A Follow-up of the 4C 38.41 Innermost Jet: Origins and Evolution of its Emission

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12th EAVW – Mito, Japan, September 2019

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- Evolution of the Jet Components
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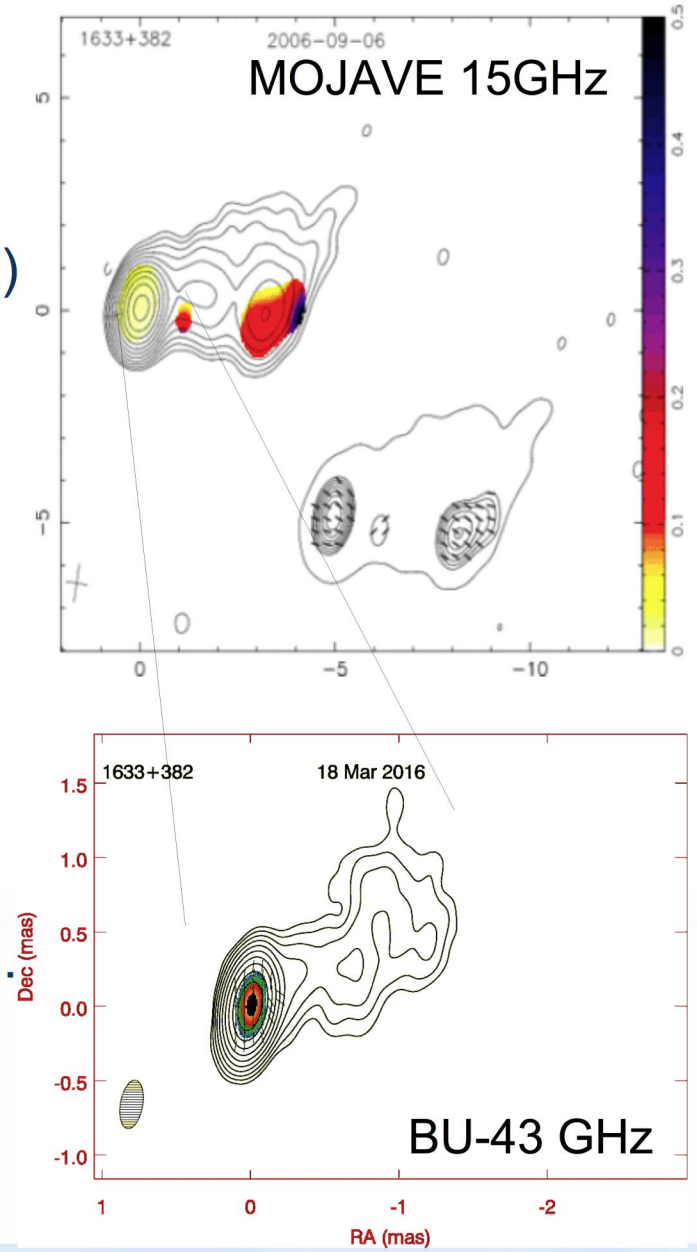
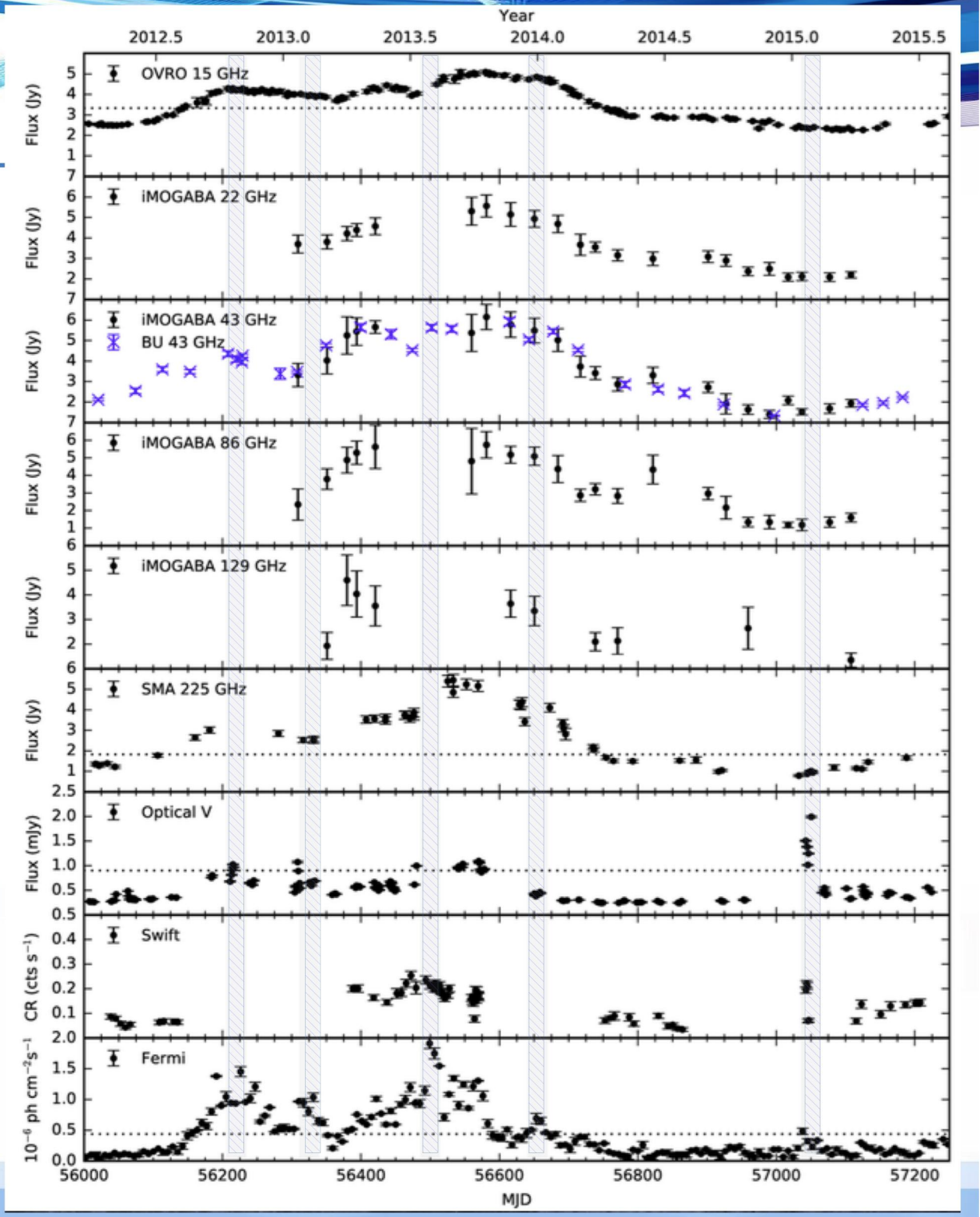
1633+382

- 1633+382, Aka 4C 38.41
  - OVV, HPQ Flat radio spectrum
  - z=1.813, ~14 Gpc, 8.54 pc/mas
  - Relatively bright in radio (Flux 2-4 Jy @15GHz)
  - γ-ray bright source
- Very popular source in various programs
  - BU-VLBA, iMOGABA, SMA, OVRO,...
  - Observational synergy
- Ideal target to study variability & γ-ray flares
- Flared period between 2013-2015
  - Observations and Data collection
  - OVRO, iMOGABA, SMA, Optical, Swift, Fermi..



Light Curve

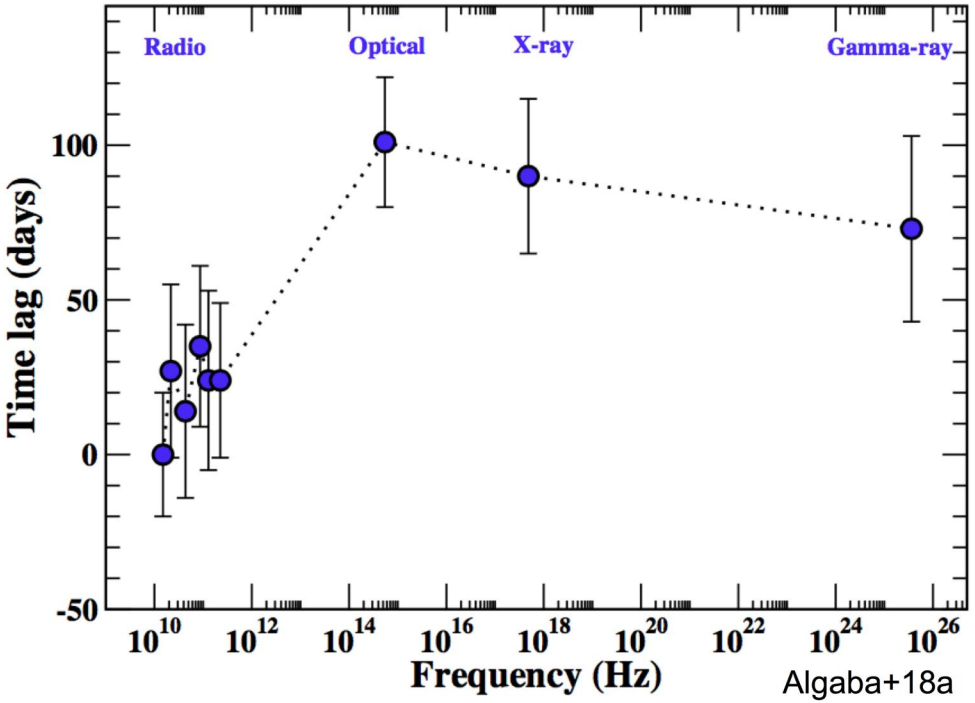
- Follow-up
  - 2012 Mar – 2015 Aug
- iMOGABA didn't observe all
  - beginning of the flares
  - Maintenance seasons
    - Gaps covered by BU 43 GHz data
- Multi-frequency comparison
  - Correlation with other frequencies
  - Other flares in high freq. bands



Algaba+18a

Correlations

- Time lags
  - Radio - Radio correlations
    - Compatible w/ zero time lag
    - Possible trend? But too large uncertainties
  - Radio - Optical correlations
    - Weak correlation
    - If any, large time lag
  - Radio - γ-rays correlation
    - Significant time lag



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  - Radio - Optical correlations
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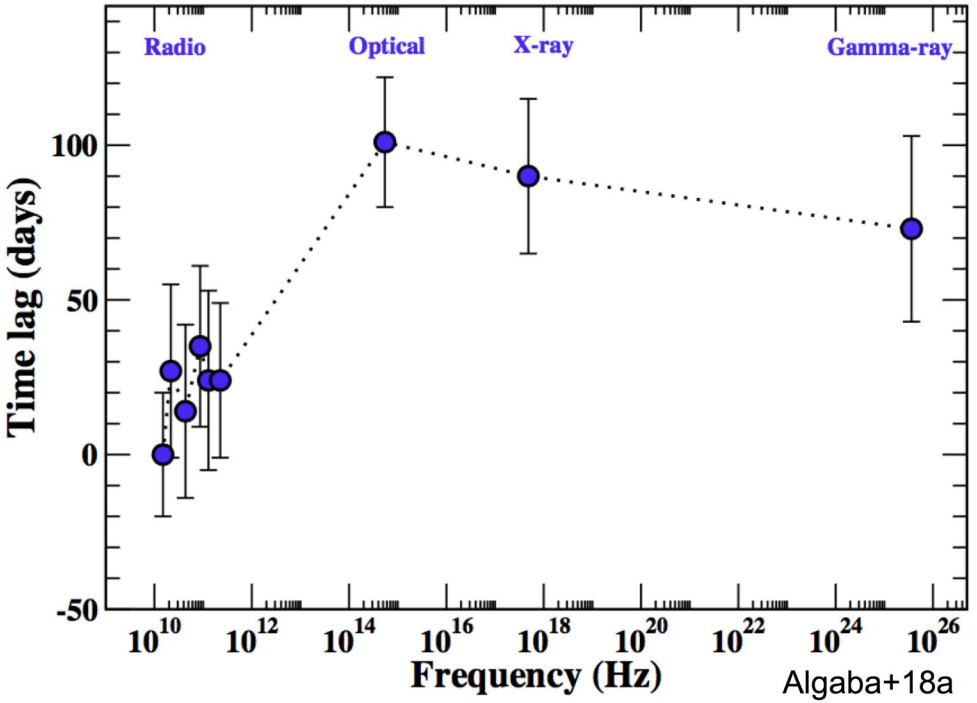
    - If any, large time lag
  - Radio - γ-rays correlation
    - Significant time lag
- Indications of different emitting regions at high energies / radio?
  - Shock-in-jet model?



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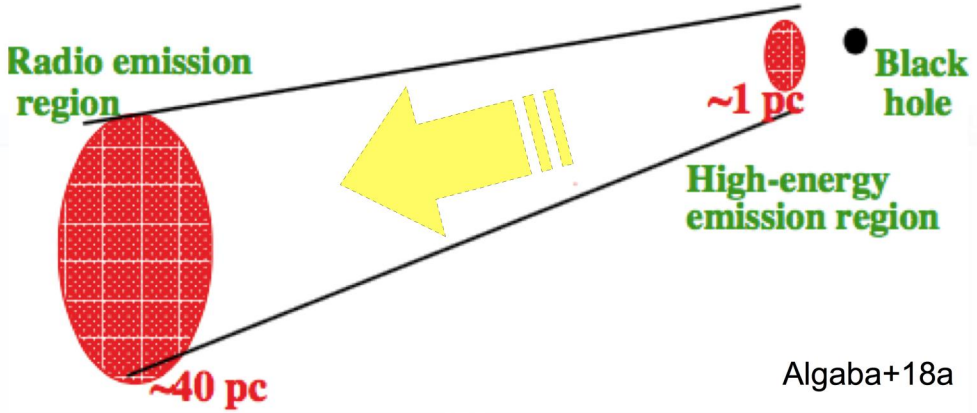

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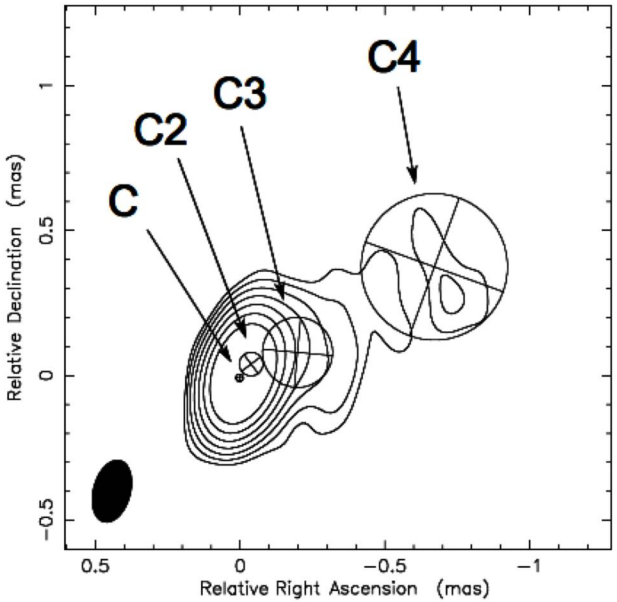
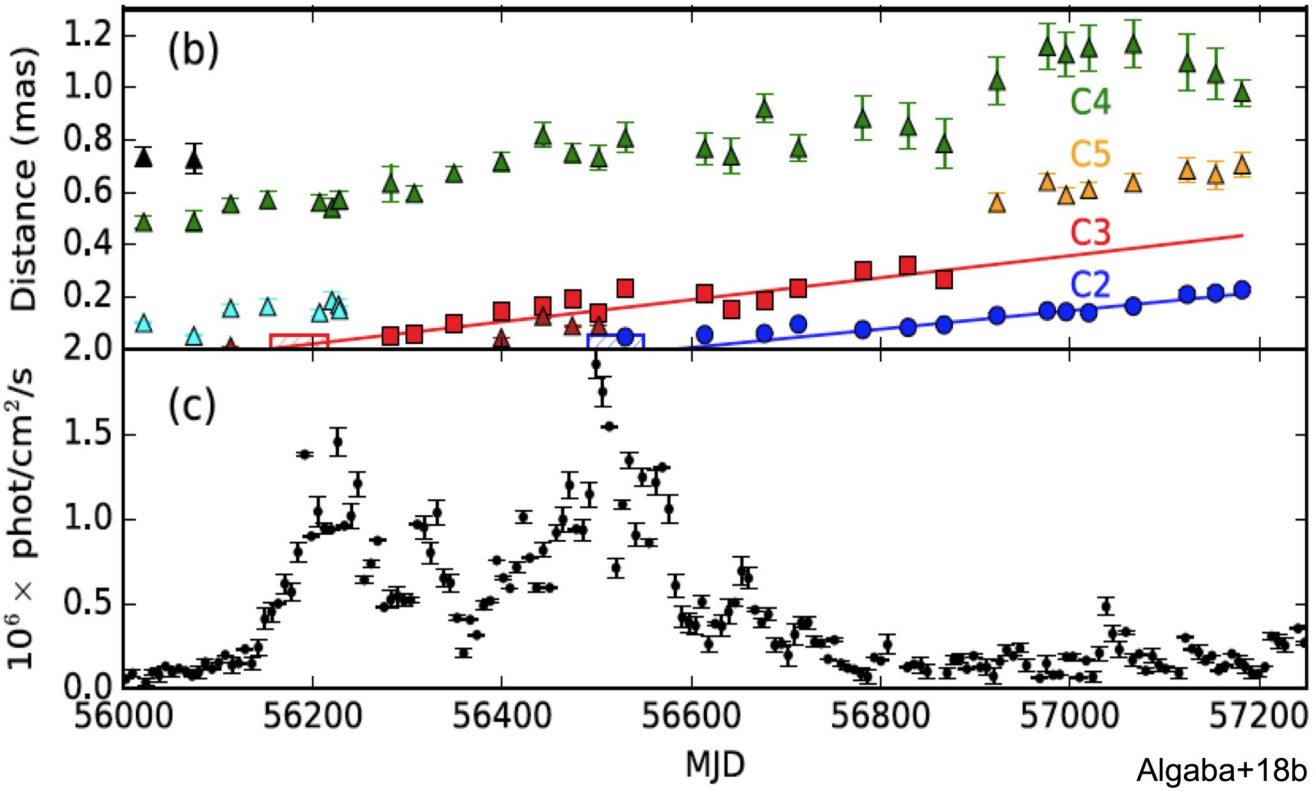
Shock-in-jet?

- Structure analysis
  - Jet components
  - Core size





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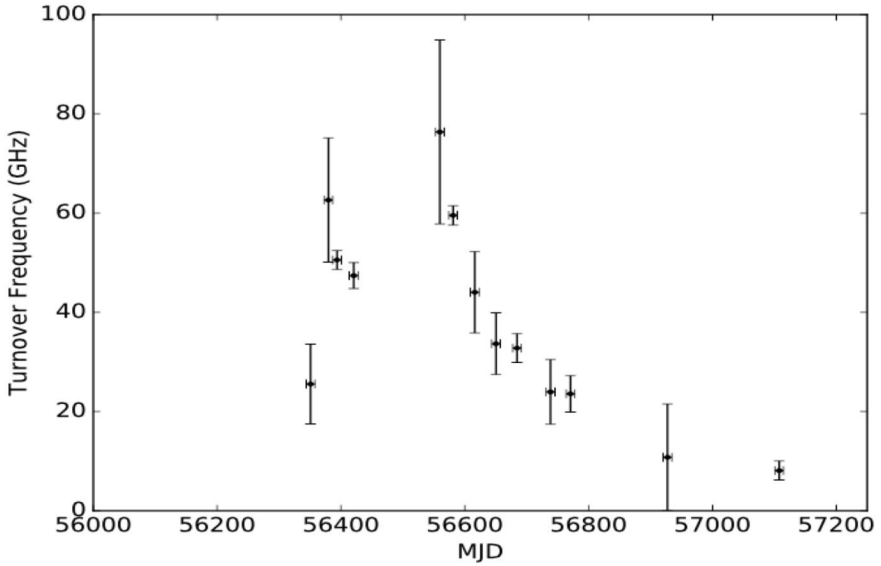
- New VLBI component ejection near brightest γ-ray flares
  - v(C2) = 10.2±0.8c
  - v(C3) = 11.7±1.6c

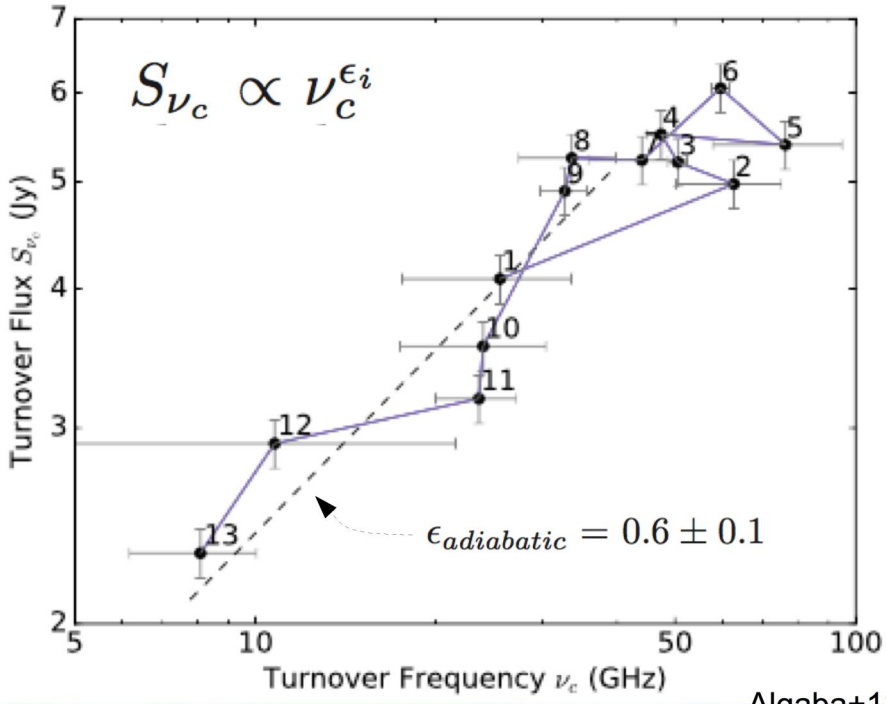
} Γ~12-14; δ~19-21 for θ~2.5°, in agreement with Hovatta+09

Shock-in-jet?

- Turnover Frequency
  - IMOGABA (22, 43, 86, 129) +
    + OVRO + SMA



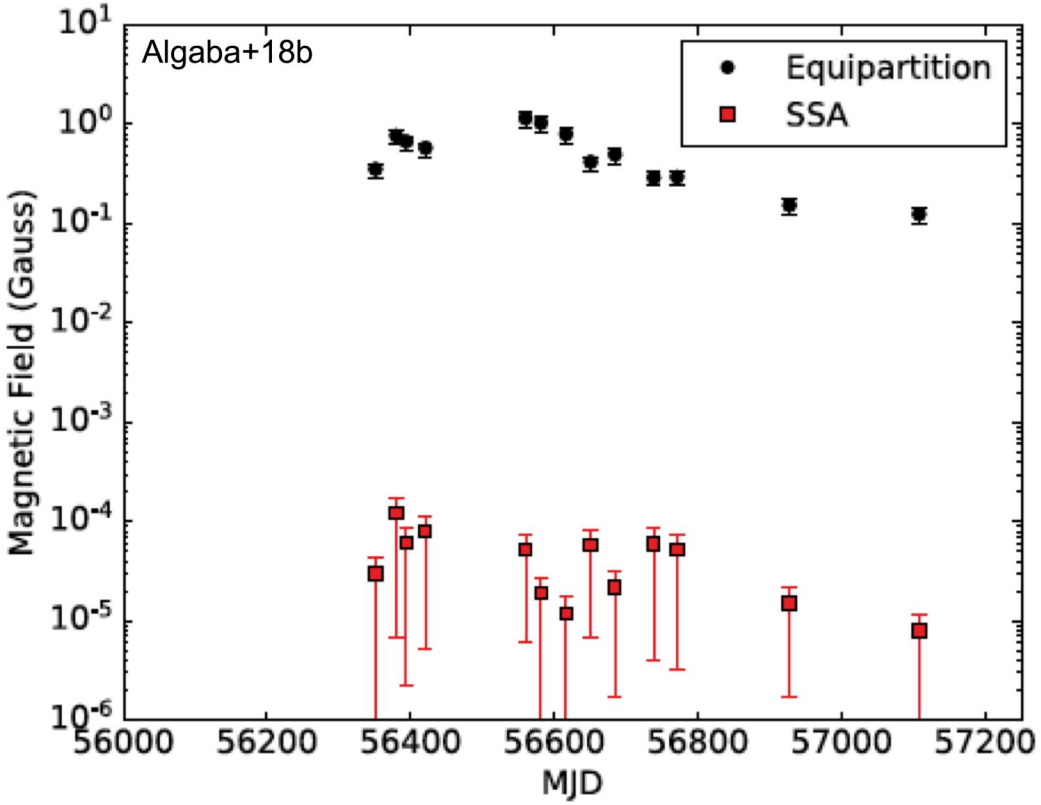
- Relation between flux density and turnover frequency
  - In the Shock in jet model, three stages: Compton, Synchrotron, Adiabatic
  - Data compatible with an small-θ ϵ_{syn} followed by ϵ_{adiab}.



Algaba+18b

Shock-in-jet?

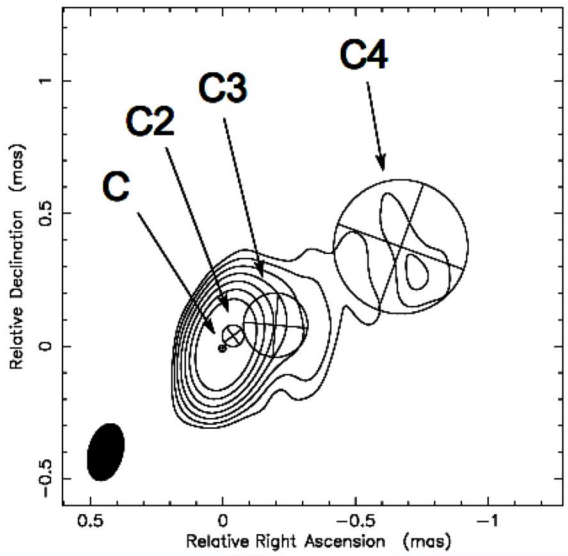
- Magnetic Fields
  - Synchrotron Self Absorption
  - Equipartition
- Characteristics
  - Constant over the whole period
  - $B_{SSA} << B_{eq}$
- Implications
  - B may not play an important role in the flares/component ejection
  - Flares associated with particle dominated regions

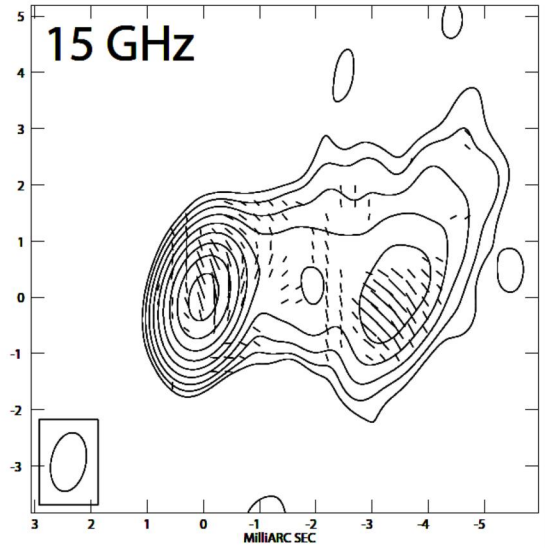


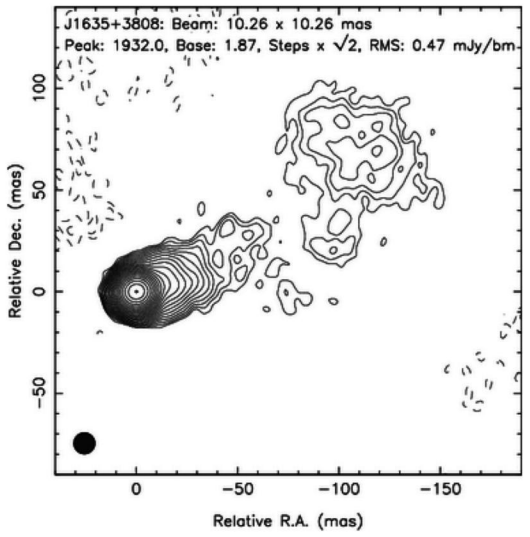
- Similar results have been discussed/reported in other works/sources
  - 0716+714 (Lee+2017)
  - Mrk 421, Mrk 501, PKS 2155-304 (Kino+2002)
  - Median T_B on a sample of sources on high state (Homan+2006, Lee15)
  - RadioAstron T_B excess (Nokhrina+2017, Pilipenko+2018)

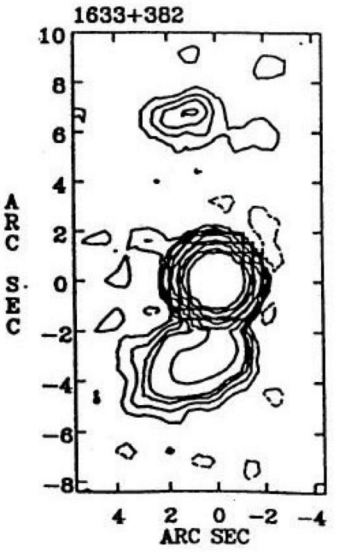
Evolution of the Jet Components

- How do these components evolve after being ejected?
  - Significant bending of the jet
  - This can be seen on all scales!
- Case Study
  - Interaction with media / intrinsic in nature (e.g., helical B fields, binary SMBH...)?









VLBA 1.4 GHz: University College Cork Program Murphy+93, MNRAS, 264, 298

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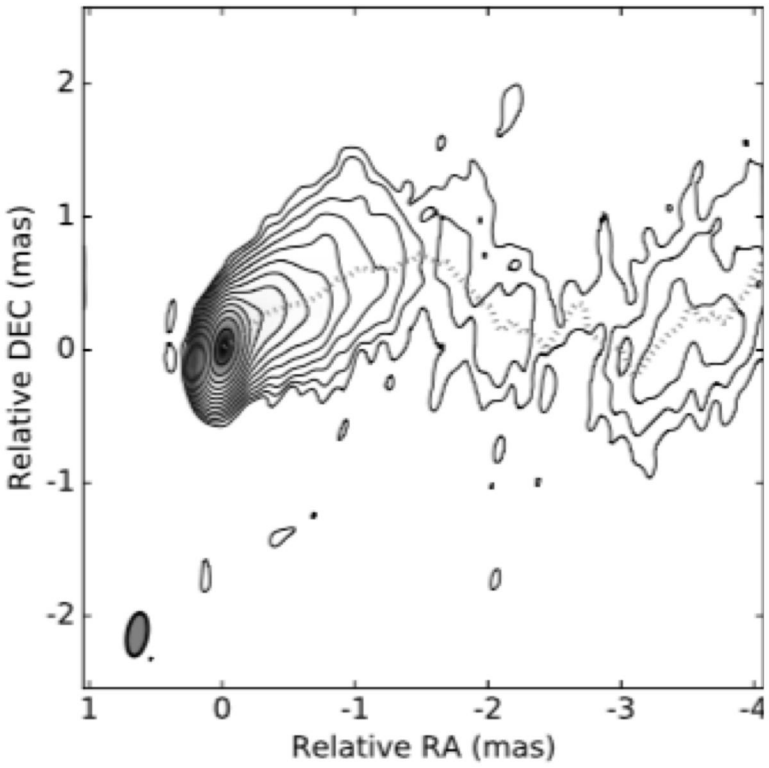
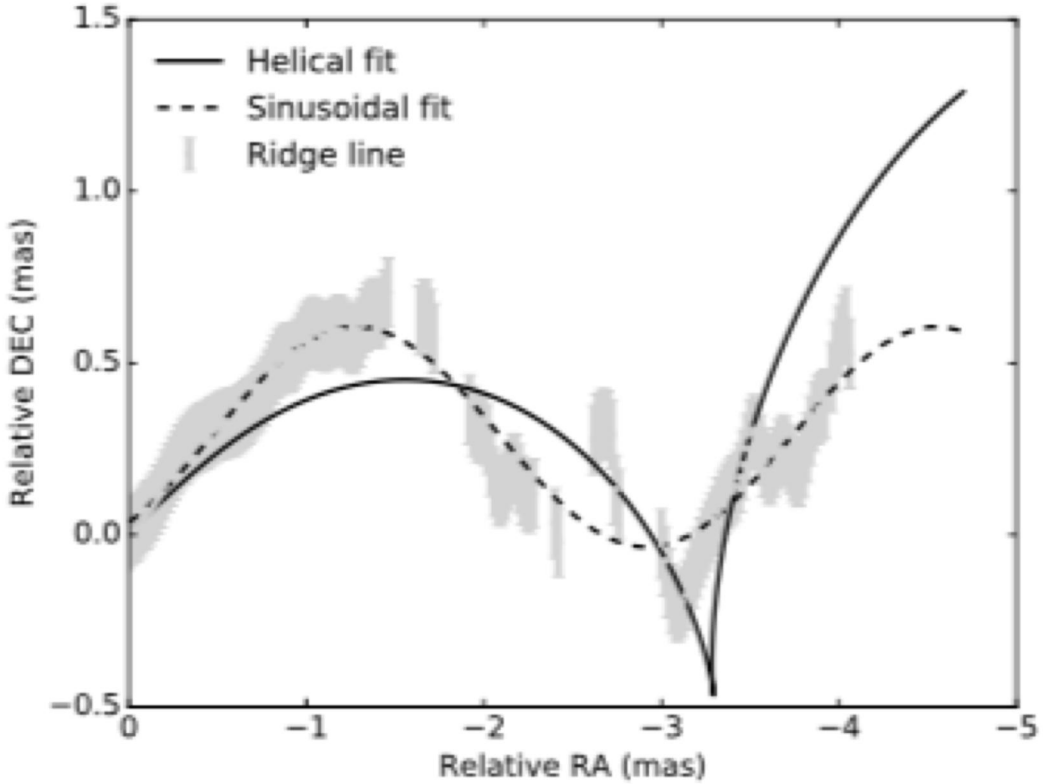
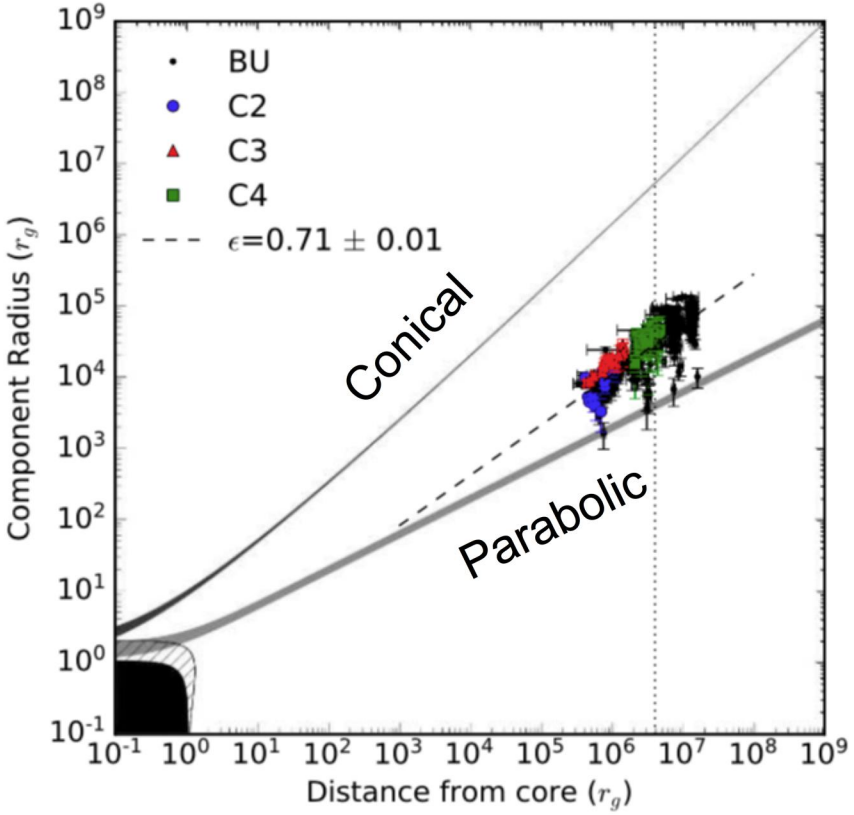




Evolution of the Jet Components

- Jet Geometry
  - Jet geometry paradigm



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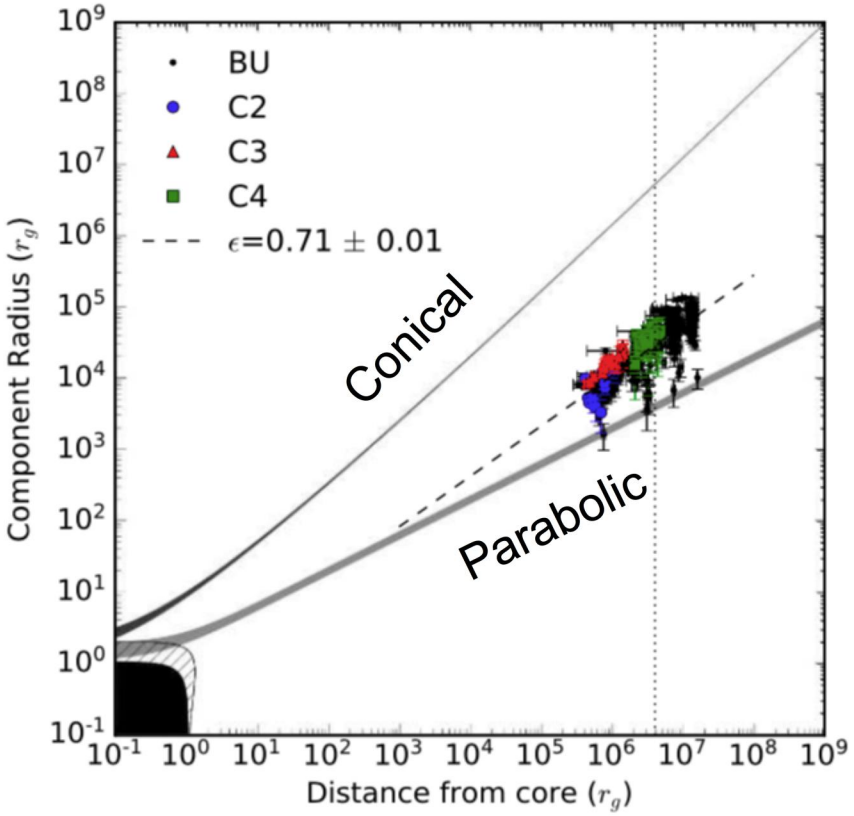

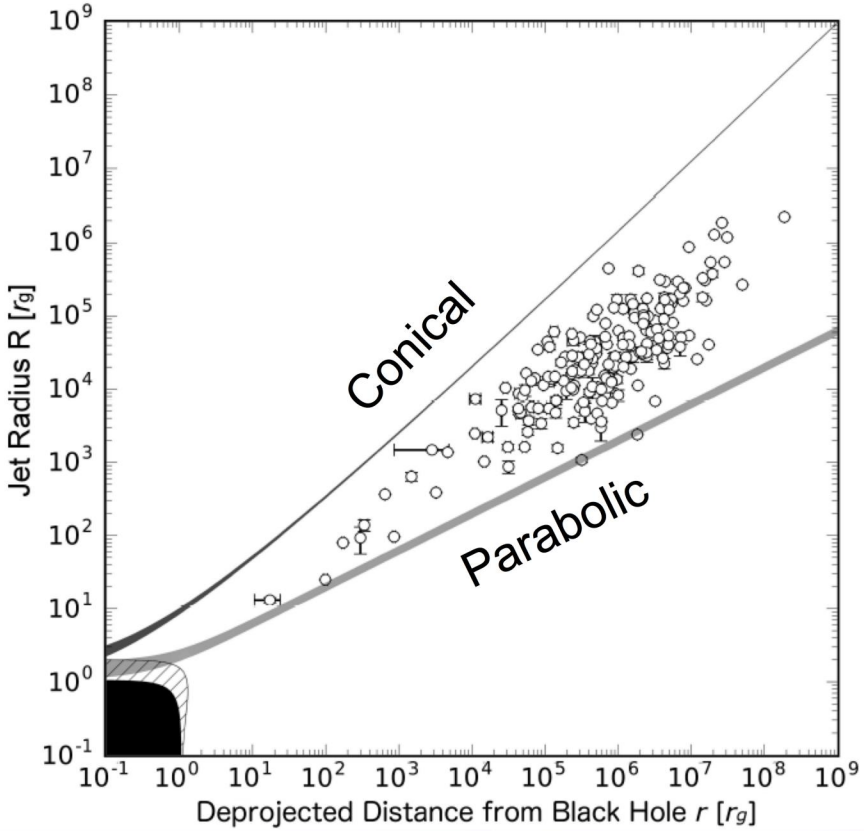

Algaba+17

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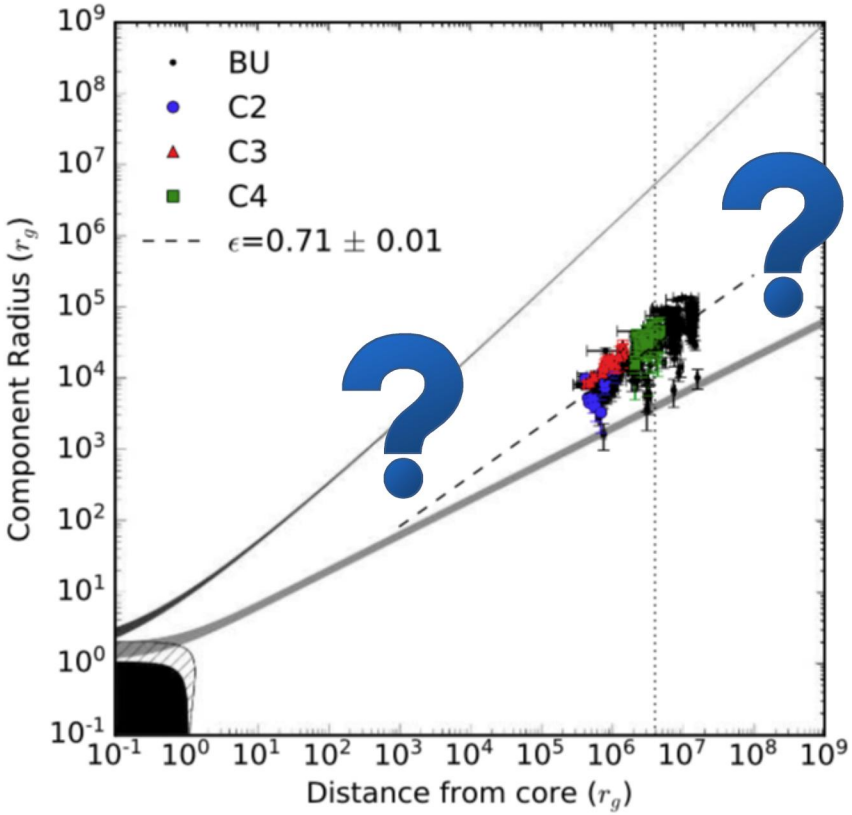
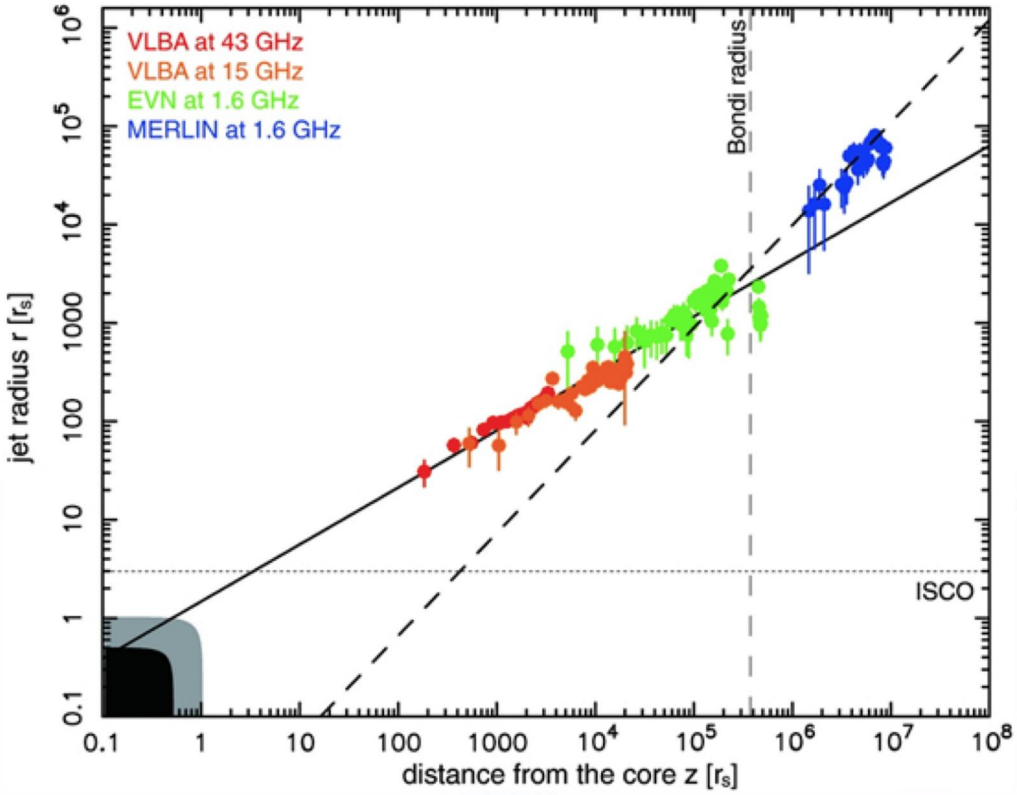
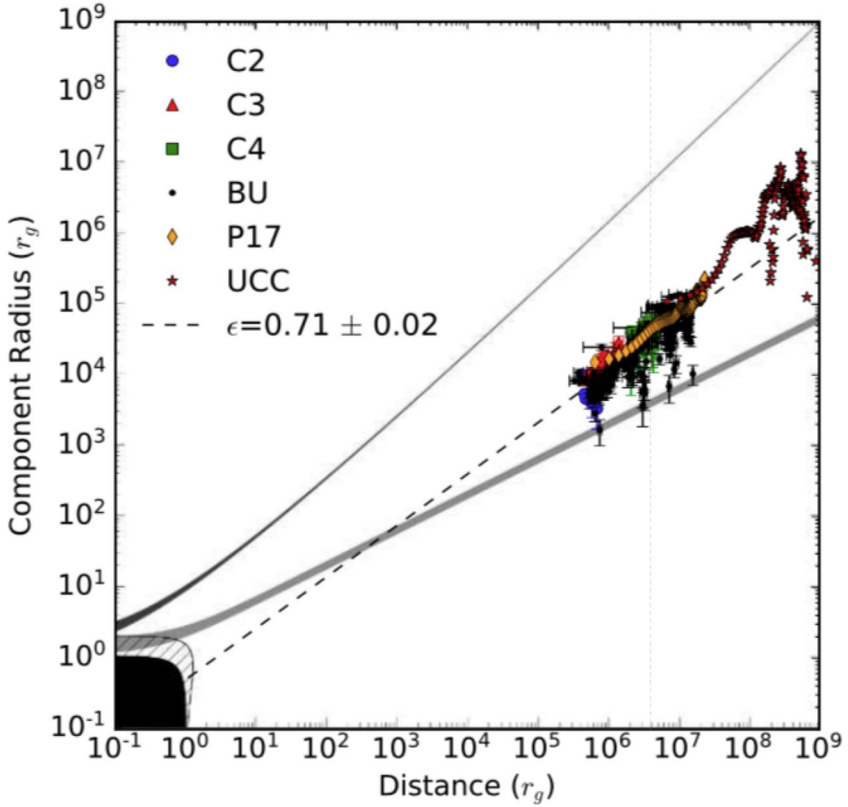


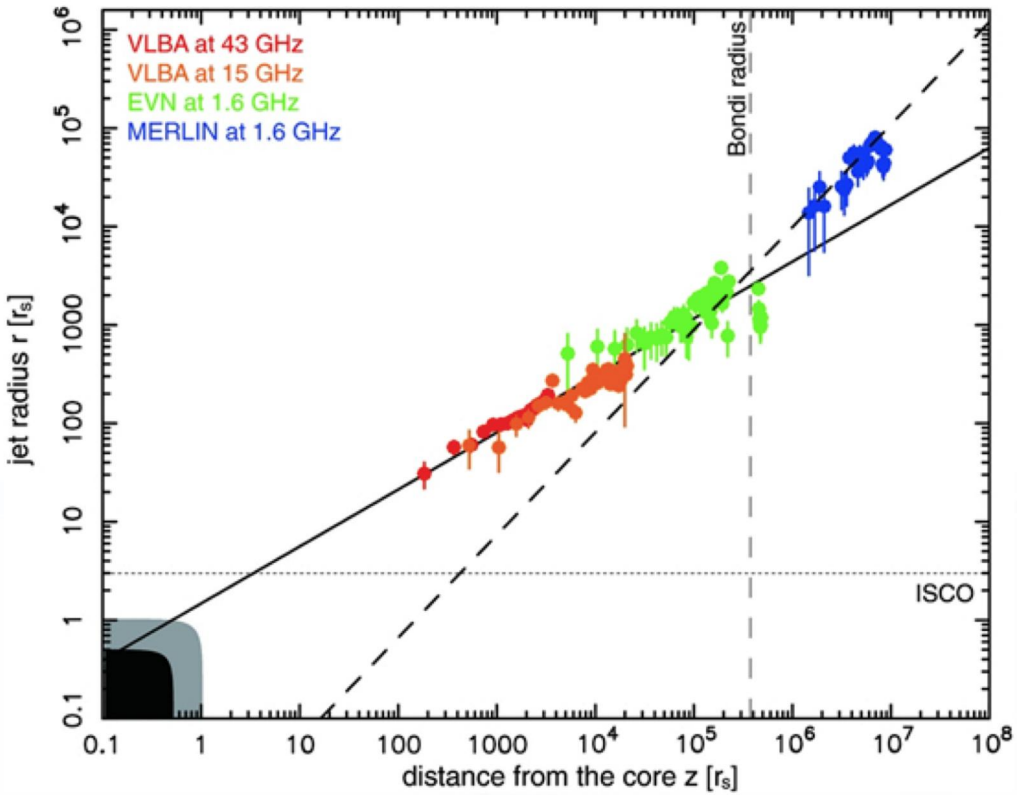


Asada & Nakamura (2012)

Evolution of the Jet Components

- Jet Geometry
  - Jet geometry paradigm
    - Deviation from a parabolic geometry
    - Extrapolation towards innermost regions may suggest BZ process?
      - If so, jet should be leptonic, initially Poynting flux dominated?

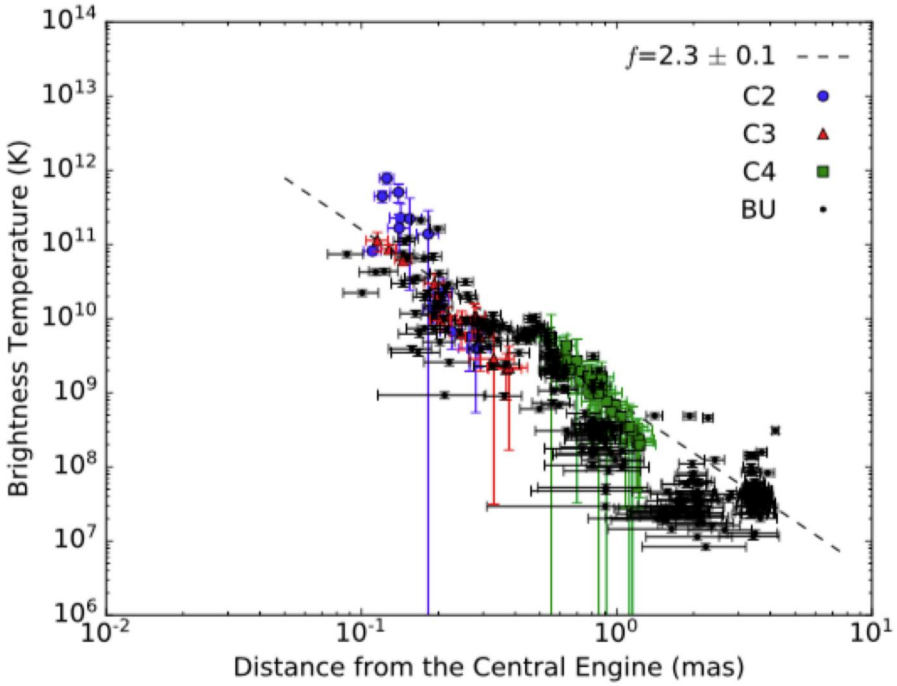


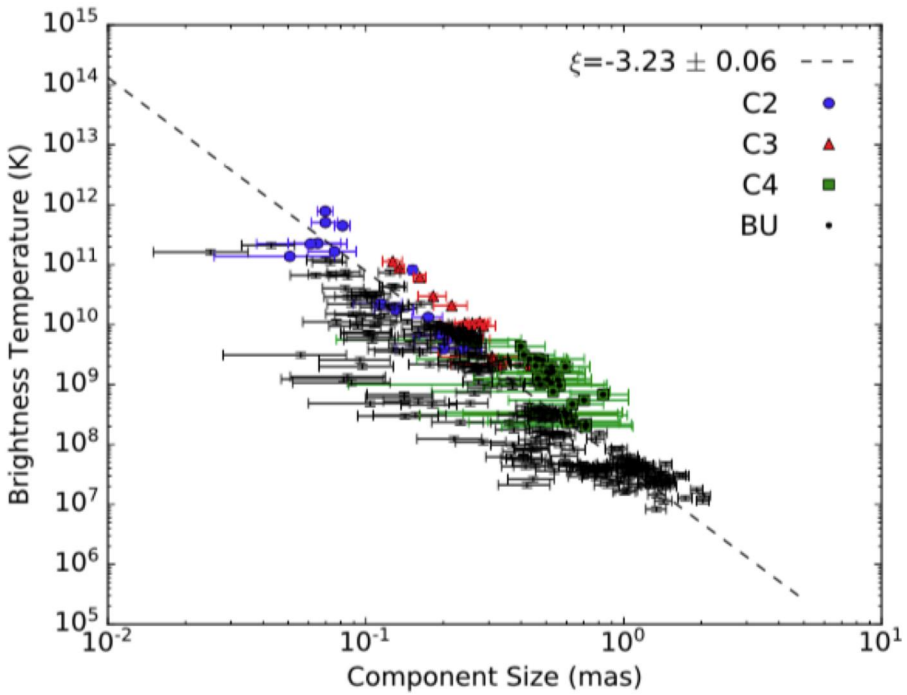


Asada & Nakamura (2012)

Evolution of the Jet Components

- Brightness Temperature





$$f = -\epsilon + n + b(1-\alpha)$$

$$\xi = [2(2s+1) + 3b(s+1)]/6$$

  - Assuming α = - 0.5, we get 3=1.5 n+b, compatible with n=1.4 and b=1
  - With α = - 0.5 ($\Rightarrow$ s = 2) and b=1, we obtain ξ =3.2

- Compatible with equipartition

Conclusions

- Gamma ray flares
  - Associated with ejection of new jet components
  - Active regions appear to be particle-dominated, far from equipartition
- Jet Evolution
  - Jet does not seem to follow a straight trajectory
    - Jet intrinsic phenomenology or interaction with the media
  - Jet conditions in agreement with equipartition
- Jet Geometry
  - Indications of a quasi-parabolic jet with a possible jet break
  - Extrapolation suggests BZ rotationally driven jet?
  - Collimation but no acceleration?