MHD Instabilities and its impact on the emission signatures of AGN jets

Sriyasriti Acharya (DST Inspire Fellow)

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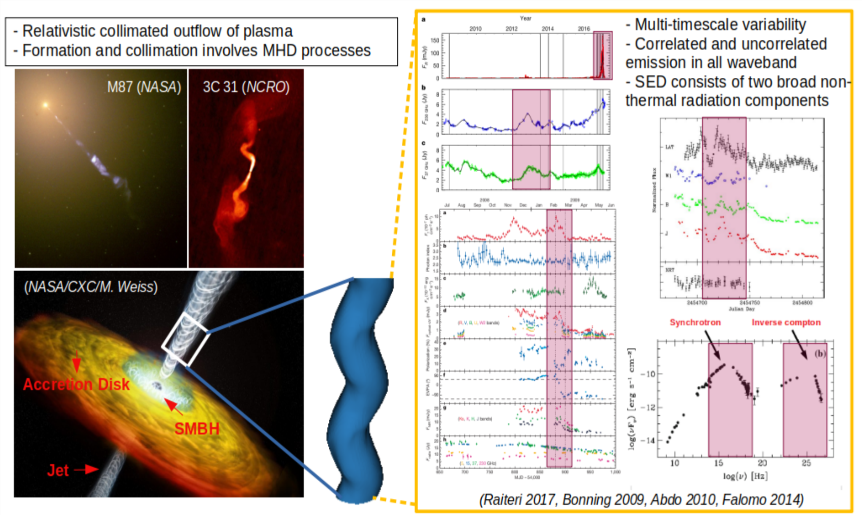
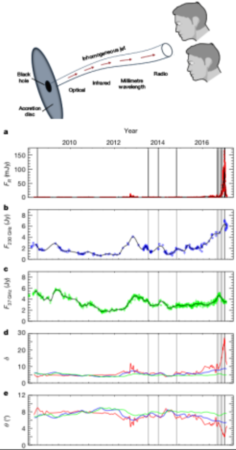
Discipline of Astronomy, Astrophysics and Space Engineering, IIT Indore

Collaborators: Bhargav Vaidya, Nikhil Borse, Gianluigi Bodo, Dipanjan Mukherjee, Paola Rossi, Andrea Mignone

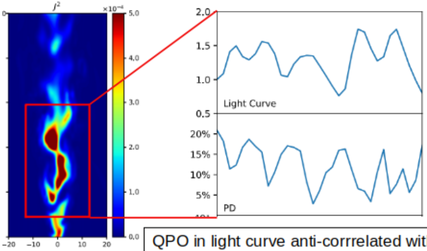
AGN jets & Instabilities?



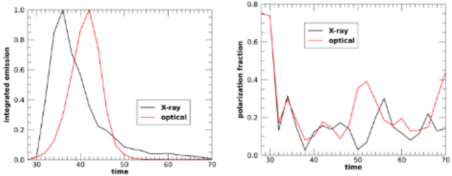
Kink instability & Variability



Long term variability of Blazars as explained by a twisted inhomogeneous jet (*Raiteri 2017*)



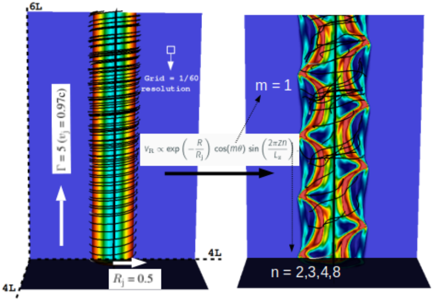
QPO in light curve anti-corrrelated with the polarisation degree (*Dong 2020*)



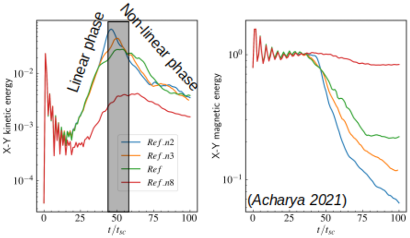
synchrotron polarization signatures of particles accelerated by the kink instability (*Bodo 2021*)

Numerical setup & Dynamics

- RMHD module of PLUTO code (*Mignone 2007*)
- Toroidal + poloidal magnetic field (*Mizuno 2011*)
- Decreasing pitch profile
- Defining t_{sc} = 0.32 years



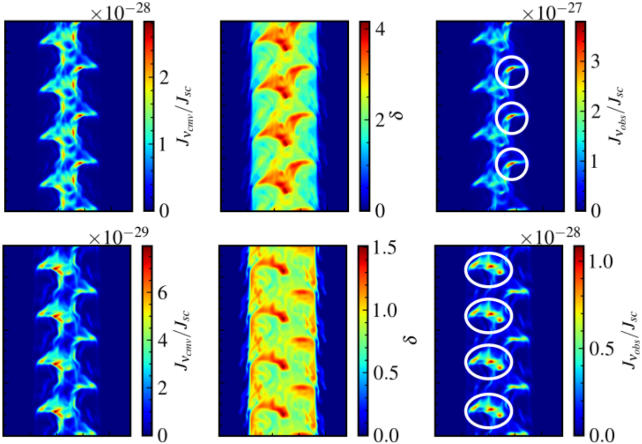
- Maxium growth rate of 0.096 is obtained for n = 1 (plot not shown here)
- Value ontained from simulation matches with analytical calculation
- Analytically max. Growth rate for n = 1 is 0.18



Runs ID	Ref_n2	Ref_n3	Ref	Ref_n8
η_{gr}	0.08	0.044	0.033	0.006
η_{diss}	0.054	0.04	0.026	0.0061

Impact of viewing angle

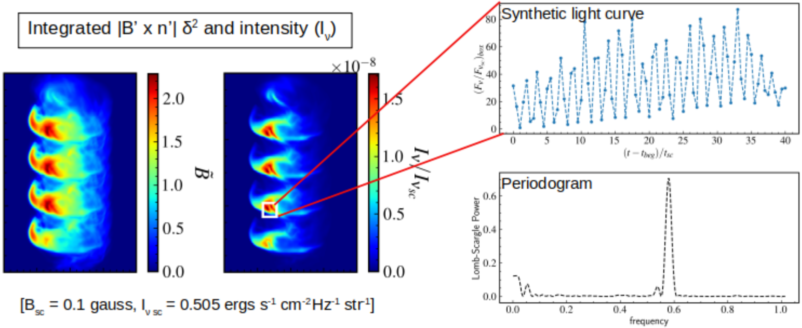
- Synchrotron emission in R-Band
- Static particle spectra with p = 3, $\gamma_{min} = 10^2$ & $\gamma_{max} = 10^6$
- Observing angle = 20 (top) and 45 (bottom) degrees



[J_{sc} = 2.805 ergs s^{-1} cm^{-3} Hz^{-1} str^{-1}]

Periodic nature associated with kink

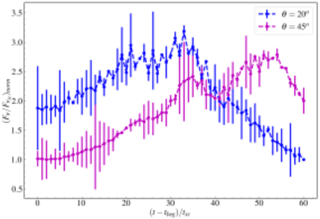
Integrated |B' x n'| δ^2 and intensity (I_ν)



[B_{sc} = 0.1 gauss, $I_{\nu\ sc}$ = 0.505 ergs s^{-1} $cm^{-2}Hz^{-1}$ str^{-1}]

- Observing angle = 45 degree
- Combination of Doppler factor and |B' x n'| contribute the most to the observed synchrotron emission

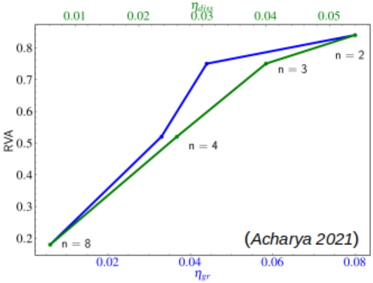
Peridocity time = 1.72 t_{sc} ~ Dynamical time taken by a single kink to traverse the whole column



Quantification of variability through statistical tests

Runs ID	f_{var}	RVA
Ref_n2	0.6± 0.002	0.84± 0.26
Ref_n3	0.49± 0.017	0.75± 0.21
Ref	0.23± 0.01	0.52± 0.19
Ref_n8	–	0.18± –

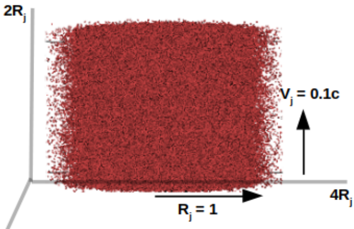
Connecting dynamics with emission features



- Correlated trend between the linear growth rate and the magnetic energy dissipation rate with an observable "RVA"

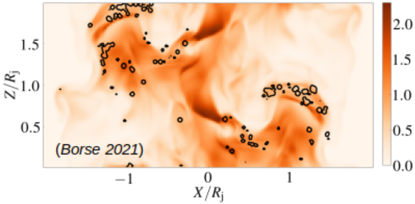
Impact of KHI on the synthetic SED

- Focus is at Kpc scale
- Less magnetically dominated with purely axial magnetic field component (*Bary & Keppens 2002*)
- Prone to shear driven Kelvin-Helmholtz instability



Setup at $t/t_a = 0$, where $t_a = 78.3$ Kyr

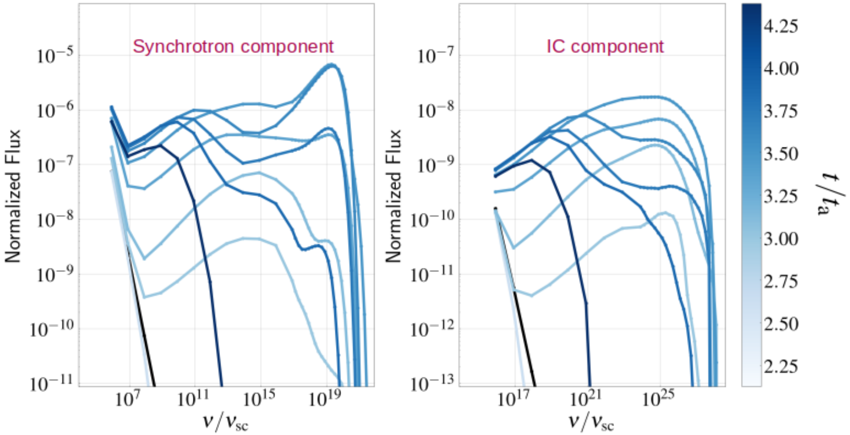
- Used hybrid macro-particle based framework in PLUTO code (*Vaidya 2018*)
- Evolving particle spectra wih initial power-law spectra p = 6, $\gamma_{min} = 10^2$ & $\gamma_{max} = 10^8$
- Emission processes: Synchrotron and IC-CMB



Over plotting the X-ray emissivity contours on the jet pressure distribution

Effect of shocks

- Emergence of multiple peaks in the emission spectra after the formation of shock
- Observing angle = 20 degree



[$F_{\nu\, sc}$ = 9.38 x 10^{-14} ergs s^{-1} cm^{-2} Hz^{-1} & ν_{sc} = 122 Hz]

Summary

- Highly magnetized jets with decreasing pitch profile are prone to kink instability
- Lowest n shows the maximum growth rate
- Location of emitting region is different for different line of sight of observer, demonstrating the objective of "helical jet model"
- Statistical estimates support the helical jet picture as a model to explain the long term flux variation for a period of $\leq$ 20 years.
- Connecting dynamics with the emission features, a correlated trend between the linear growth rate and the magnetic energy dissipation rate with RVA is obtained
- At kpc scale with the only axial magnetic field, jets are prone to KHI
- Particle re-acceleration at the shock formation site leads to the emergence of a secondary population of highly energetic electrons that causes flattening of the SED