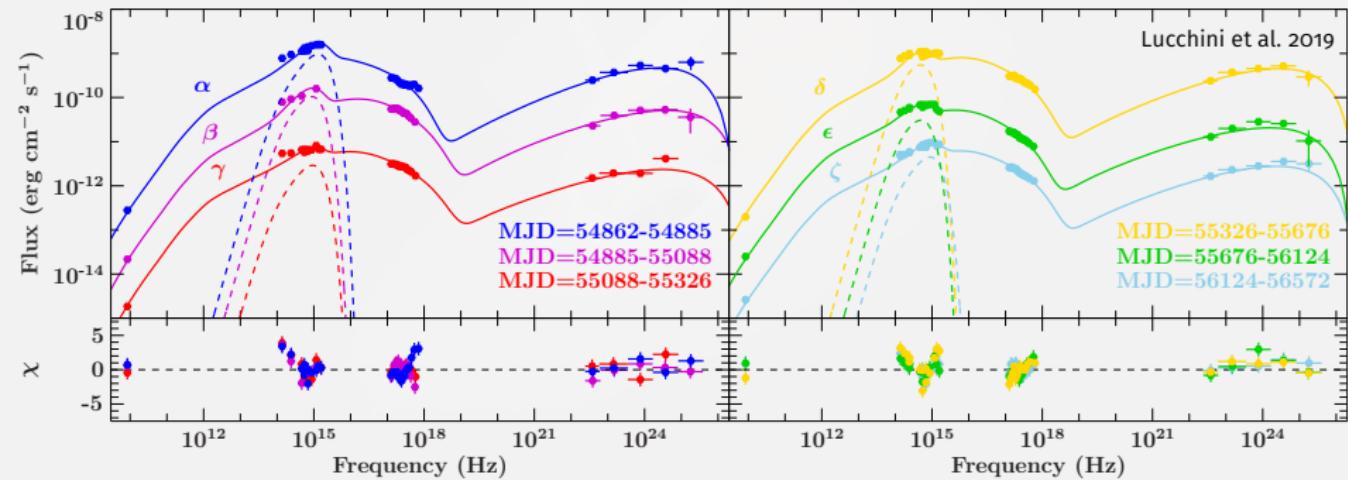
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- Six quasi-simultaneous SEDs (Krauß et al. 2016), model long-term variability
- Excellent data: I can use statistics instead of “fitting by eye”!
- Radio to γ -ray data reproduced with reasonable parameters, however
- Degeneracy, multi-modal parameter space

Modelling PKS2155-304: joint fits

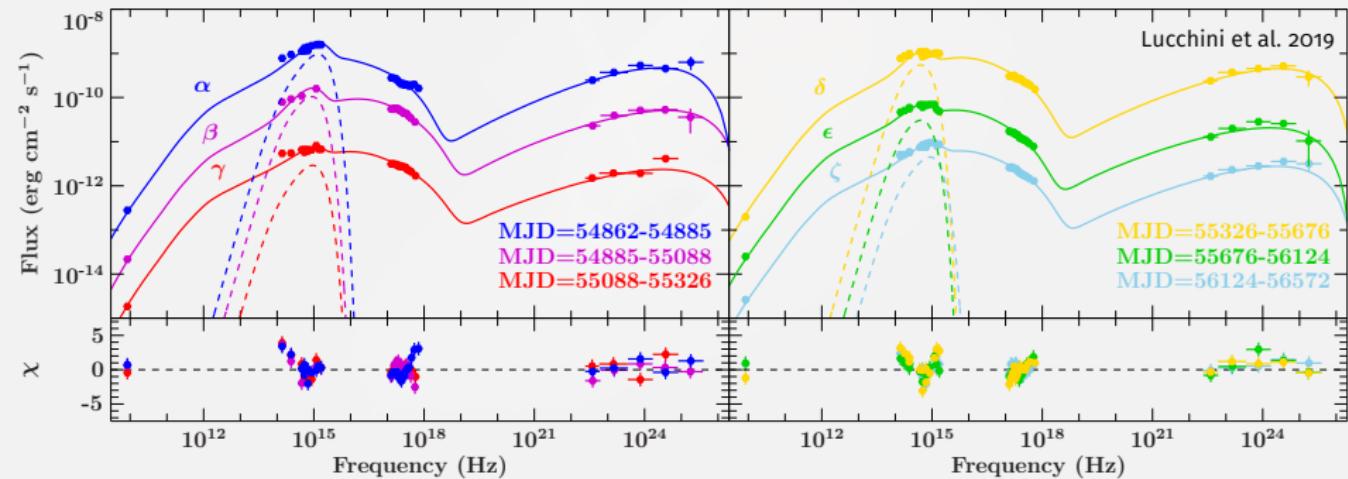
Degenerate parameters tied together while fitting:



Constant dynamics/geometry; bulk acceleration on small scales

Modelling PKS2155-304: joint fits

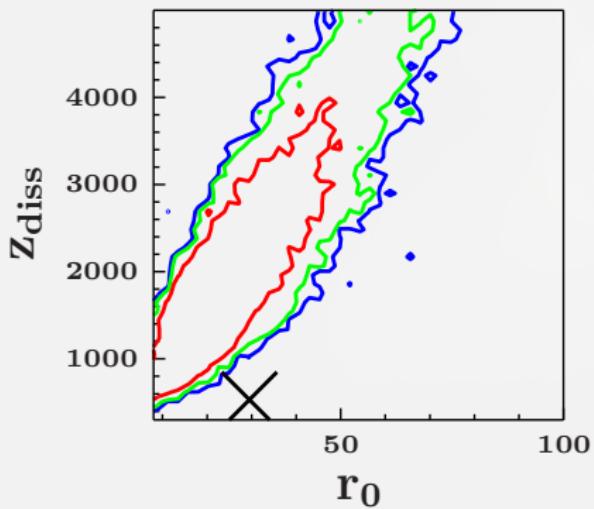
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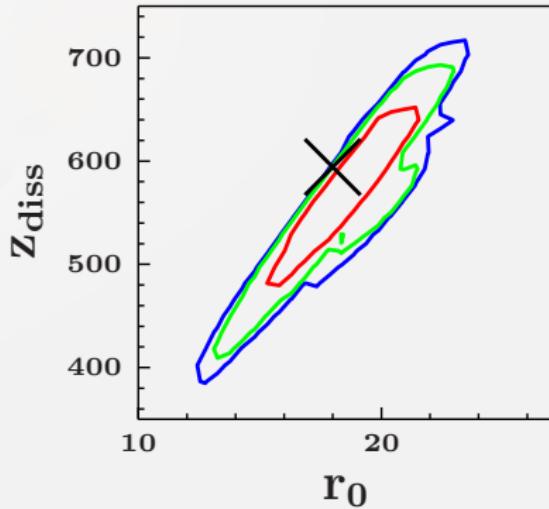
Constant dynamics/geometry; bulk acceleration on small scales
Long term variability reproduced by changes in particle distribution
Parameter space is very well behaved!

Modelling PKS2155-304: degeneracies

Individual fit:

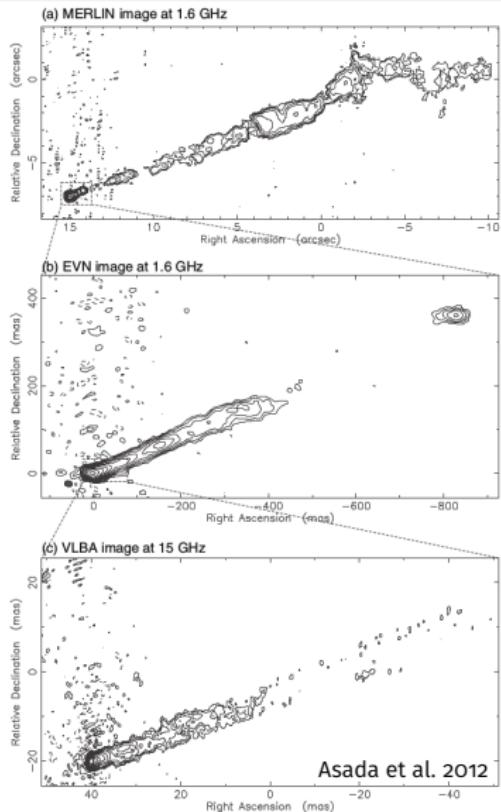


Joint fit:



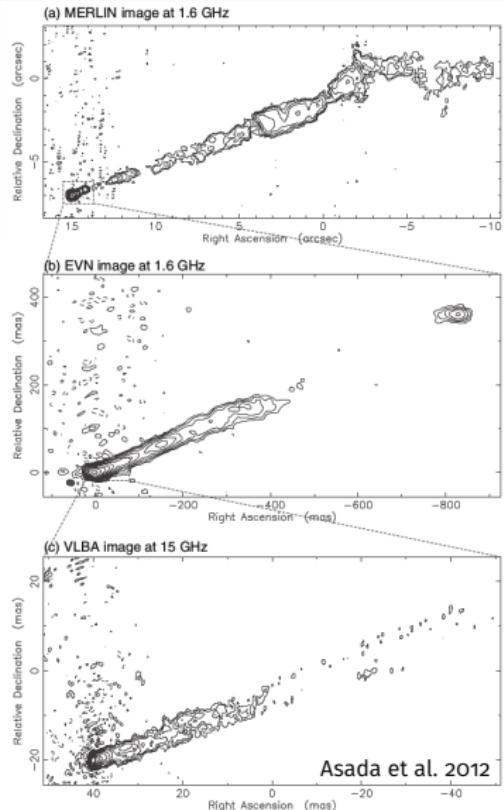
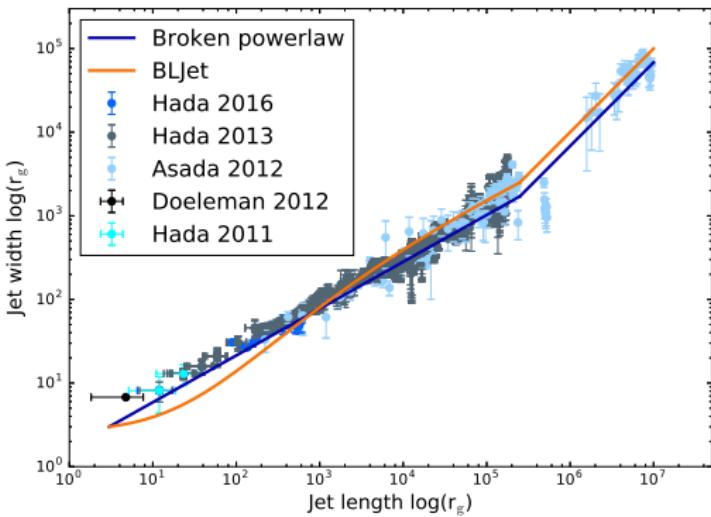
Second application: M87

- Very close to Earth + large BH mass → Event Horizon Telescope target
- VLBI mapping of jet profile

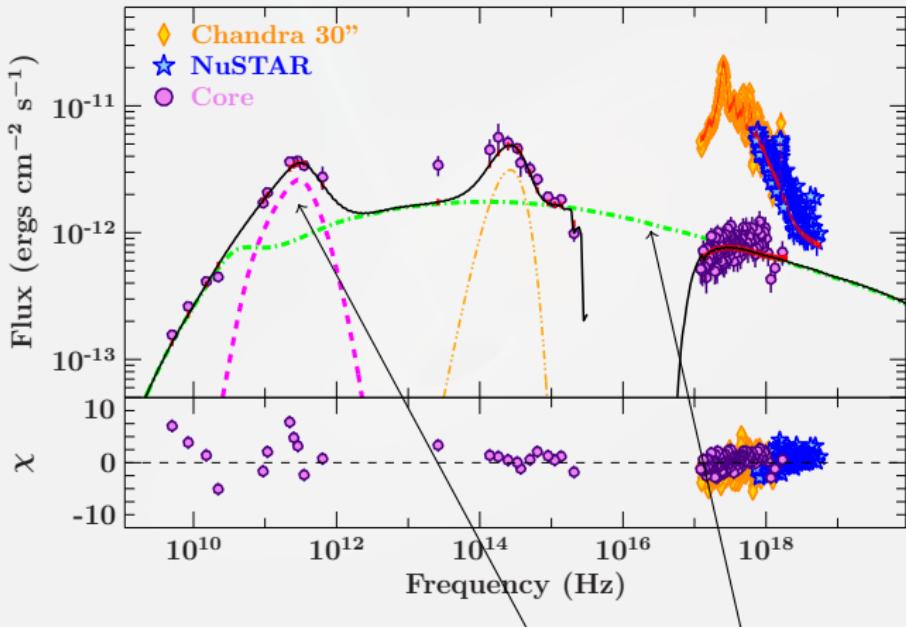


Second application: M87

- Very close to Earth + large BH mass → Event Horizon Telescope target
- VLBI mapping of jet profile
- Profile transition at $\approx 10^5 R_g$

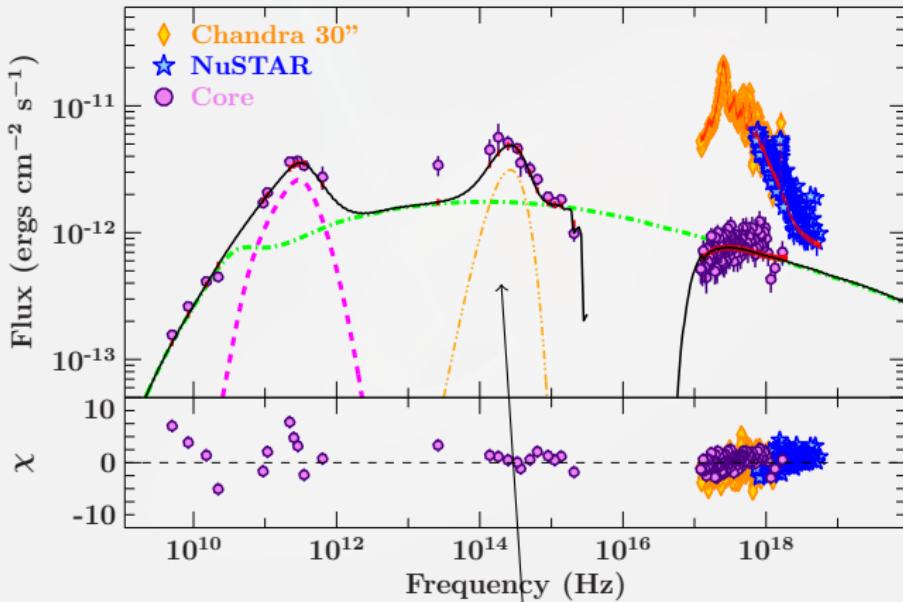


Modelling M87: resolved SED+NuSTAR



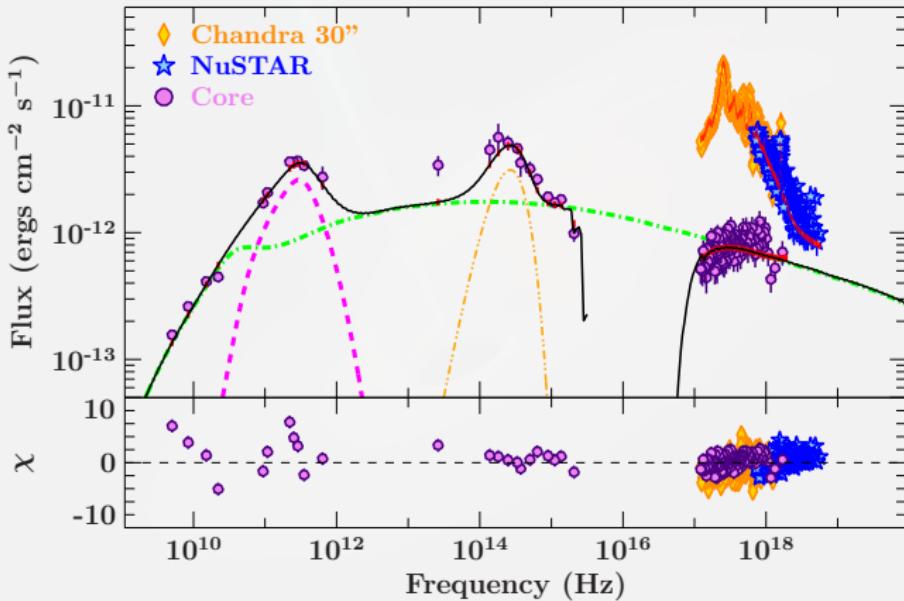
Radio/X-ray emission fit by thermal+non-thermal synchrotron

Modelling M87: resolved SED+NuSTAR



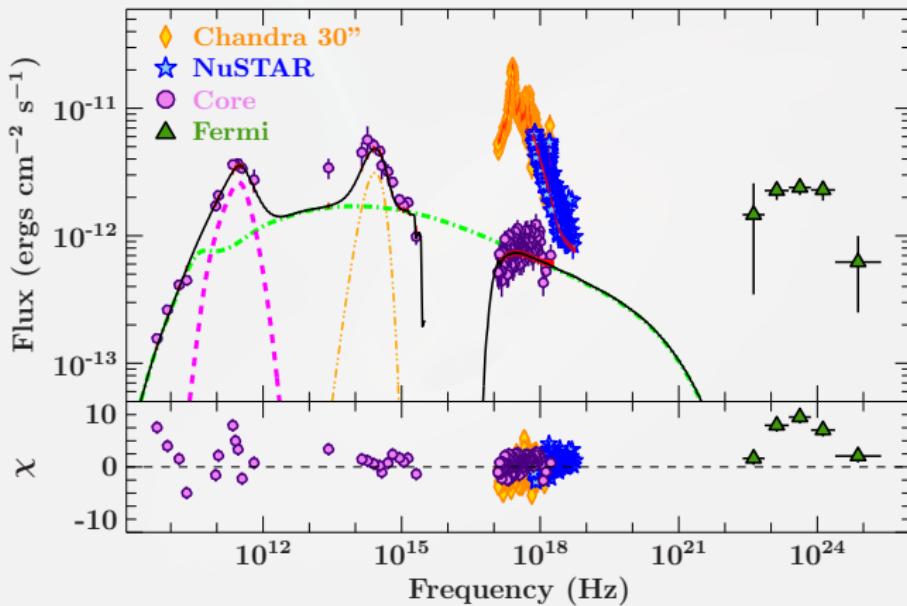
Radio/X-ray emission fit by thermal+non-thermal synchrotron
Black body (host galaxy?) dominates optical/IR

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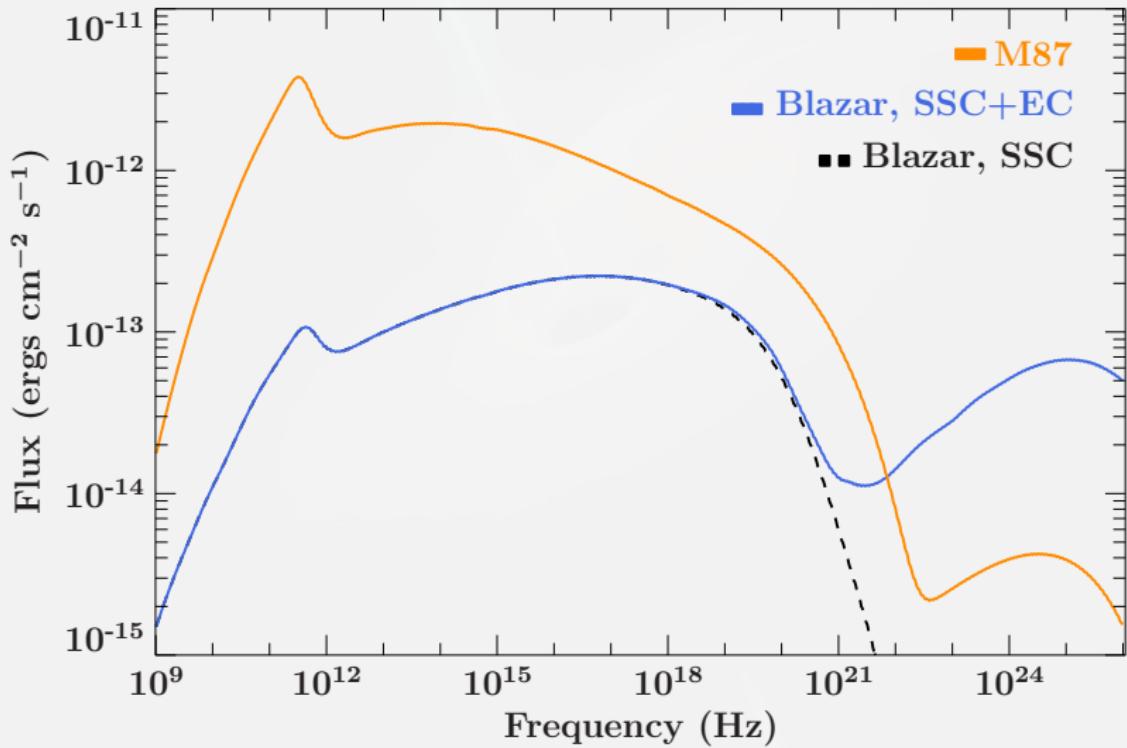
Radio/X-ray emission fit by thermal+non-thermal synchrotron
Black body (host galaxy?) dominates optical/IR
Low jet power, particle acceleration close to BH ($\sigma \gg 1$)

Modelling M87: resolved SED+NuSTAR+3FGL



IC from the core far below 3FGL!
Suggests different origin of γ -ray emission

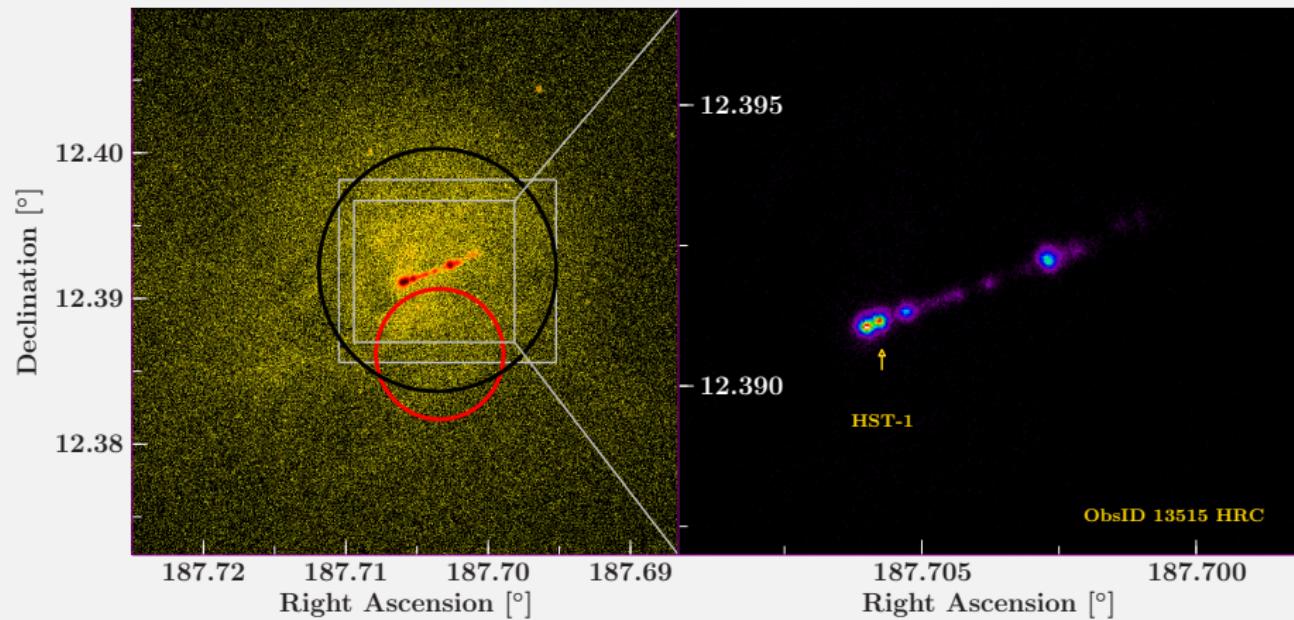
Is M87 a misaligned blazar?



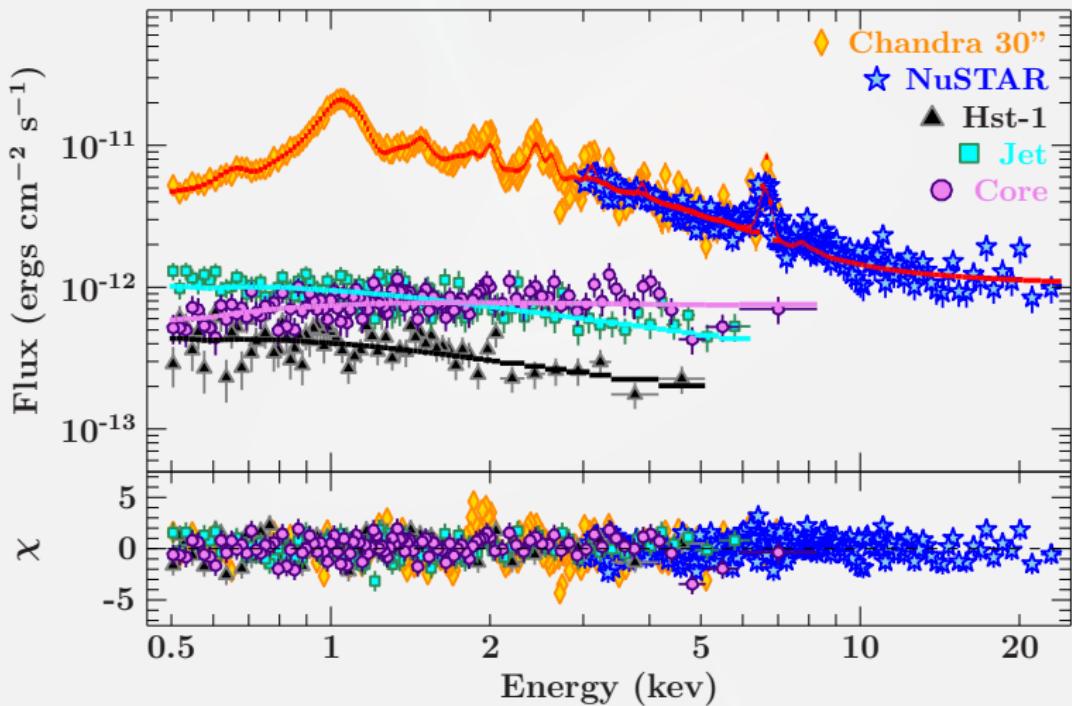
Conclusions

- Improvements in datasets and modelling “push” beyond single-zone
- PKS 2155–304: joint fit to isolate jet dynamics, remove degeneracy
- M87: imaging/SED combined imply complex origin of γ -ray emission

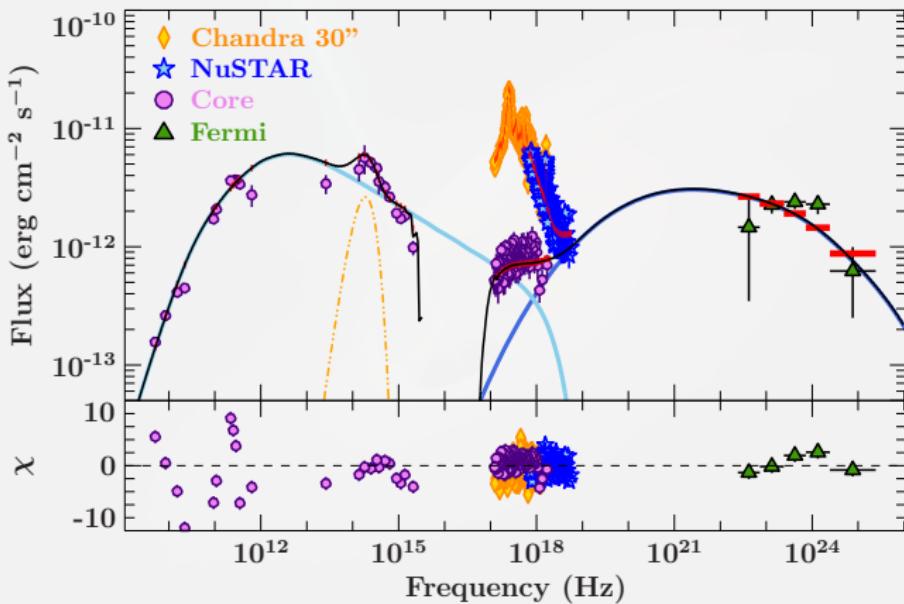
Modeling M87: core hard X-ray emission



Modeling M87: core hard X-ray emission



Modelling M87: origin of γ -rays?



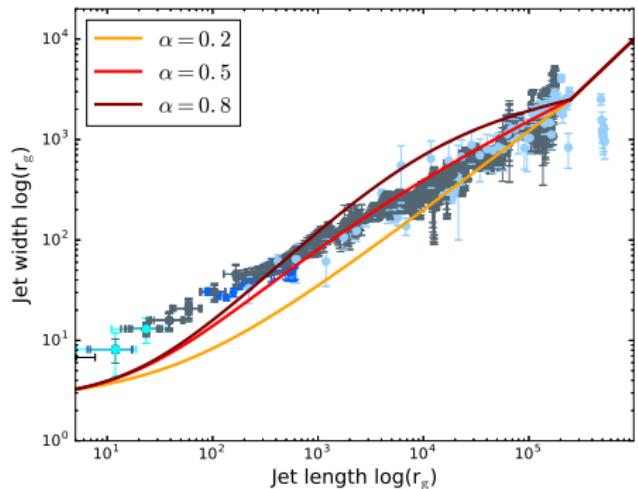
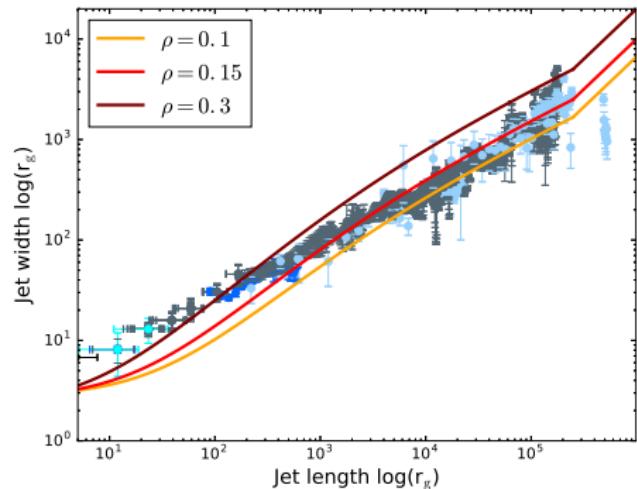
One-zone $\rightarrow U_e/U_b \approx 500$
Spine/layer \rightarrow cooling?

Hadronic interactions \rightarrow power?
Others? Kpc jet? Magnetosphere?

Modelling M87: constraints from imaging

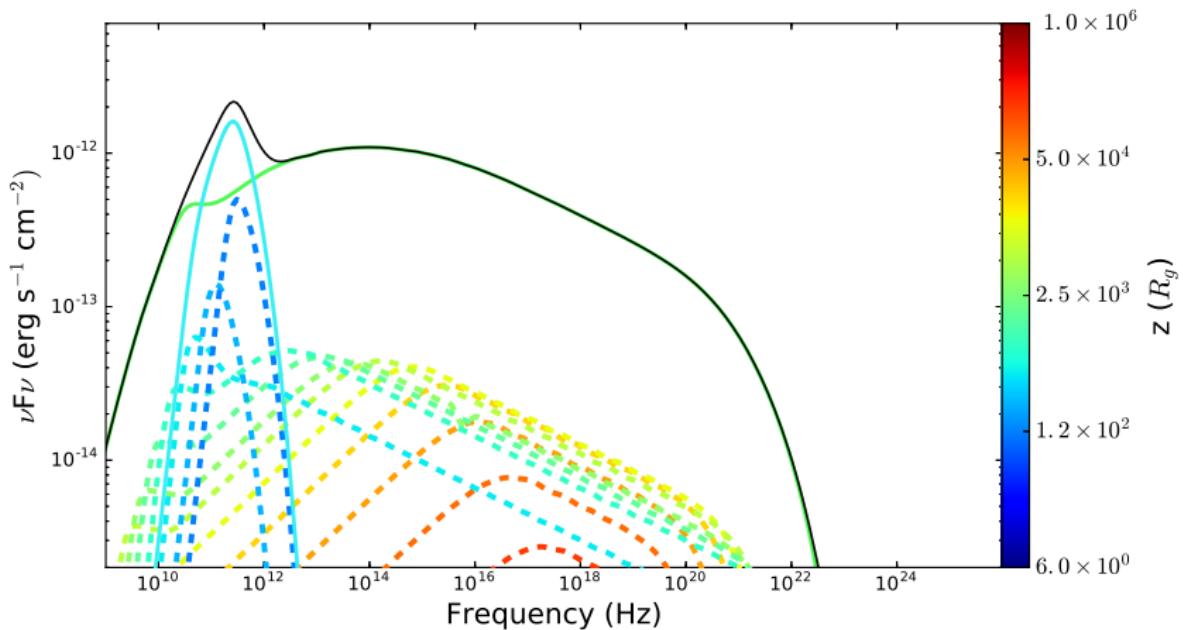
$$\theta_{\text{jet}}(z) = \rho / \gamma_{\text{jet}}(z)$$

$$\gamma_{\text{jet}}(z) \propto z^\alpha$$

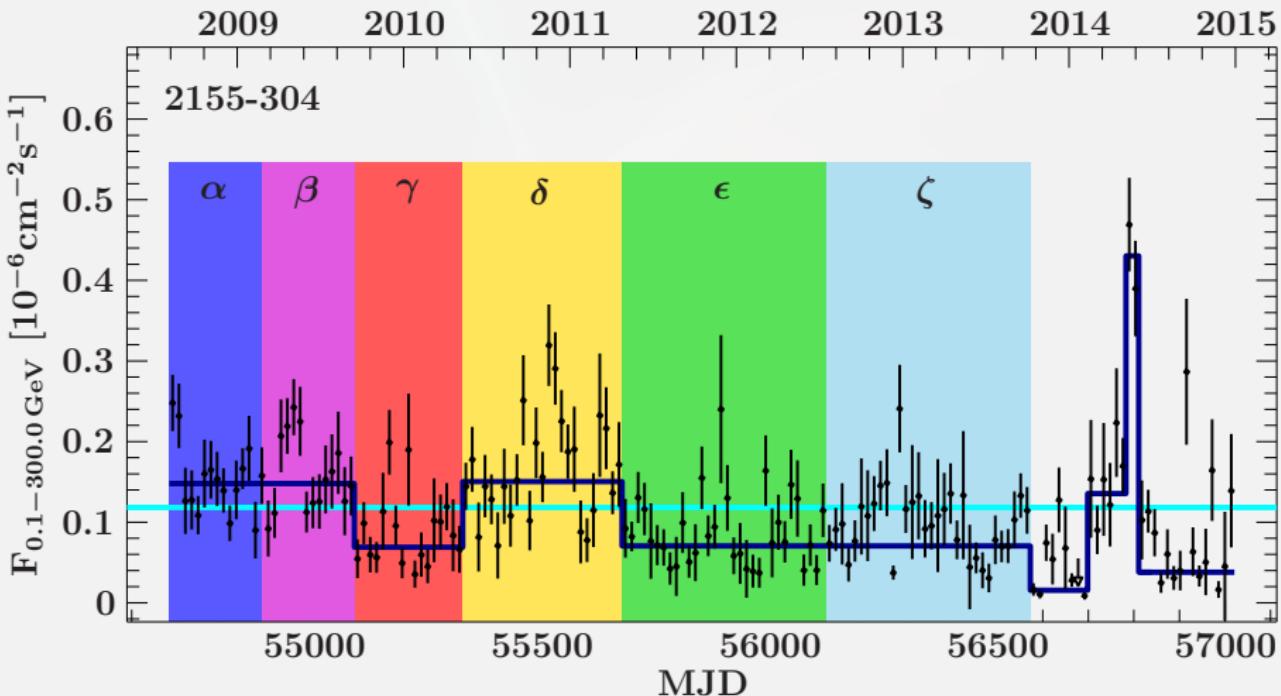


$$\rho = 0.15, \alpha = 0.5, r_0 = 3 R_g, z_{\text{diss}} = 3.3 \cdot 10^5 R_g$$

Modelling M87: the origin of the emission

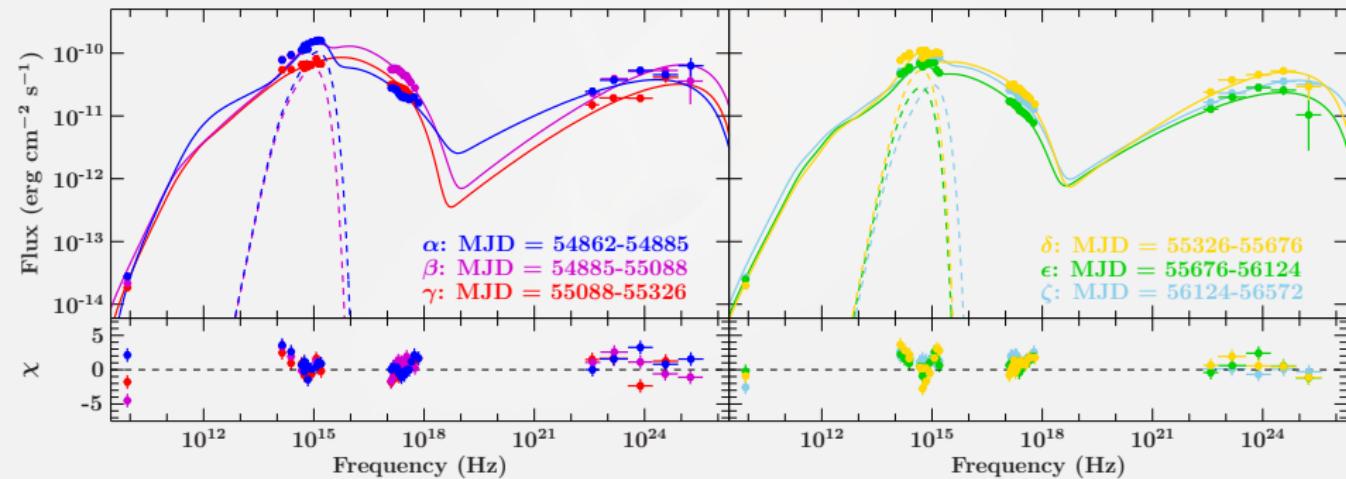


Modelling PKS2155-304: TANAMI SEDs

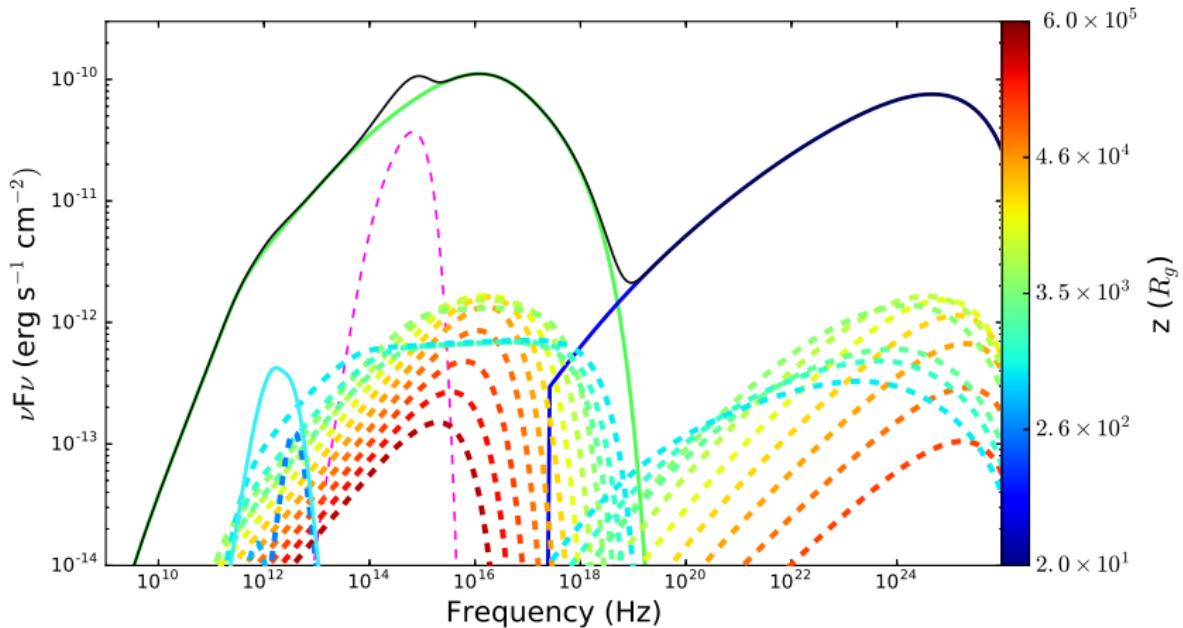


Krauß et al. 2016

Modelling PKS2155-304: single fits

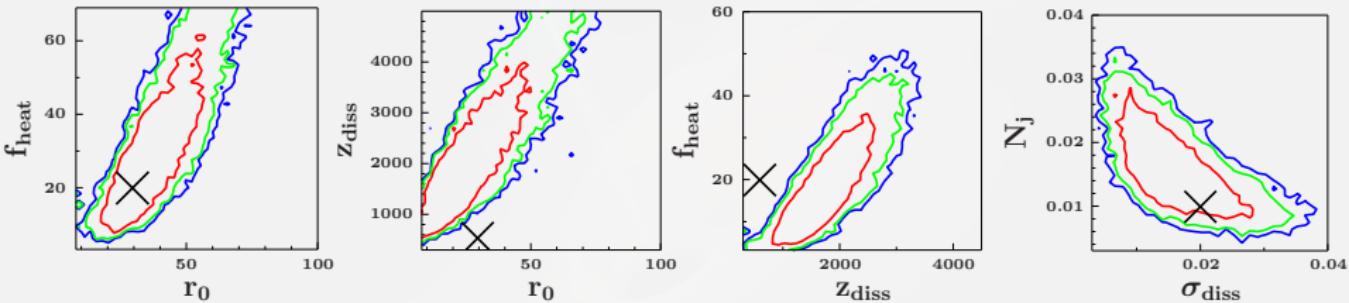


Modelling PKS2155-304: the origin of the emission

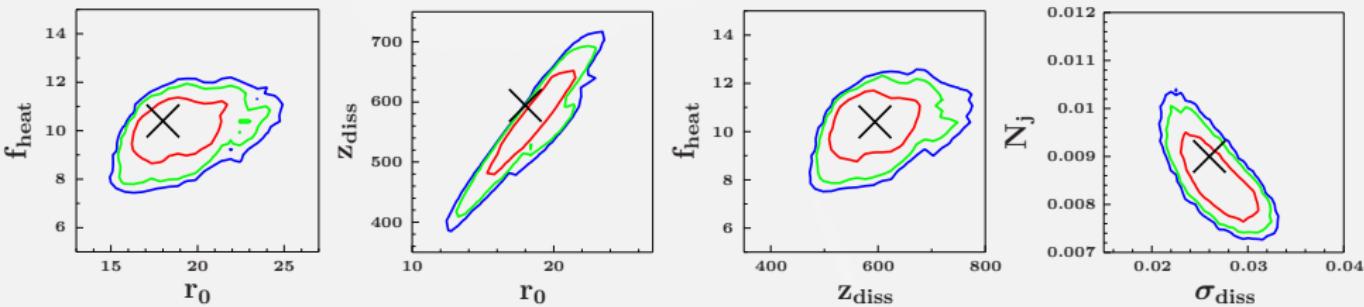


Modelling PKS2155-304: degeneracies

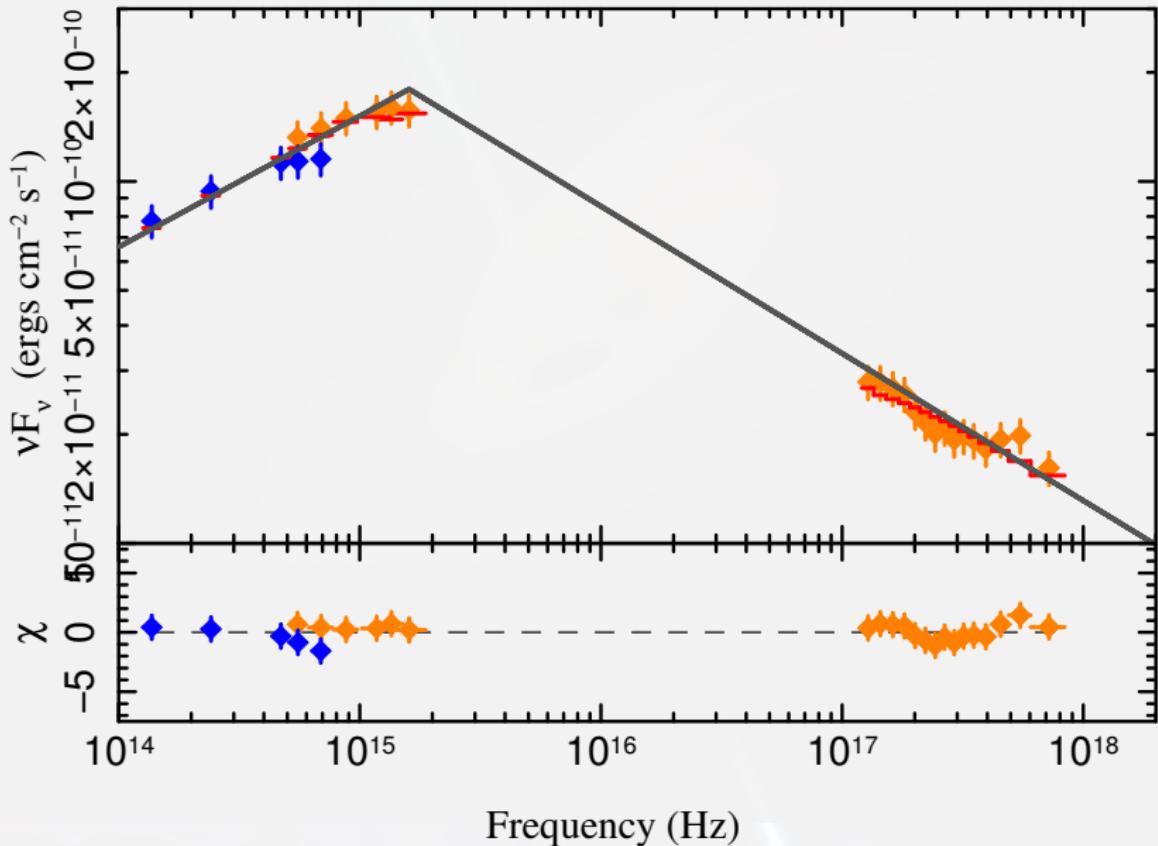
Individual fit, 10^4 MCMC loops:



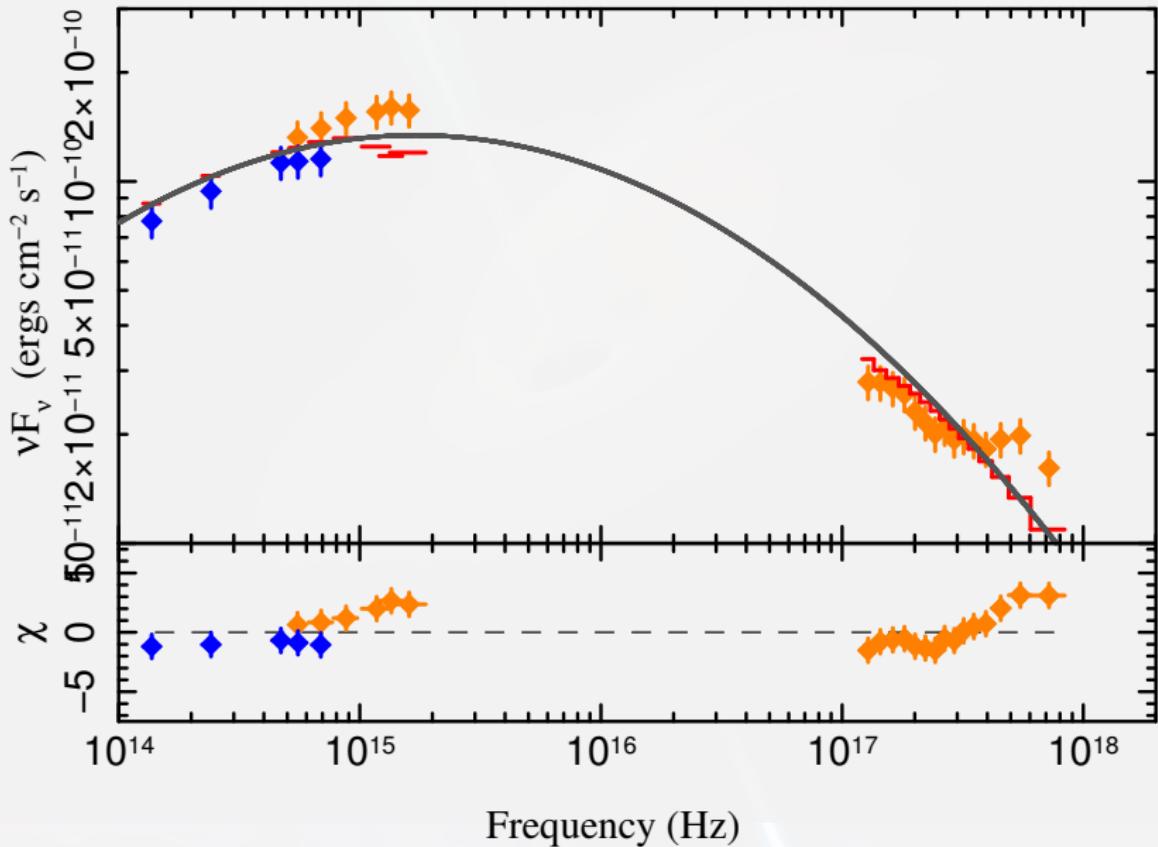
Joint fit, 10^3 MCMC loops:



PKS2155-304: accretion disk?



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