Kink-Driven Transient Quasi-Periodic Oscillations In Blazars

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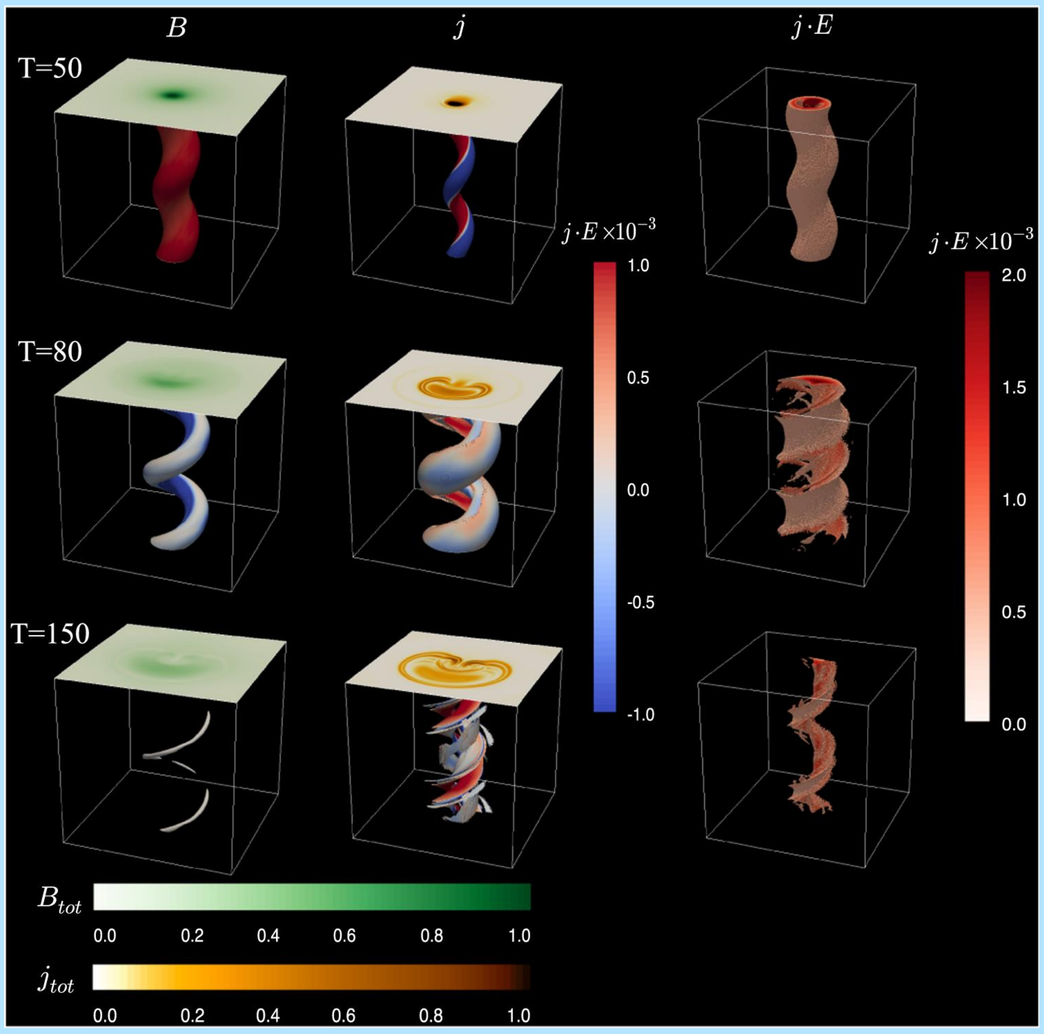
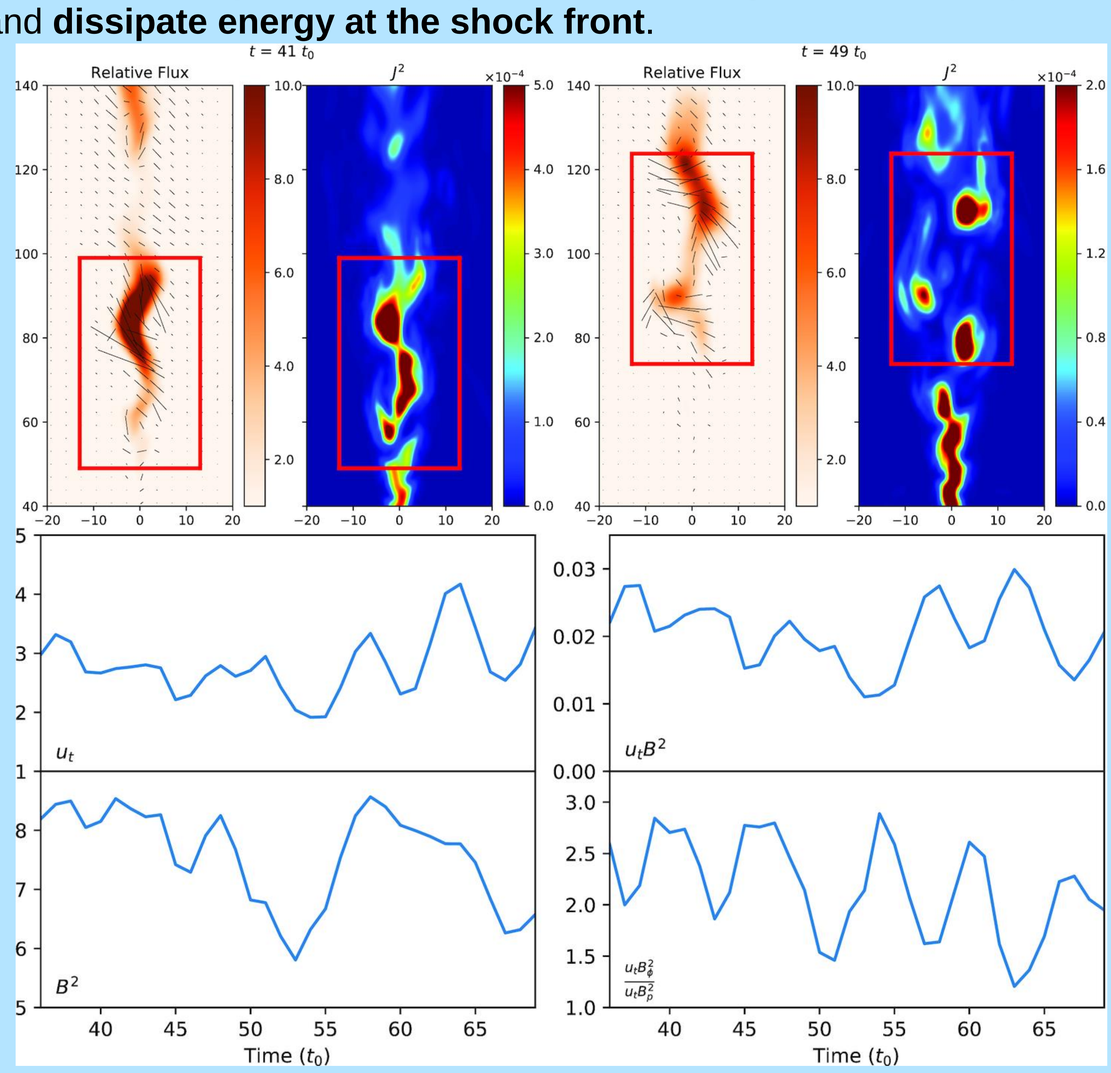
What is Kink Instability?

- Kink instability is a **magnetic-driven** plasma instability.
- It happens when the toroidal magnetic field is strong and the plasma jet propagates a long distance, natural to blazar jets.
- Kink instability is by nature a **quasi-periodic structure** and can **develop turbulence**.



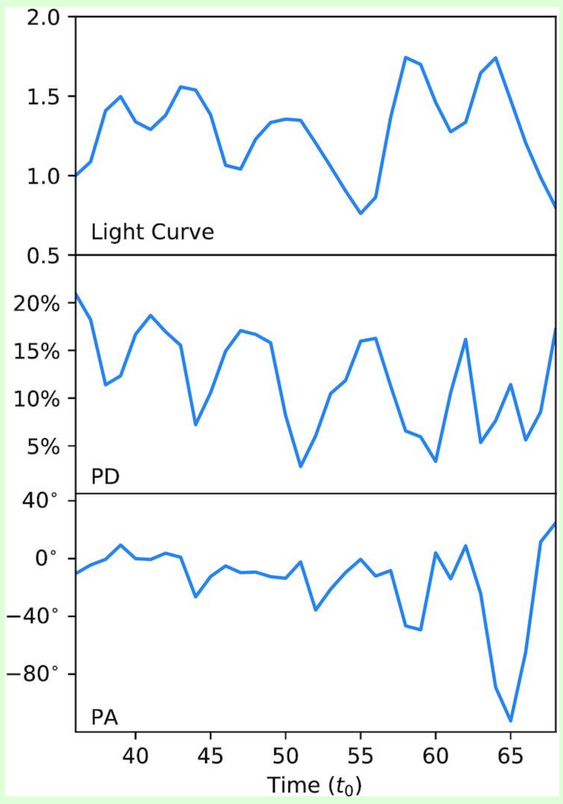
How does Kink Drive Quasi-Periodic Oscillations (QPOs)?

- Kink can cause **quasi-periodic energy dissipation in the central spine** of the jet, where the **poloidal magnetic field** component is strong.
- Alternatively, a shock may propagate through the **quasi-periodic structure** of the kinked region, enhancing the **toroidal magnetic field** component and **dissipate energy at the shock front**.



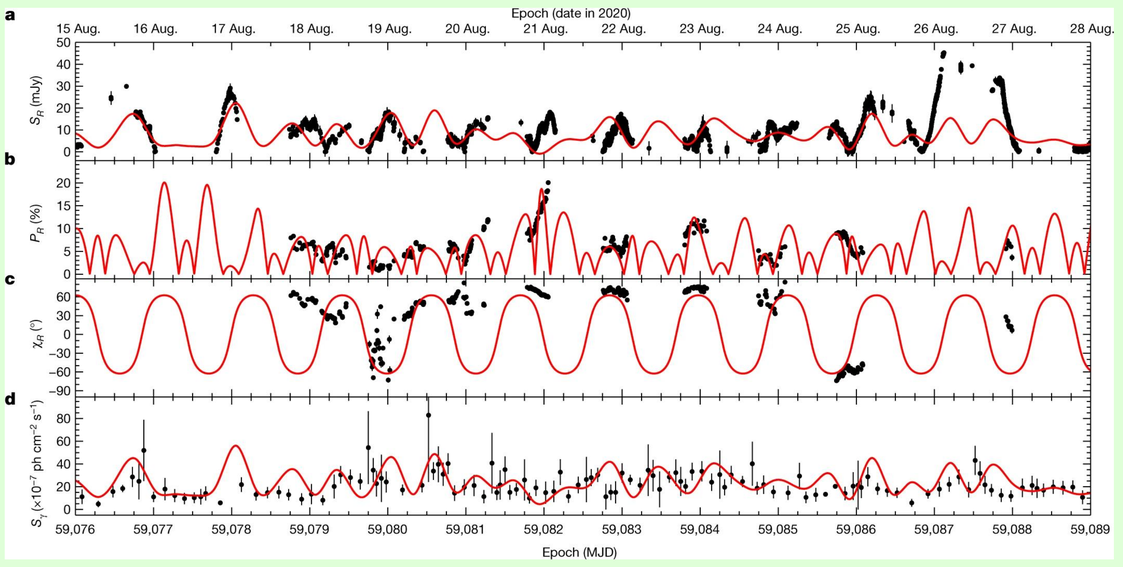
What are the Observable Properties of Kink-Driven QPOs?

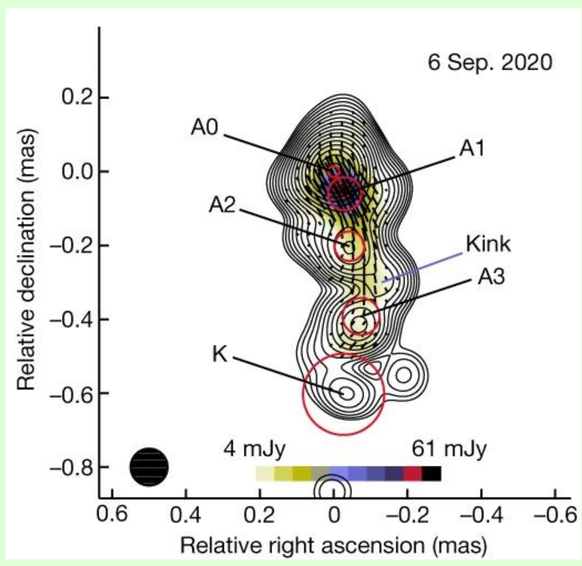
- Period should be $\frac{R}{v_{tr}\delta}$ for QPOs from kink itself, or $\frac{L}{v_{sh}\delta}$ for QPOs from shock in a kinked jet. For typical blazars the **period is between day to month**.
- **Both flux and polarization should show QPOs**. And the two QPOs are **correlated** because Stokes I and Q have the same period.
- **QPOs are transient** and can only last a few to ten-ish periods. QPOs in flux and polarization **may be contaminated by turbulence**.
- **Radio observation may show a curved jet** that resembles a kink instability.



What do Observations Say?

- BL Lac shows **correlated QPOs in Fermi and optical flux and polarization** during an active state.
- **QPOs last about 15 cycles**. Both periodogram and MCMC model fit converge to **a period of ~0.5 day**.
- **Radio band reveals a curved jet**, which can be the large-scale jet spine affected by kink instabilities.





How to Find More Kink-Driven QPOs?

- **High-cadence optical polarization** data is necessary to confirm kink-driven QPOs.
- **Fermi can send alerts for potential transient QPO** if two to three cycles are observed **to trigger high-cadence optical polarization monitoring campaign**. If the same period continues a few more cycles in Fermi and optical polarization, a candidate kink-driven QPO is detected.
- If the observational data can **pass multiple QPO data analysis tests and yield the same period**, and the **MCMC model fitting** based on kink instabilities **converge to the same period**, and the differences between the model curves and actual data all follow Gaussian distributions, which are likely due to turbulence, then the event can be confirmed as a kink-driven QPO event.
- Kink-driven QPOs can happen to all kinds of blazars. However, for **high synchrotron peaked blazars**, the **correlated flux and polarization QPOs are likely in the X-ray and TeV bands**, which can only be observed by IXPE and TeV Cherenkov telescopes.
- There are already **a number of transient QPOs in optical and Fermi bands** in literature. However, except for the above BL Lac observation, **none of them have sufficient optical polarization data**.
- **A new paper detailing how to observe and model kink-driven QPOs is in progress, stay tuned!**

What New Physics can be Learnt from Kink-Driven QPOs?

- Direct evidence that the **jet is magnetic-driven**.
- Direct evidence that the **blazar zone is considerably magnetized**.
- Direct evidence that **nonthermal particles are accelerated via magnetic reconnection**.
- Strong constraints on the **size of the blazar zone**.
- Strong constraints on the **jet energy partition and dissipation during its propagation**.

References

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Jorstad+ 2022, Nature, 609, 265