Solving the Puzzling Kinematics of FSRQ 1928+738

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Abstract

Here we present the preliminary results of ≈ 1.5 year monitoring of the quasar 1928+738 with KaVA at 43 GHz. We found increasing apparent velocities from 1.37c to 5.55c and varying position angles from 79.4 degree to 70.6 degree as function of distance from the black hole. We attribute its unusual kinematics to a combination of bulk acceleration and jet bending towards our line of sight.

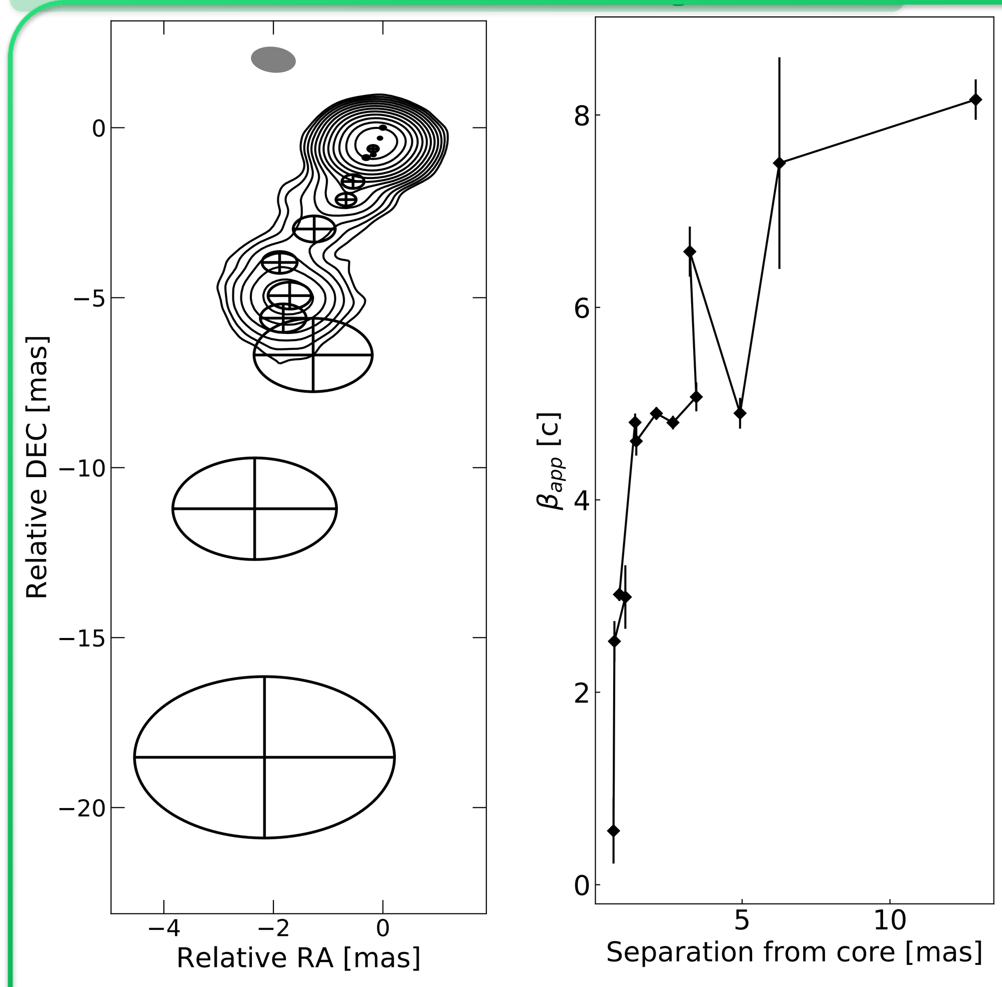
Backgrounds

- Basic information of FSRQ 1928+738 (4C +73.18)
  - ✓ z ~ 0.3
  - ✓ Relativistic jet motion (e.g. Lister + 2013)
  - ✓ Jet viewing angle $\theta \sim 13^{\circ}$ (e.g. Hovatta + 2009)
- Flat Spectrum Radio Quasar (FSRQ)
  - ✓ The jet direction is closely aligned to our line of sight
  - ✓ High accretion rate
- Relativistic jet motion towards our line of sight
  - ✓ Doppler boosting
    : The time frame shrinks by δ
    & The observed flux is boosted by δ^3
  - ✓ Superluminal motion
    : Apparent velocity can exceed the light speed

$$\delta = \frac{1}{\Gamma(1-\beta\cos\theta)}$$

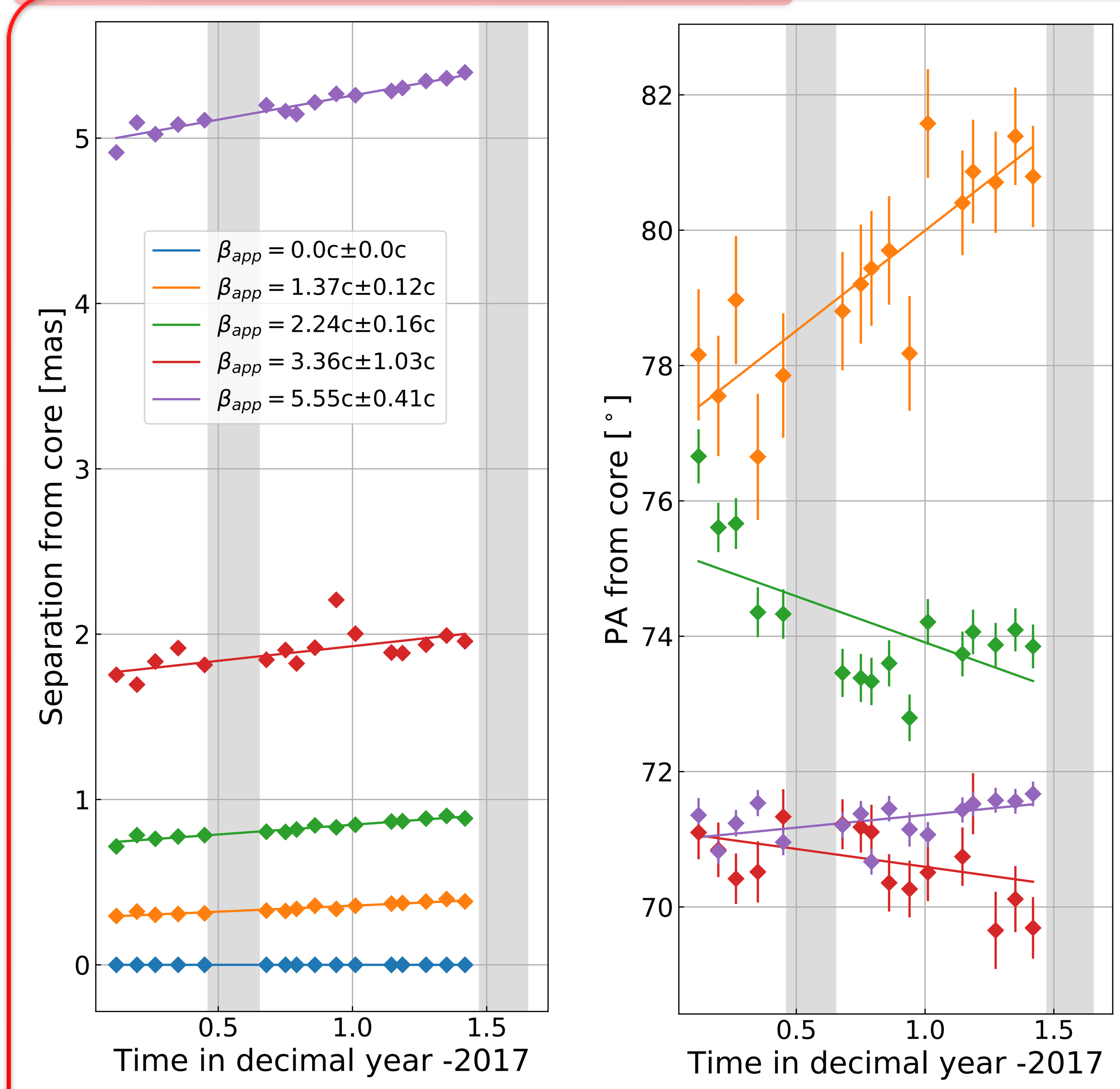
$$\beta_{app} = \frac{\beta\sin\theta}{1-\beta\cos\theta}$$

Archival Analysis

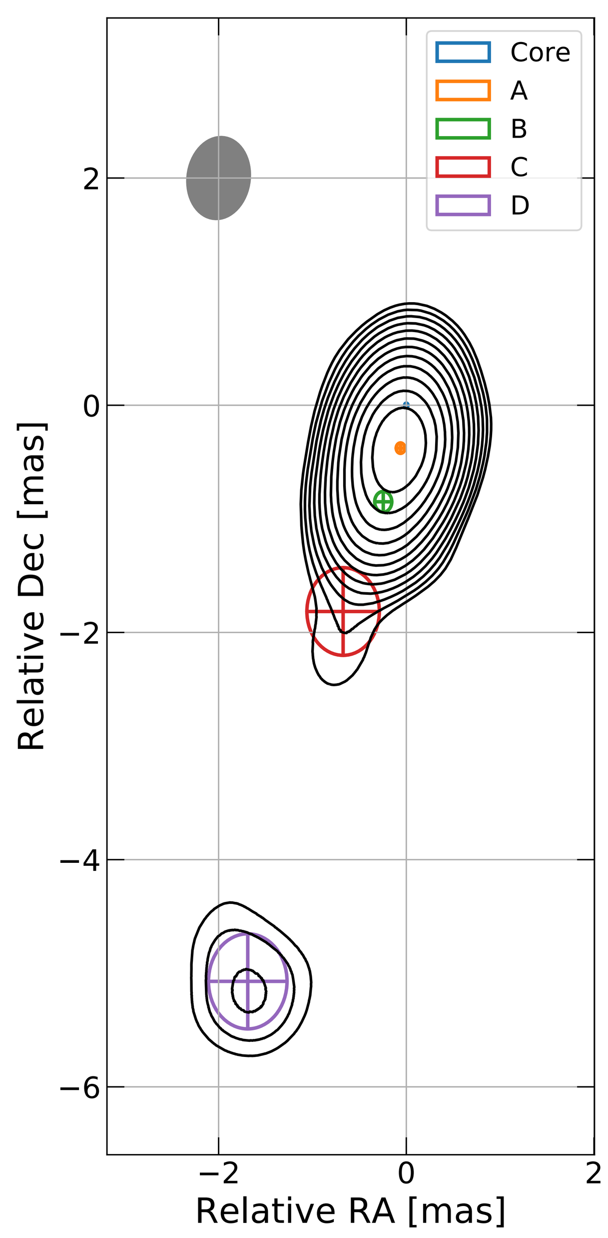


- The pc scale jet morphology can be separated into 2 parts.
  ① Core : most upstream (0,0)
  ② Jet components (=Knots) (circles with crosses)
- All blobs move outward
  - ✓ Superluminal motions
  - ✓ ***β_{app}* increases as a function of distance!**
    : puzzling kinematics
    ➝ ***What is the origin?***
- Archival VLBA 15GHz data (MOJAVE program by Lister + 2013)
  - ✓ *Left* : Intensity map, *Right* : Apparent velocity as a function of distance

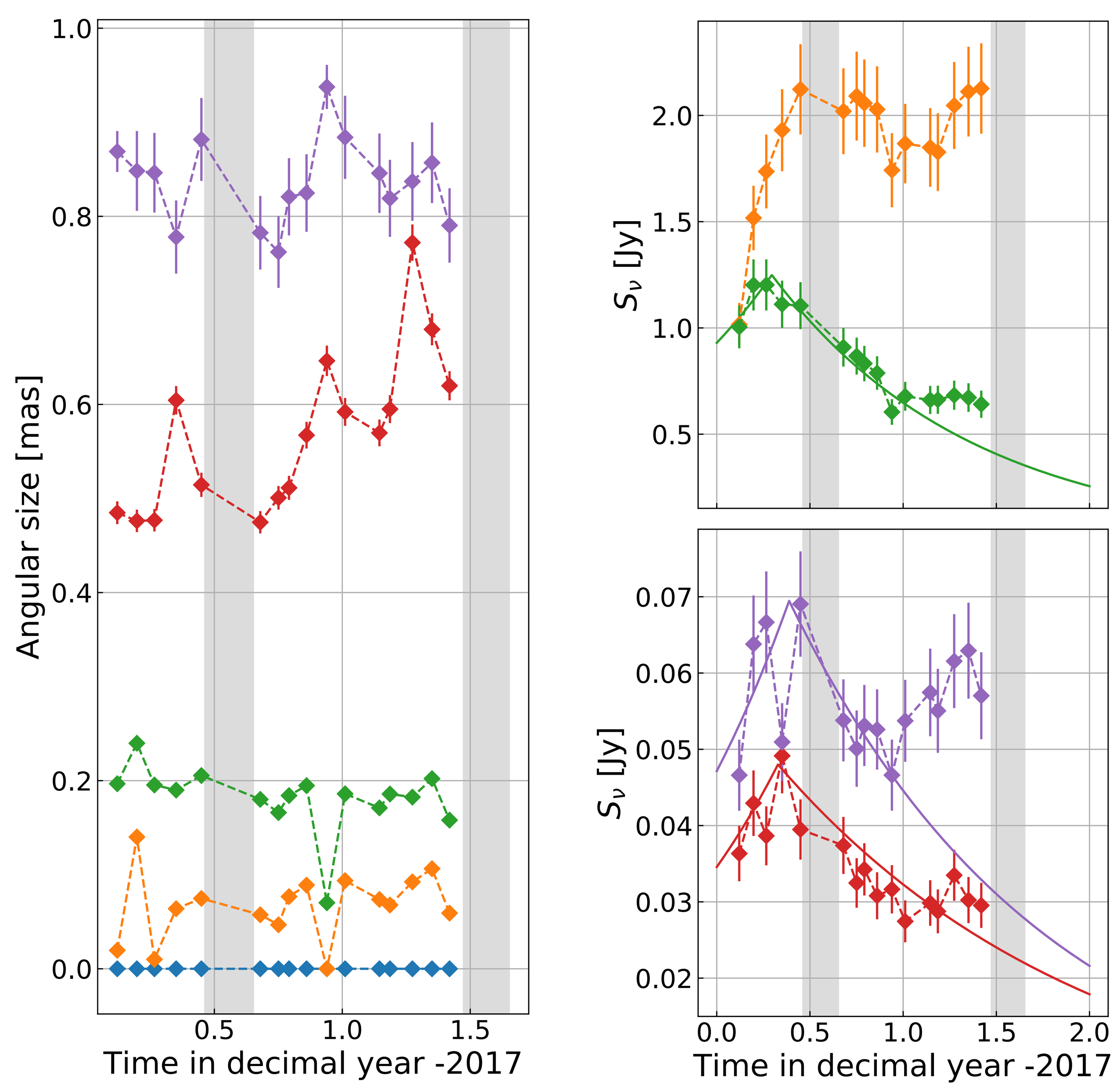
KaVA Monitoring



- Separation & Position Angle (PA) from the core
  - ✓ Polar coordinates, instead of RA & Dec
  - ✓ Explained well by linear analysis
  - ✓ The wide range of PA : free movement inside the jet
    ➝ Related to the jet width

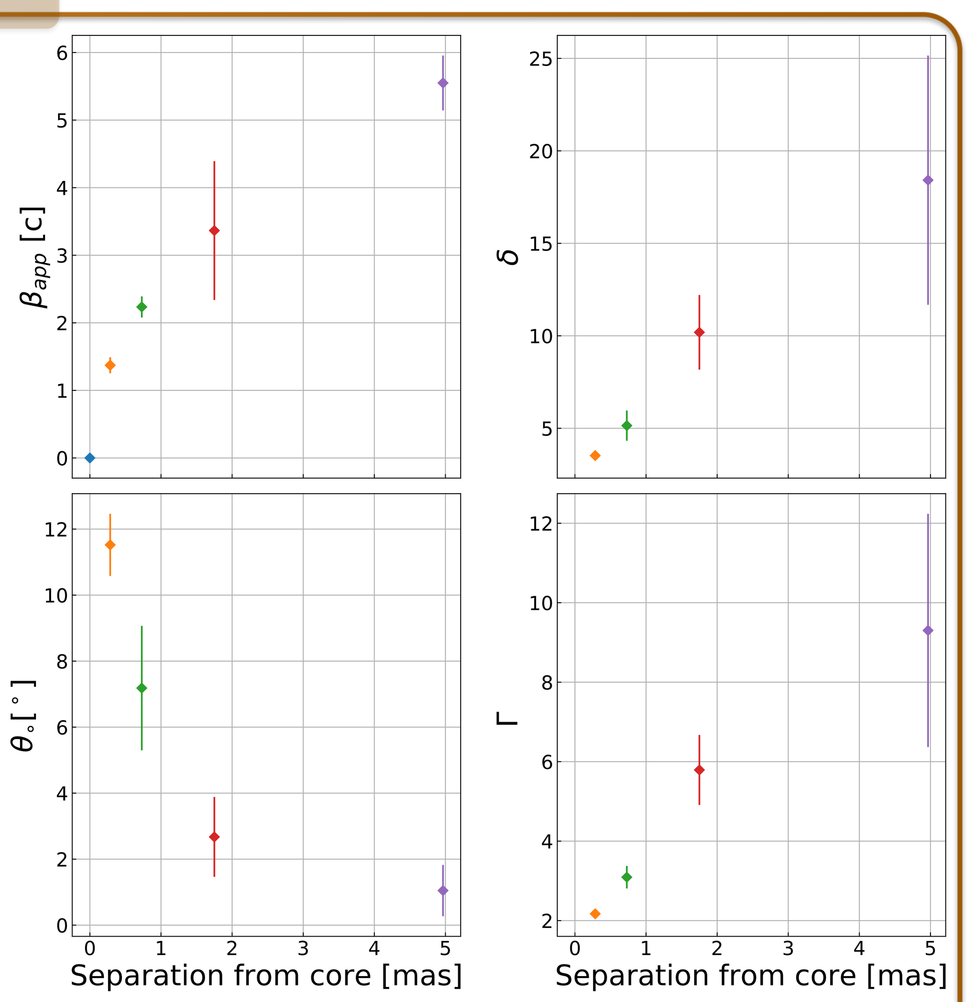


- KaVA monitoring at 43 GHz
  - ✓ for ≈ 1.5 years (16 epochs)
  - ✓ monitoring is still on going (in 2018B)
  - ✓ Core and Knots A~D are noted with different colors



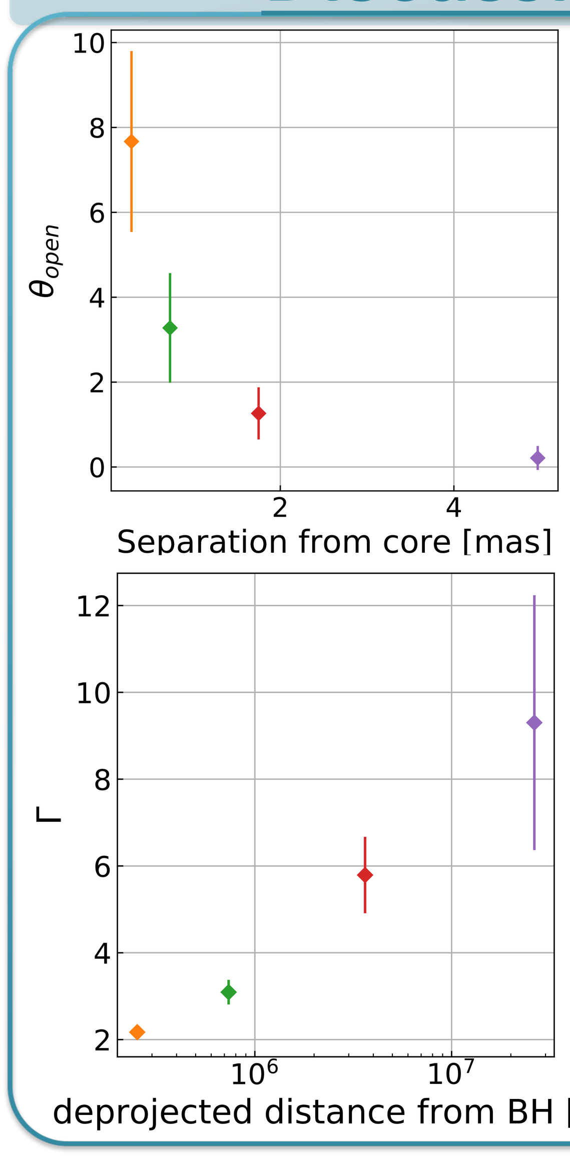
- Angular size (s) and Light curve
  - ✓ Deriving the Doppler factors
    - $\delta = sD_L/[(1+z)c\times\tau_{cool}]$ (by Jorstad +05, 17)
    - Assumption : Radiative cooling is dominant (valid for 43 GHz)

Jet Kinematics



- β_{app} increases as a function of distance
  - ✓ from 1.37c to 5.55c
  - ✓ ***Consistent with archival study***
- δ also increases as a function of distance
  - ✓ from 3.53 to 18.42
  - ✓ ***New finding!***
  - ✓ ***Also puzzling***
- Coupled β_{app} & δ
  ⇔ Coupled θ & Γ (convertible)!
  - ✓ Jet viewing angle θ
  - ✓ Lorentz factor Γ
  - ✓ ***A key to solve its puzzling kinematics***
- Γ increases as a function of distance
  - ✓ ***2nd solution***
    - ● ***Bulk acceleration of the jet!***
- θ decreases as a function of distance
  - ✓ ***1st Solution***
    - ● ***The jet is bending towards our line of sight***

Discussion



- Deriving the half opening angle θ_{op}
  - ✓ $s_l = R$ (separation from core)
  - ✓ $s_t = R \times \sin(|\overline{PA} - PA|) + r$
    ➝ projected θ_{op} & using viewing angle θ
    ➝ intrinsic θ_{op}
- θ_{op} decreases as a function of distance
  - ✓ ***The jet is being collimated!***
  - ✓ ***Acceleration and Collimation are co-spatial!***
- Bulk acceleration
  - ✓ ~$10^6 r_s$ from BH (applying constant $\theta \sim 13^{\circ}$)
  - ✓ ***~$10^7 r_s$ from BH (applying the bending geometry)***
- FSRQ 1928+738 in conclusion
  - ✓ ***Excellent laboratory for studying Jet acceleration, collimation, and bending !!***

References

Lister et al. 2013 AJ, 146, 120 Hovatta et al. 2009 A&A, 494, 527 Jorstad et al. 2005 AJ, 130, 1418
Jorstad et al. 2017 ApJ, 846, 98 Kun et al. 2014 MNRAS, 445, 1370