Spin-reversals in the X-ray binary pulsar OAO 1657-415

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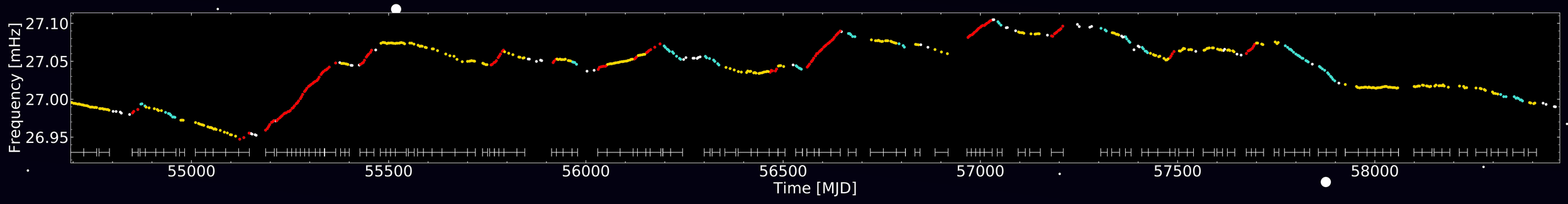


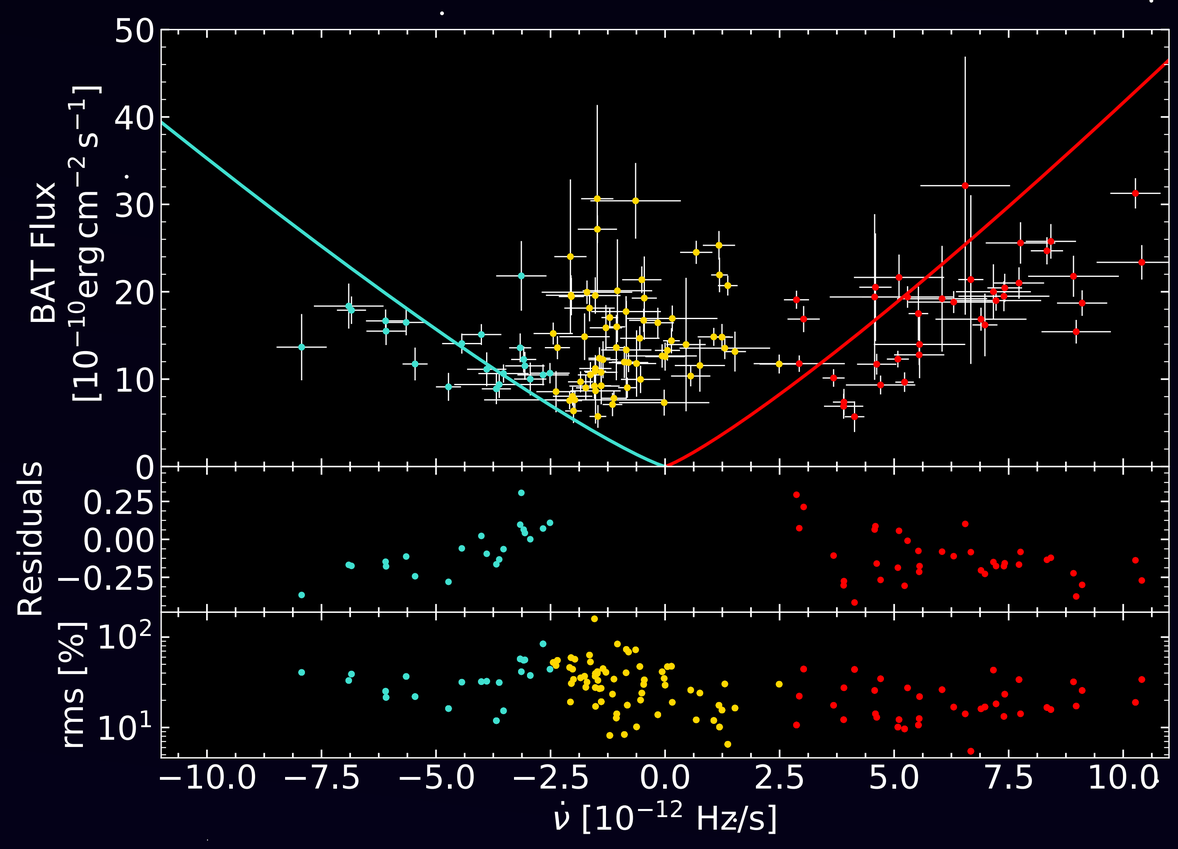
Abstract

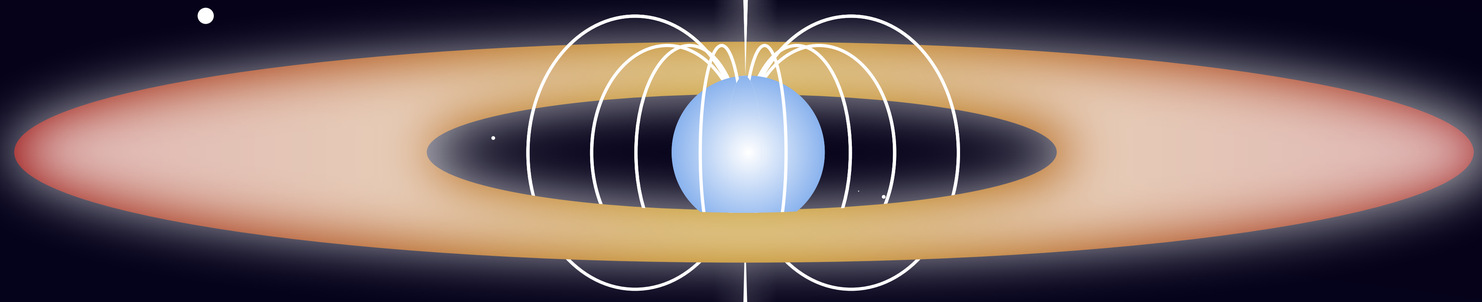
OAO 1657-415 is an X-ray binary pulsar that exhibited a long-term spin-up trend with short-term torque reversals in the past. In this work we present over 10 years of data from Fermi/GBM and Swift/BAT to study the long-term spin behavior and the torque-flux relation of this source, using current accretion torque models.

The frequency history shows that the source is no longer on a spin-up trend but has settled in an equilibrium spin period of about 27 mHz with short-term spin-reversals.

The analysis of the torque-flux relation shows a correlation when the source is spinning up, indicating that matter is likely accreted from a stable accretion disk. The observations during the spin-down of the pulsar could be explained by accretion from a retrograde disk or a sub-Keplarian behavior of the disk. The accretion process in this regime, however, remains elusive. A domain where the torque is close to zero has also been observed with a highly variable flux, which could be explained by direct accretion from the stellar wind of the companion.

Torque-Flux Correlation





Theory

- Ghosh & Lamb 1978 (ApJ, 223, L83), 1979 (ApJ, 232, 259), 1979 (ApJ, 234, 296) model:
  - Disk accretion including the magnetic coupling between star and disk
  - Axis-symmetric disk accretion by aligned rotator
  - Torque-flux relation: $\dot{\nu} \propto F^{6/7}$

Data & Methods

- Over 10 years of data:
  - Fermi/GBM and Swift/BAT
  - 16 August 2008 - 8 December 2018
- Fermi Timing:
  - Frequency history (see figure at the top)
  - Derivative calculated for indicated time intervals
- BAT Flux (15 - 50 keV):
  - Extrapolated for an energy range 0.1 - 200 keV
  - Measured fluxes during eclipse removed
  - Averaged during time intervals

Results & Discussion

- Timing Results
  - OAO 1657-415 is at equilibrium frequency ~27.04 mHz
  - Short-term (few hundred days) spin-up and spin-down
- Torque-Flux Correlation
  - Three domains: Spin-up, spin-down, and in-between (red, green, yellow in plots)
  - Correlation during spin-up evident
  - Ghosh-Lamb fit (green and red lines in plot) with $\dot{\nu} \propto F^{6/7}$ results in trends in residuals
  - Variability: spin-up: 20.9%, spin-down: 36.5%, in-between: 34.8%

Conclusions

- Torque-Flux Correlation
  - Spin-up: accretion from a stable accretion disk
  - Spin-down: possibly accretion from a retrograde accretion disk
  - In-between: accretion from stellar wind or two-stream accretion
  - Model of Ghosh & Lamb represents data insufficiently (as indicated by the trends in the residuals)

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