A Universal Variability Structure Function For Disc Emission?

Christian Wolf (ANU), Ji-Jia Tang (ANU, ASIAA) & John Tonry (IfA Hawai'i) et al.

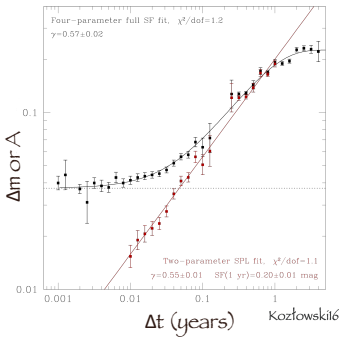
Abstract:

The 5,000 brightest quasars vary their brightness in a universal pattern when clocks run on disc orbital timescales. But quasars with windy discs vary more slowly – why? Inclination, BH spin and dust extinction don't seem to explain it.

Variability structure function

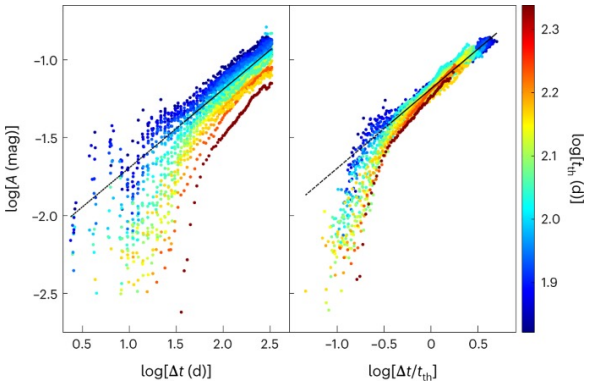
- Pick all magnitude pairs in light curve, variability amplitude is $A = \Delta m = m_1 - m_2$
- Random-walk makes power law: $\log A/A_0 = \gamma \log \Delta t$
- Shot noise sets floor A_{noise}
- Long-term saturation?
- What do A_0 and γ depend on?
- Long history of measurements

(Hughes+92, Vanden Berk+04, Kelly+09, MacLeod+10, Mushotzky+11, …, Caplar+17, Burke+21, Stone+22)



Results

- Bootstrap analysis yields $\log A/A_0 = \frac{1}{2} \times \log \Delta t$
- Slope $\gamma = 0.503 \pm 0.002$ most robust when Δt in units of $t_{orbital} \sim t_{thermal}$
- Quasars are standard flicker sources when clock runs in units of $t_{orbital}$ i.e., natural clock for Magneto-Rotational Instabilities (MRI) in discs



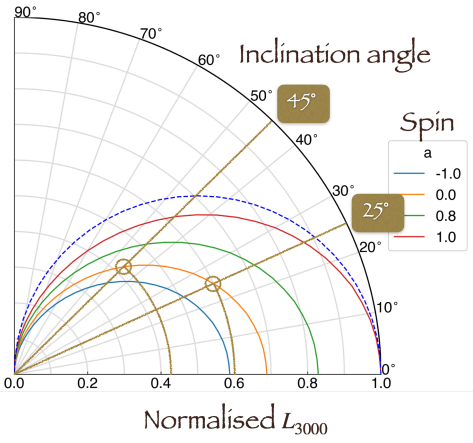
Tang, Wolf & Tonry, 2023, NatAs, 7, 473

Our data set

- Sample of 5,000+ brightest quasars with $0.5 < z < 3$, Gaia Rp < 17.5 mag
- NASA/ATLAS light curves in cyan and orange passbands over 6 years
- Cadence: 4x nightly weather permitting ↦ 2+ billion magnitude pairs

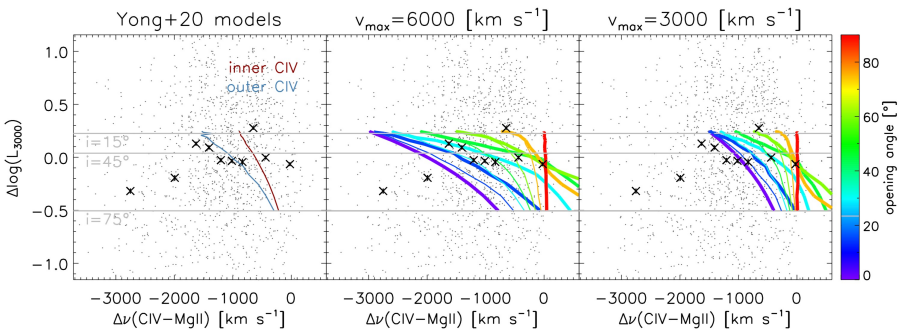
Open question: second parameter

- Scatter among individual quasars ranges over ½ dex in $\log A_0$ = 1 dex in $\log t_{orb}$ = 2 dex in L_{3000}, but scatter between subsamples from bins in luminosity and rest-frame wavelength is negligible
- t_{orb} is estimated from observed luminosity L_{3000}, which is affected by:
  - Anisotropic emission, inclination 0° to 60° ↦ 0.4 dex in L_{3000} = 0.2 dex in $\log t_{orb}$
  - Black hole spin dependence over a = -1 to +1 ↦ 0.2 dex in L_{3000} = 0.1 dex in $\log t_{orb}$
  - Host dust extinction from E(B-V) = 0 to 0.1 ↦ ¼ dex in L_{3000} = 1/8 dex in $\log t_{orb}$
  - Flatter temperature profile of disc increases t_{orb} (and what effect from 3D slim discs?)
- Try selecting subsamples by inclination, BH spin, T profile – how to know these?

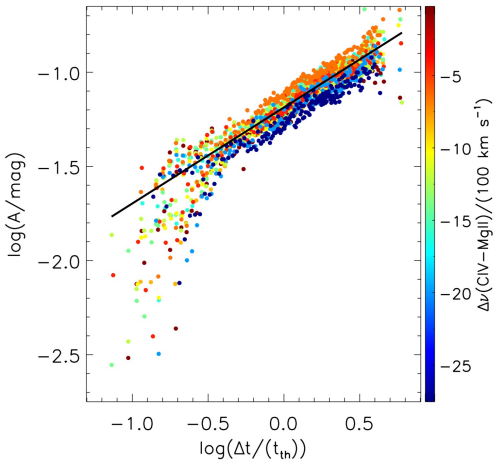


Explore VSF trends with CIV blueshift:

- High-CIV blueshift quasars: windy discs (many authors) or pole-on viewing angle (e.g. Yong+20)?
- CIV blueshift < -1,800 km/s: apparently lower VSF amplitude and short-term break shifted longer
  More likely: t_{orb} is under-estimated ↦ +0.13 dex higher $\log t_{orb}$ would shift them in line with bulk
- Wrong sign for pole-on view; SEDs disagree with dust, flatter T profile; spin effects a little weak



Unattributed figures from Tang et al. 2023, MNRAS, submitted



Looking forward to LSST!

will provide beautiful data for many and diverse quasars