Magnetohydrodynamic Interpretation of Superluminal Jet Kinematics

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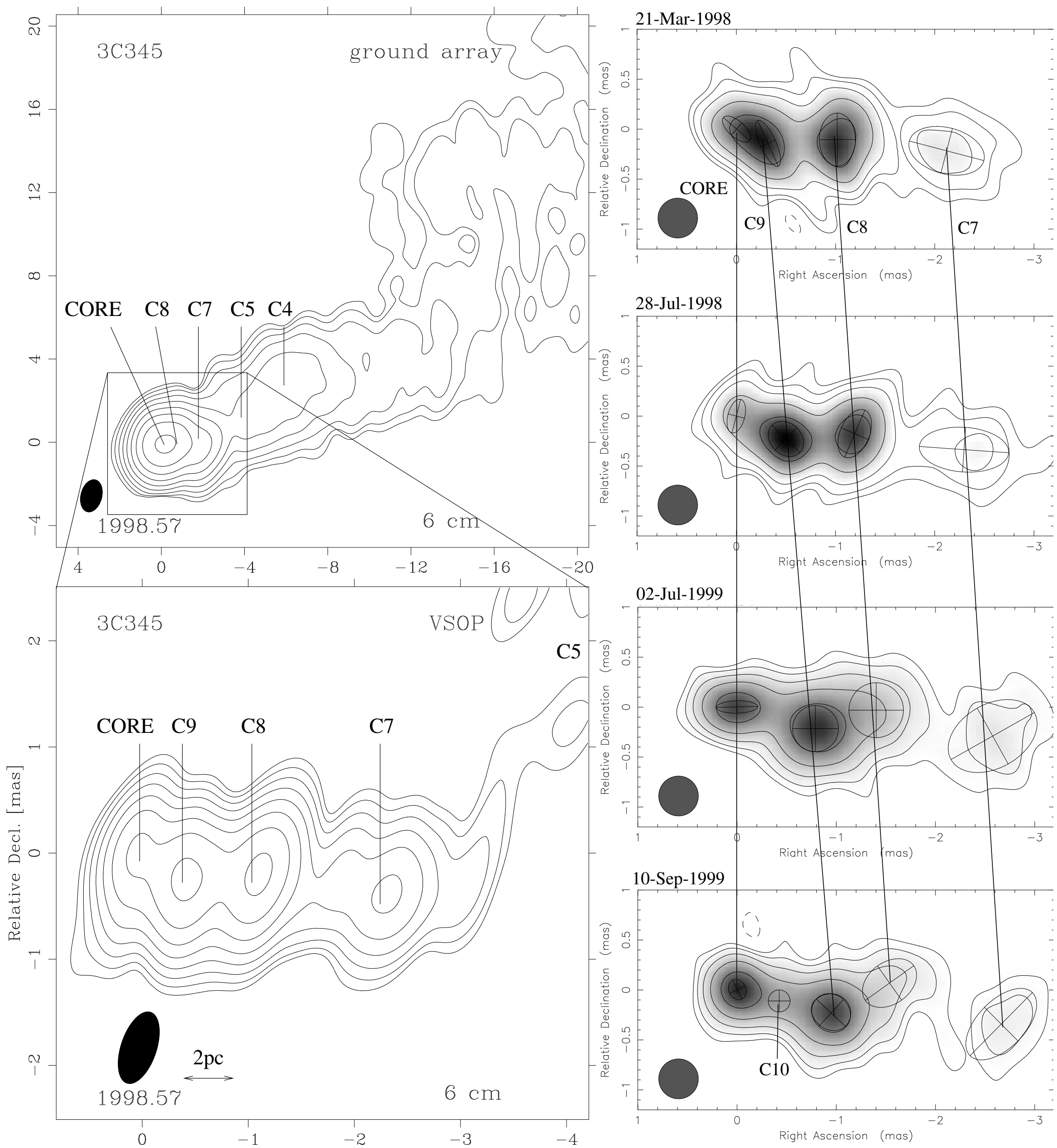
Outline

- what observations infer
- MHD model
- results

The quasar 3C345

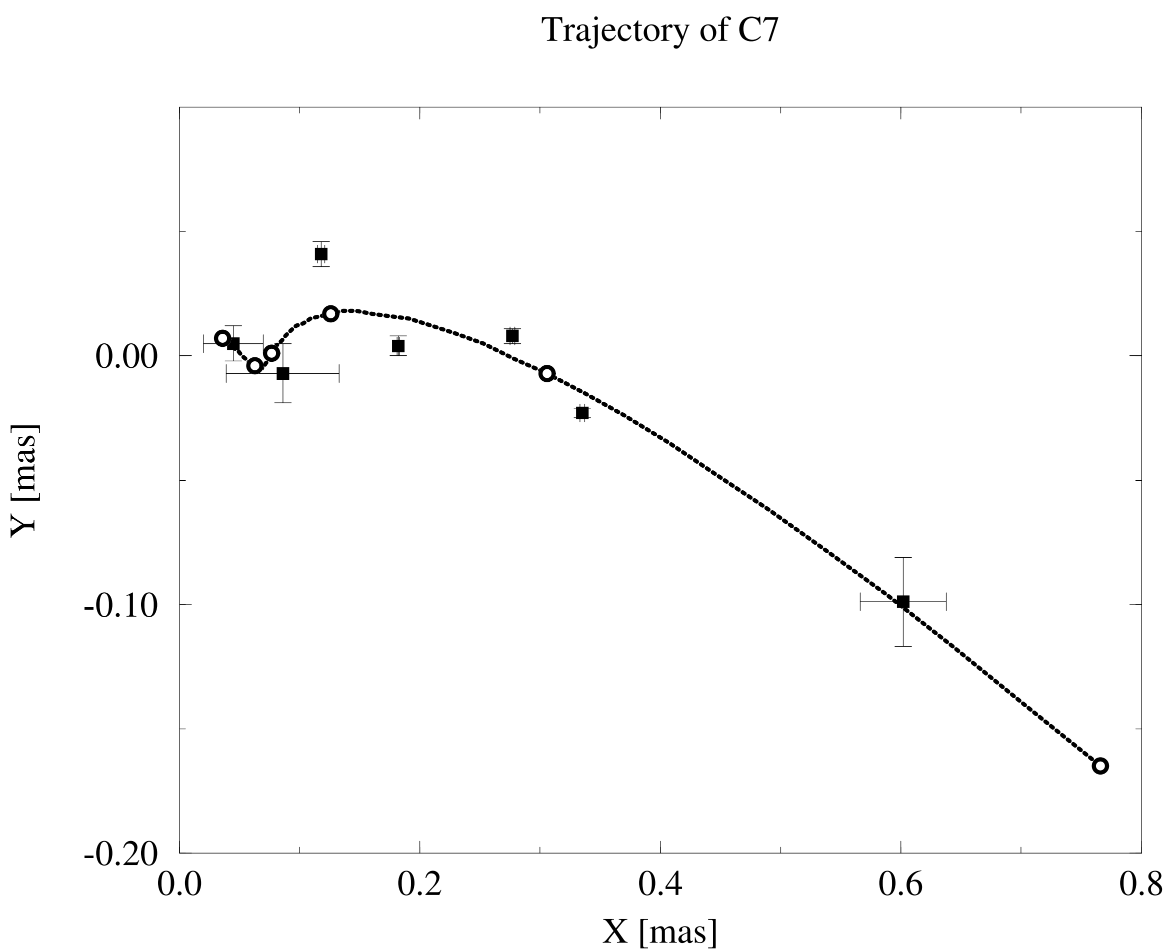


(credit: Klare et al)

The plasma components move with an apparent speed of 3-20c

These plasma components travel on curved trajectories

These trajectories differ from one component to the other



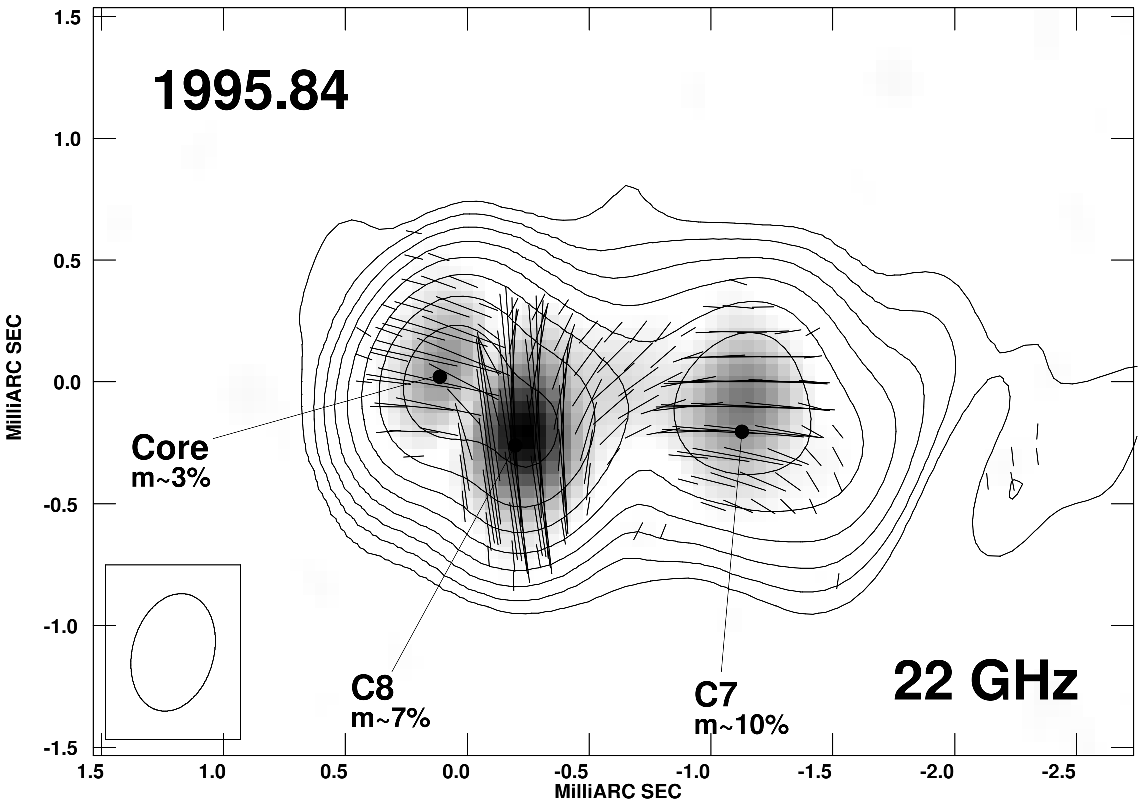
(credit: Lobanov's thesis)

- Superluminal apparent motion $\Rightarrow \beta_{\rm app}$
- Compare radio- and X-emission (SSC) $\Rightarrow \delta$

From $\delta(t_{\rm obs}) \equiv \dfrac{1}{\gamma\,(1-\beta\cos\theta_V)}$ and $\beta_{\rm app}(t_{\rm obs}) = \dfrac{\beta\sin\theta_V}{1-\beta\cos\theta_V}$
we find $\beta(t_{\rm obs})$, $\gamma(t_{\rm obs})$ and $\theta_V(t_{\rm obs})$.

For the C7 component of 3C 345 Unwin et al. (1997) inferred that it accelerates from $\gamma \sim 5$ to $\gamma \sim 10$ over the (deprojected) distance range (measured from the core) $\sim 3-20\ {\rm pc}$. Also the angle θ_V changes from ≈ 2 to $\approx 10^o$ and the Doppler factor changes from ≈ 12 to ≈ 4. ($t_{\rm obs} =$ 1992 – 1993.)

- pc-scale acceleration → nonthermal origin
- Polarization → magnetic fields



(credit: Ros et al)

- collimation

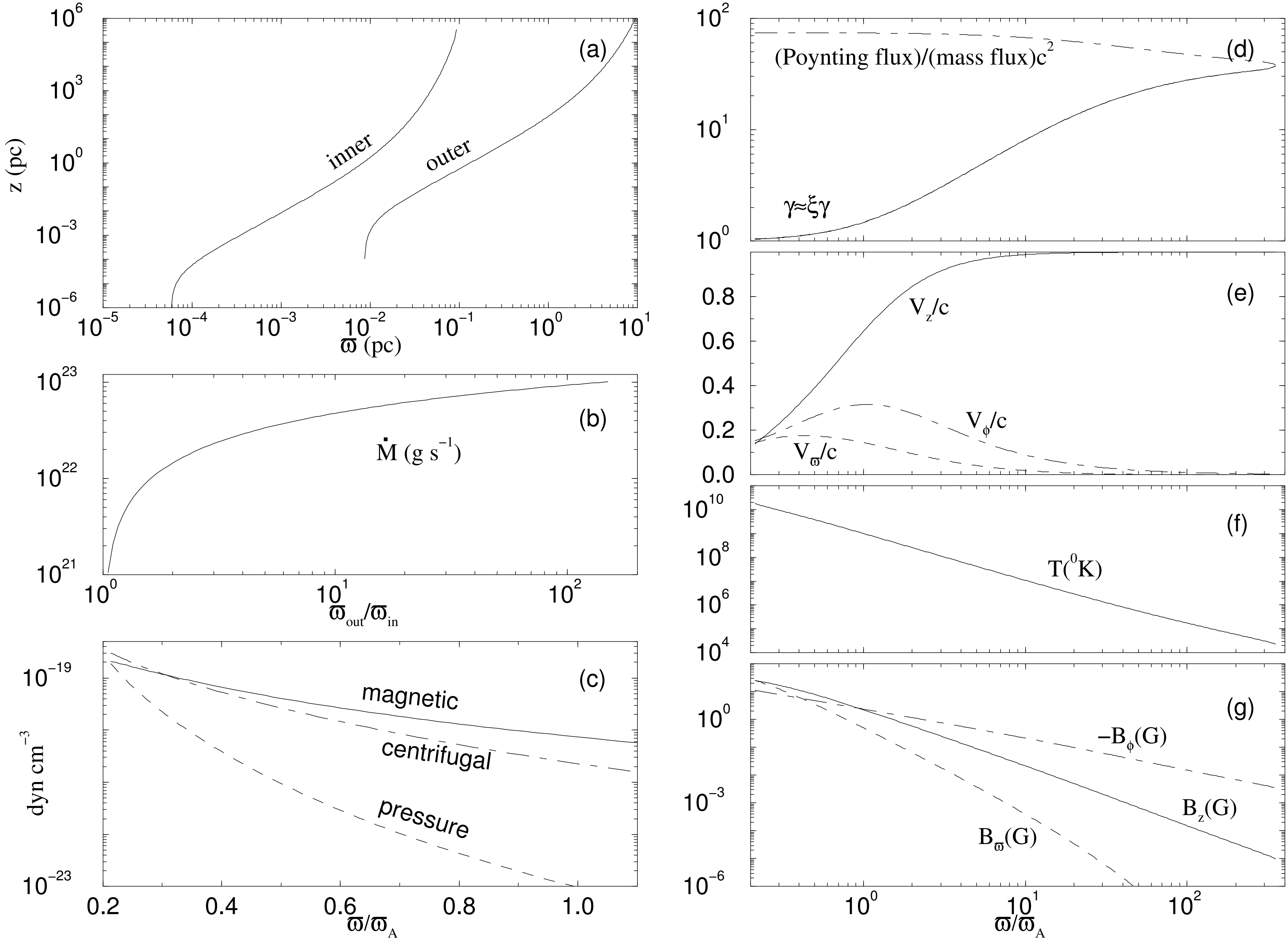
The MHD model

- We examine outflows taking into account
  - matter
  - large-scale electromagnetic field

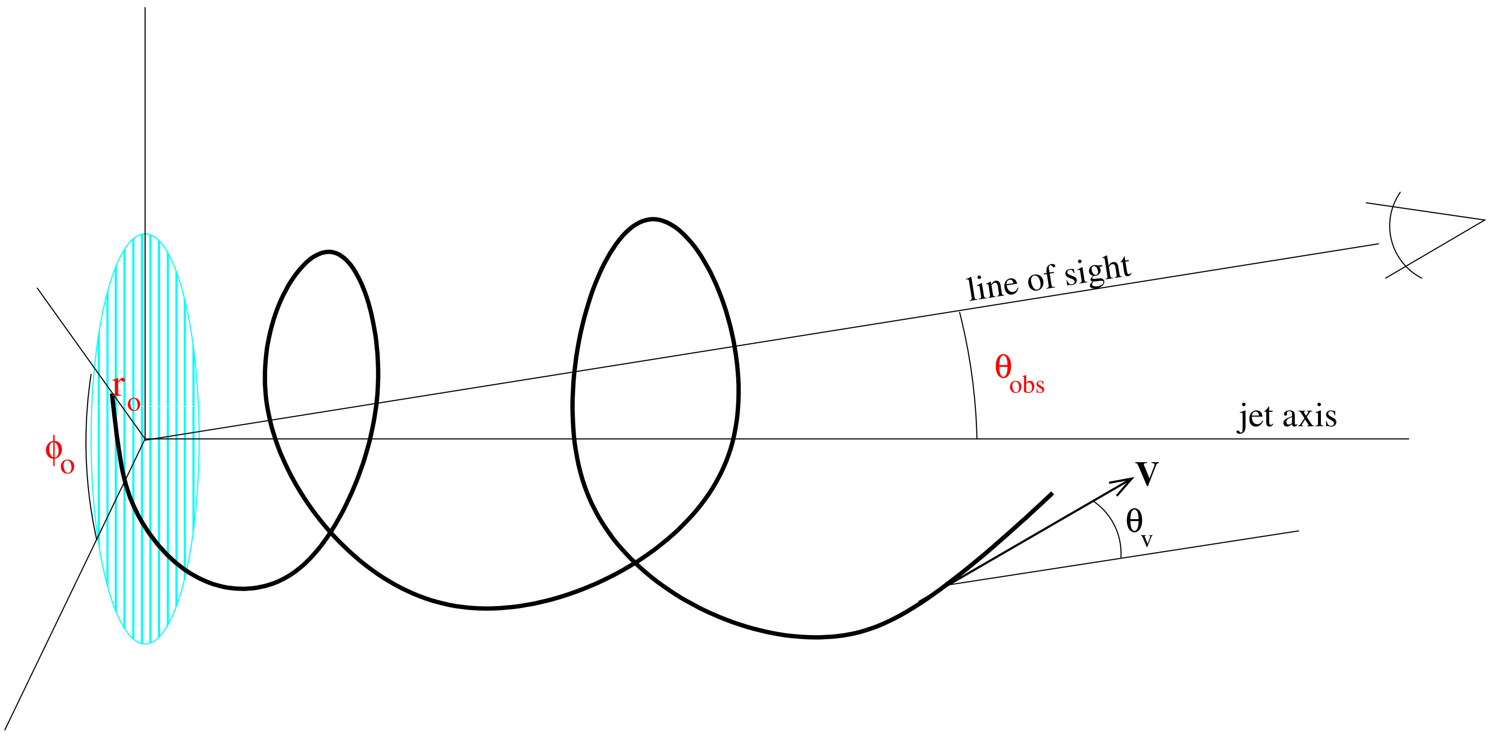
- Assumptions:
  - axisymmetry
  - steady-state
  - special relativity
  - ideal MHD
  - r self-similarity (all quantities on the conical disk surface are power laws in r)

(details of the model can be found in Vlahakis & Königl 2003, ApJ, 596, 1080)

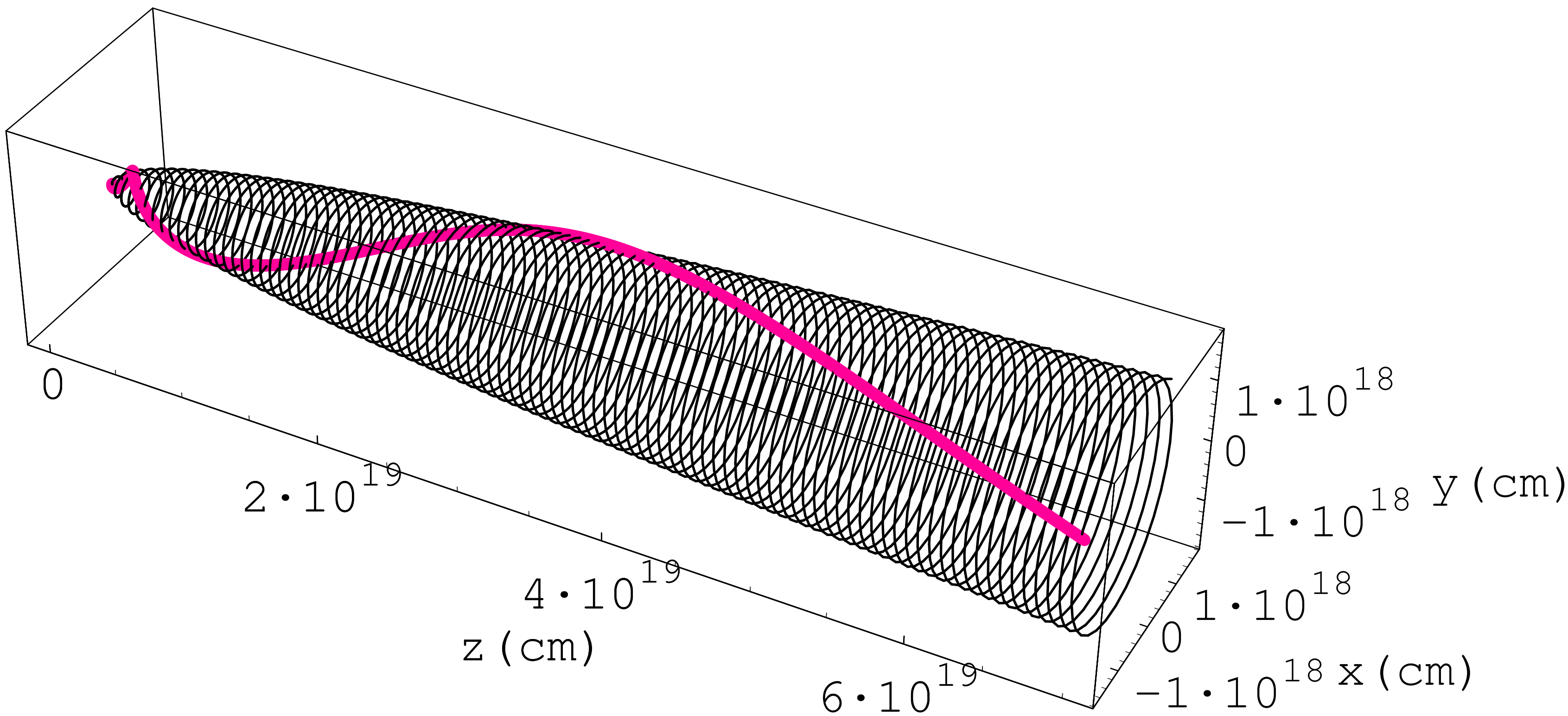
First results (Vlahakis & Königl 2004, ApJ, 605, 656)



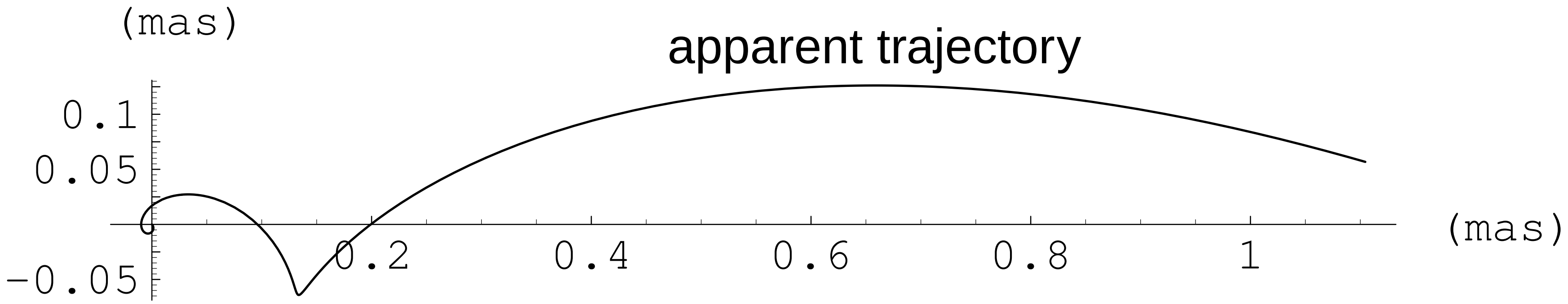
Next step: For given $\theta_{\rm obs}$ (angle between jet axis and line of sight) and ejection area on the disk (r_o, ϕ_o) project the trajectory on the plane of sky and compare with observations. Find the best-fit parameters r_o, $\theta_{\rm obs}$, ϕ_o.



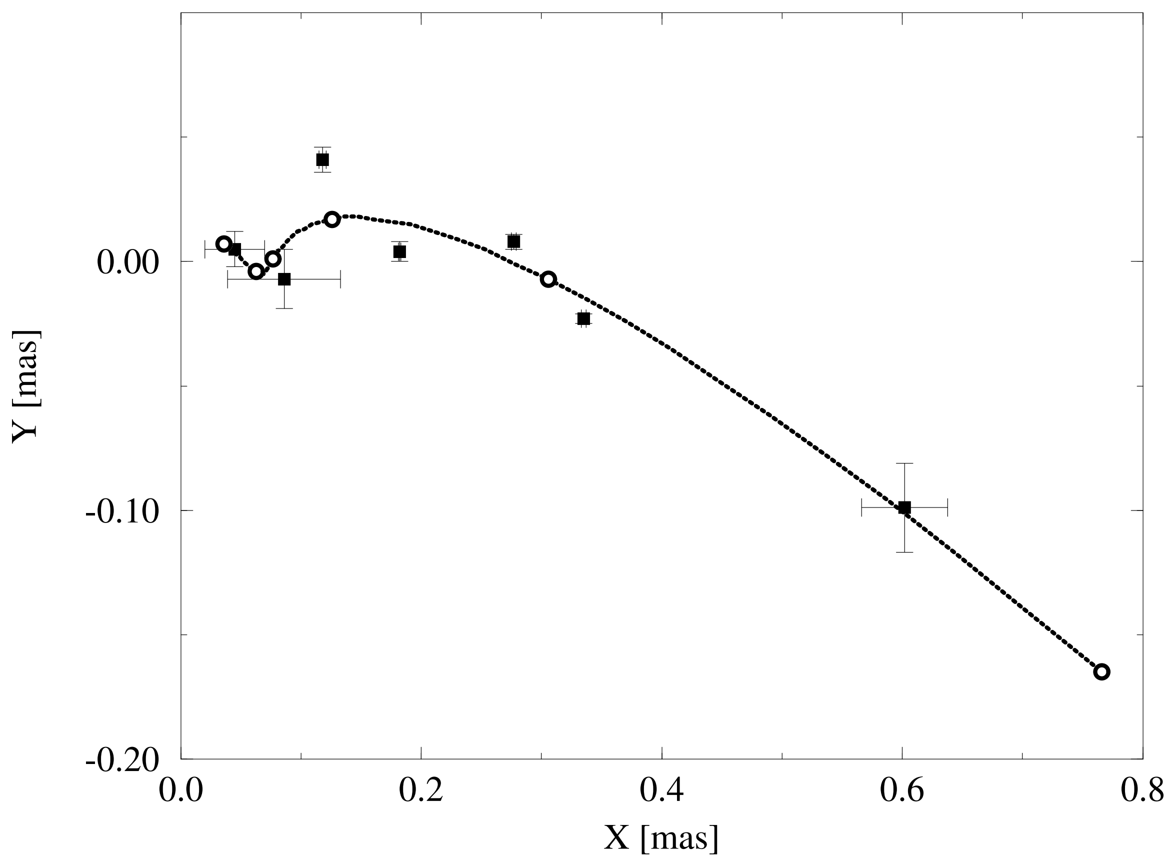
Preliminary results

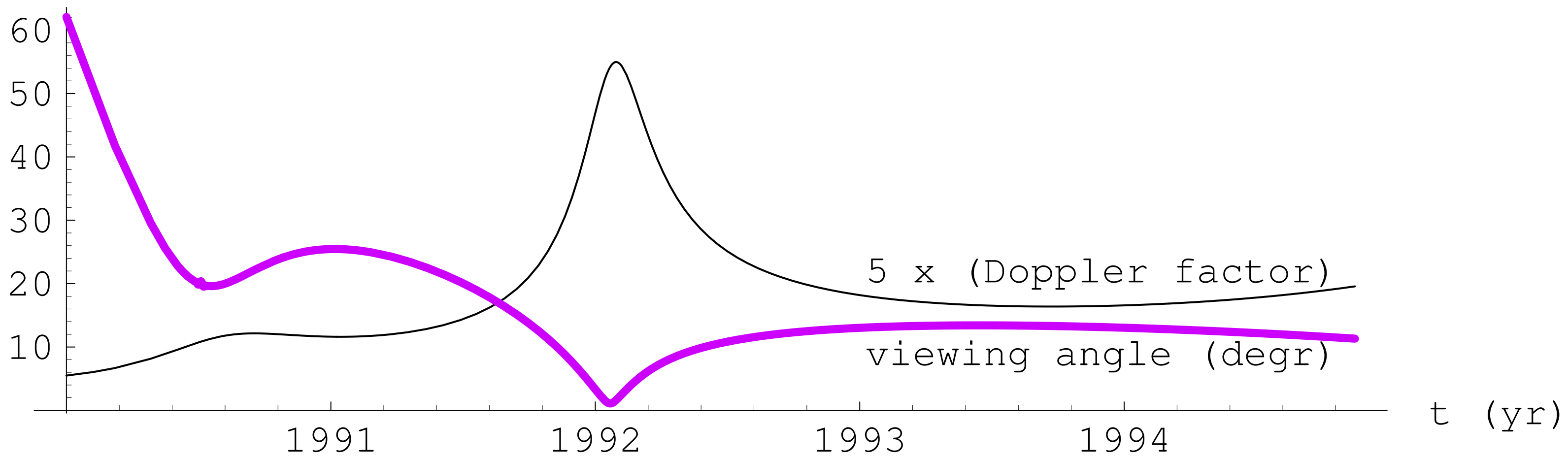


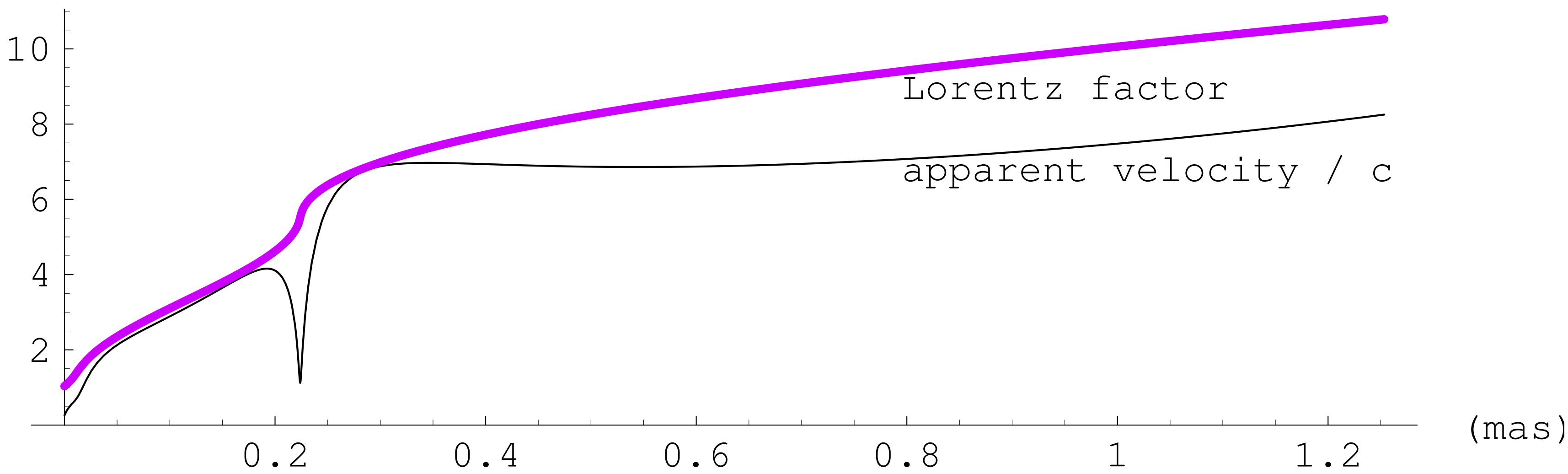
best-fit: $r_o \approx 2 \times 10^{16}$cm, ϕ_o=180^o and $\theta_{\rm obs}$=9^o



Trajectory of C7




60
50
40
30
20
10
5 x (Doppler factor)
viewing angle (degr)
t (yr)
1991
1992
1993
1994


10
8
6
4
2
Lorentz factor
apparent velocity / c
(mas)
0.2
0.4
0.6
0.8
1
1.2

Discussion

- generalization of Camenzind & Krockenberger (1992) (we solve the momentum equation, address the acceleration and collimation)

- other interpretations of the helical trajectories: K-H instabilities (Hardee 2000), binary black hole (Caproni & Abraham 2003) may have contributions, but cannot explain the acceleration

- Next steps:
  - complete the analysis for the kinematics of C7 and the other components in 3C 345 (new data – Klare's thesis)
  - polarization
  - other sources (e.g., 3C 279, 0735+178) show similar behavior