Magnetic fields in the jets of Active Galaxies from multi-frequency radio observations

Nadia Kudryavtseva

University College Cork

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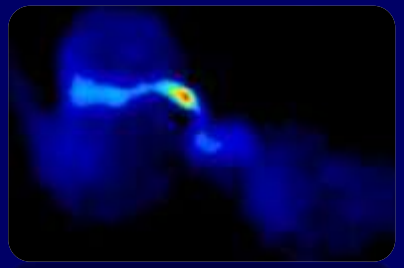
Collaborators:

Denise Gabuzda, University College Cork

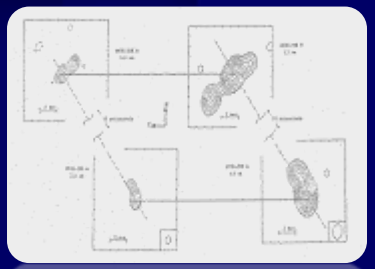
Margo Aller, Michigan University

Hugh Aller, Michigan University

Outline



1. Introduction – what is optically thick inner part of the jet, how it is connected with magnetic fields

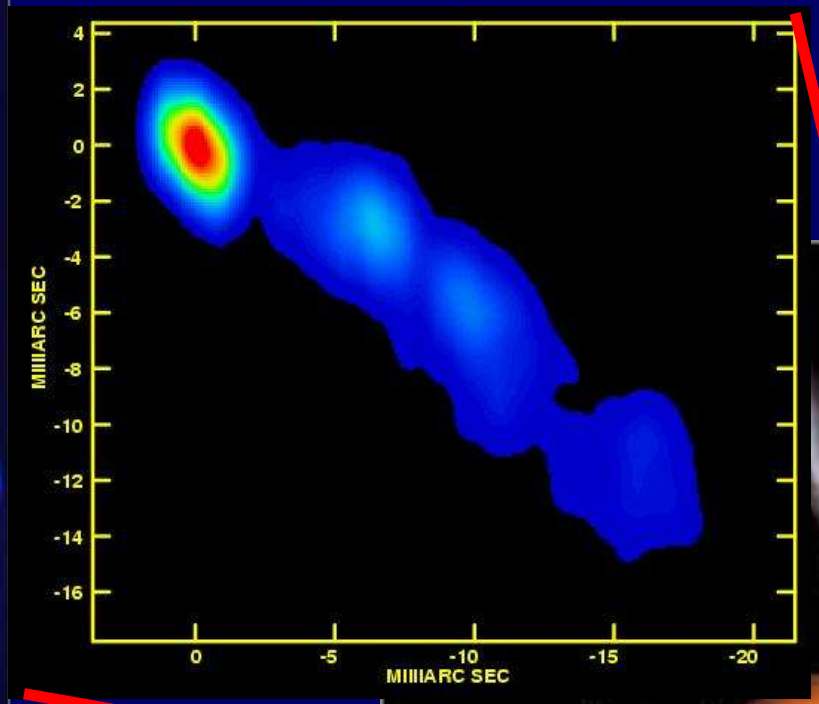


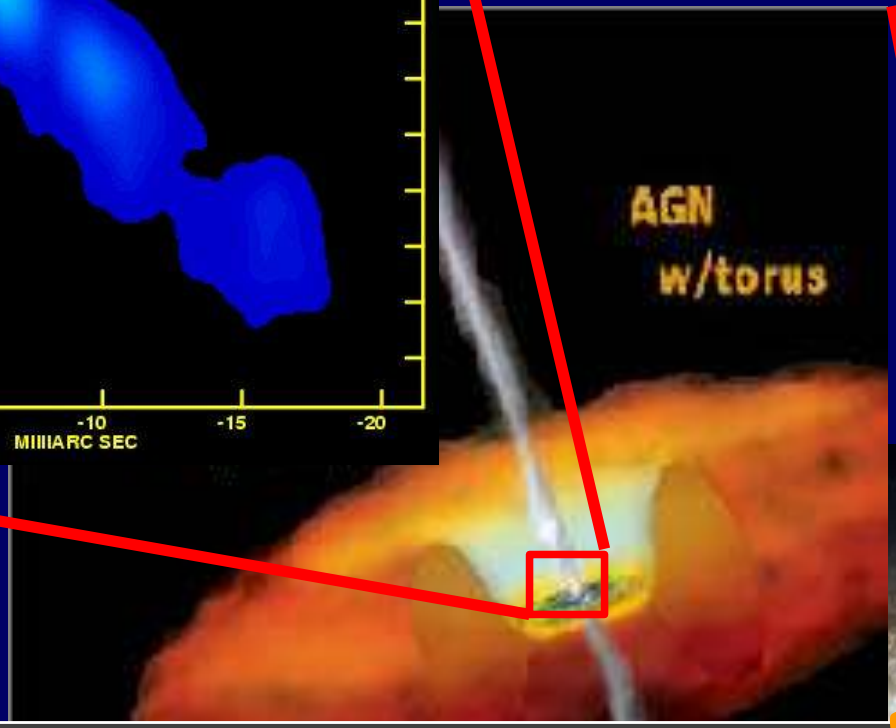
2. New method estimating magnetic fields using radio total flux-densities

3. Results

4. Summary

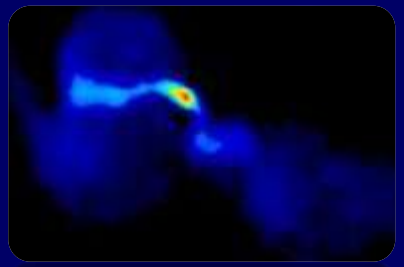
Open questions





1. How the jet is collimated? From pc to kpc ?
2. Magnetic field strength? ?
3. Magnetic field configuration? ?

Outline



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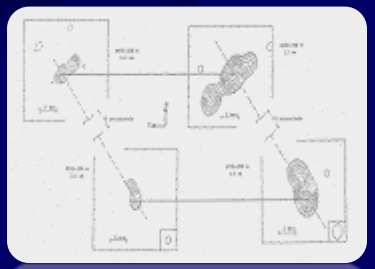

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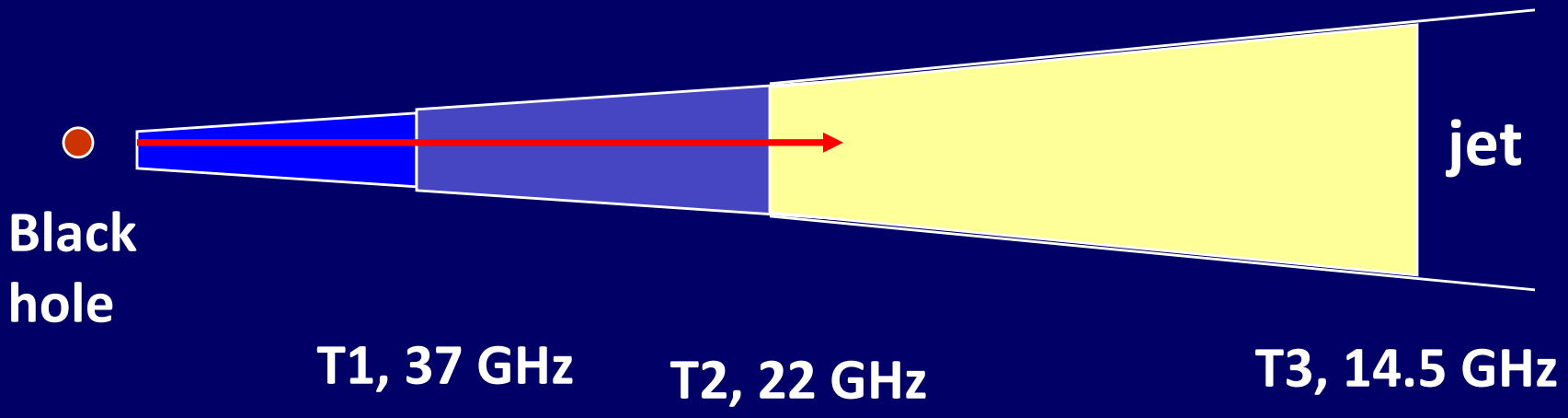
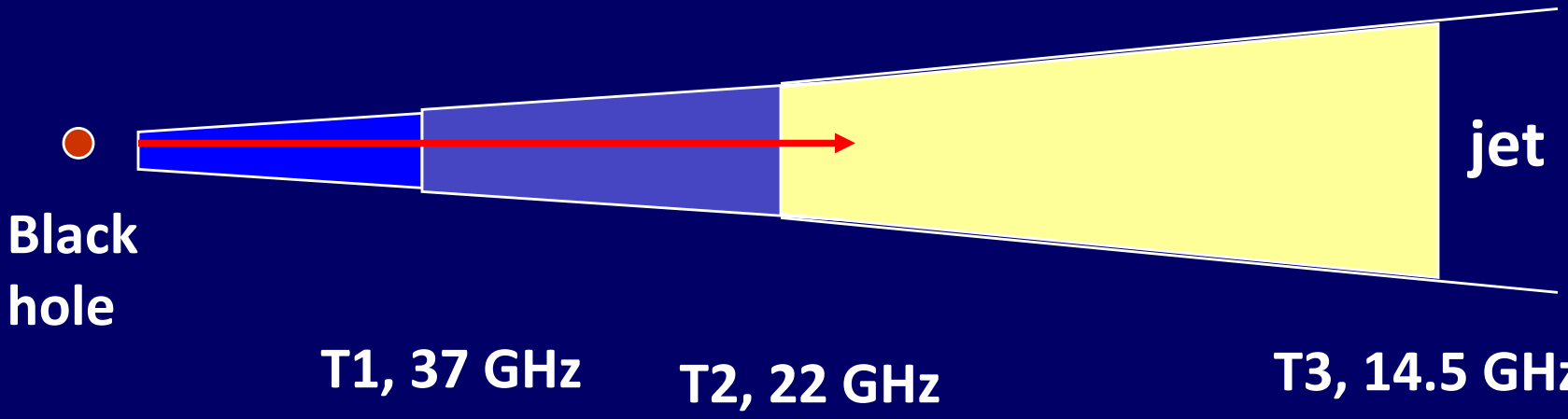
Magnetic fields from opacity



- Optical depth along the jet depends on frequency
- $r_{core} \propto \nu^{(-1/k_r)}$ (Blandford&Konigl 1981)
- Because of synchrotron self-absorption

Magnetic fields from opacity



Core location:

$$r[\mathrm{pc}] = (B_1^{k_\mathrm{b}} F/\nu)^{1/k_\mathrm{r}}$$ (Königl 1981)

Core offset measure:

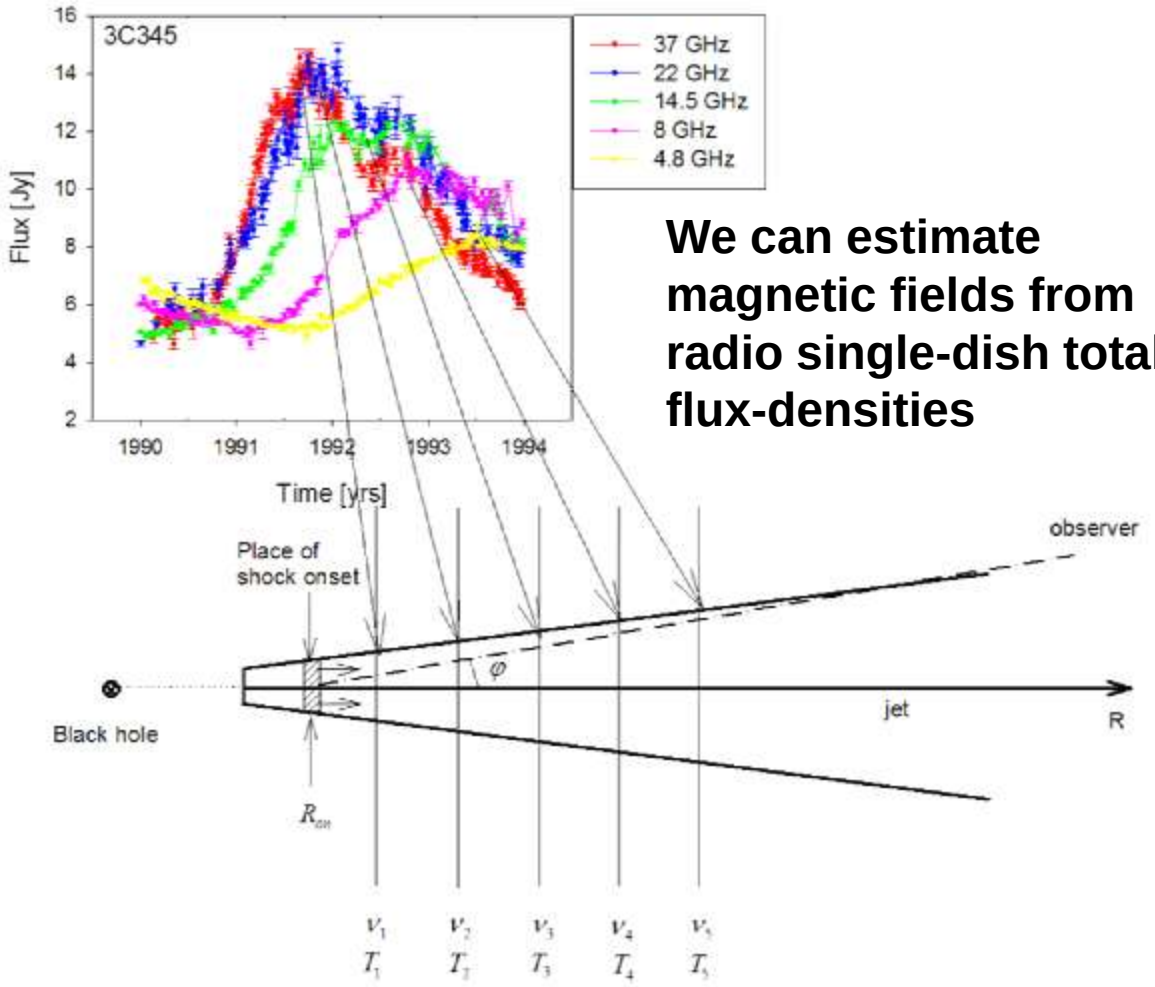
$$\Omega_{r\nu} = 4.85 \cdot 10^{-9} \frac{\Delta r_{\mathrm{mas}} D_\mathrm{L}}{(1+z)^2} \cdot \frac{\nu_1^{1/k_\mathrm{r}} \nu_2^{1/k_\mathrm{r}}}{\nu_2^{1/k_\mathrm{r}} - \nu_1^{1/k_\mathrm{r}}}$$ (Lobanov 1998, Hirotani 2008)

Derived magnetic field:

$$B_1 = (\Omega_{r\nu}/\sin\theta)^{k_\mathrm{r}/k_\mathrm{b}} F^{-1/k_\mathrm{b}}$$

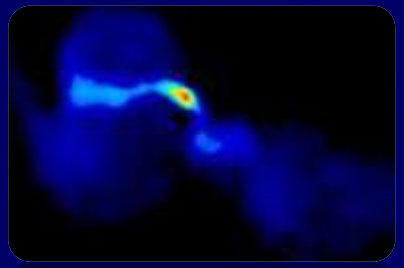
Very difficult to measure, was done either for a few sources or for only a few frequencies (Kovalev 2008, Lobanov 1998)

New method



We can estimate magnetic fields from radio single-dish total flux-densities

Outline



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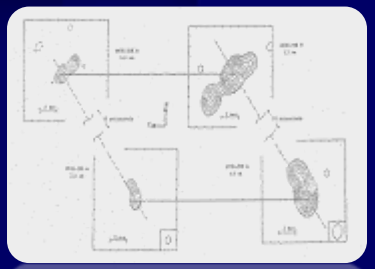

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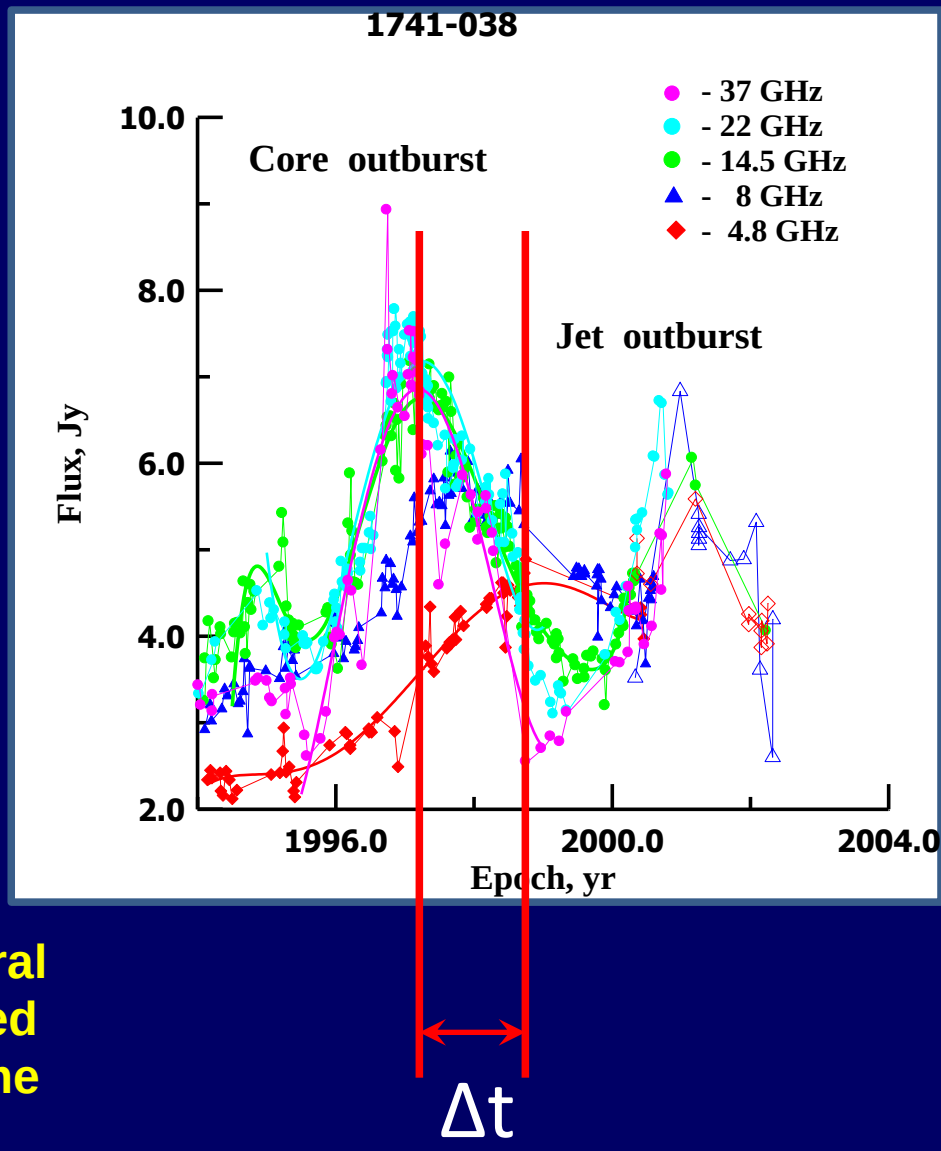
Data

- University of Michigan Radio Astronomical Observatory Monitoring
  - 14.5, 8, 4.8 GHz
  - *Aller H.D., Aller M.F. Et al. (1985)*
- Metsahovi Radio Astronomical Observatory Monitoring
  - 37 and 22 GHz
  - *Terasranta H. et al. (1992)*
- SEST
  - 90 GHz



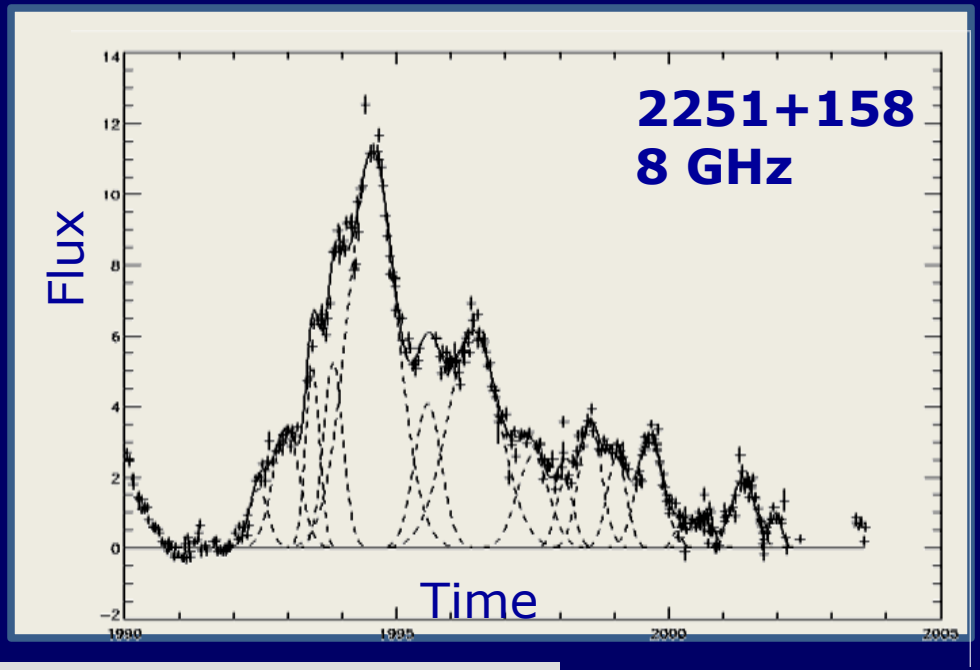
Checked the method for several sources – core shifts estimated from the time lags are the same within the error bars

Measuring time lags

Approximation of the light curves with a sum of Gaussian functions

The trends were removed

Time lags were calculated as a time interval between the Gaussian maxima

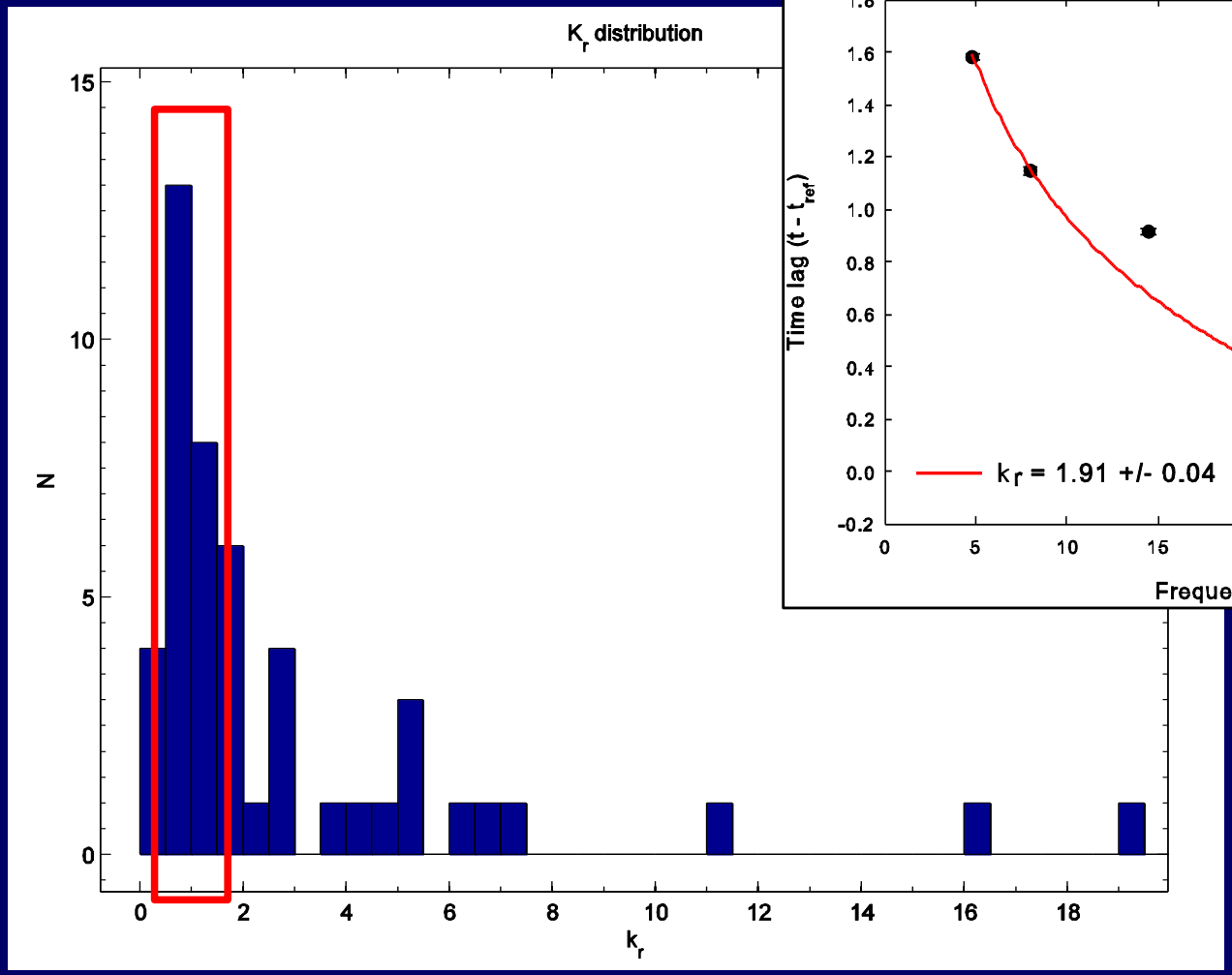


0059+581
0133+476
0202+149
0316+413 (3C 84)
0458-020
0528+134
0735+178
0923+392 (4C 39.25)
0945+408
1308+326
1510-089
1641+399 (3C 345)
1730-130
1739+522
1741-038
1803+784
2145+067
2223-052 (3C 446)
2230+114 (CTA 102)
2251+158 (3C 454.3)

21 sources
-- 15 quasars, 4 blazars and 1 radio galaxy

Was checked before only for a few sources.
BL Lac, 3C 345
(Lobanov 1998, O'Sullivan 2009)

Equipartition

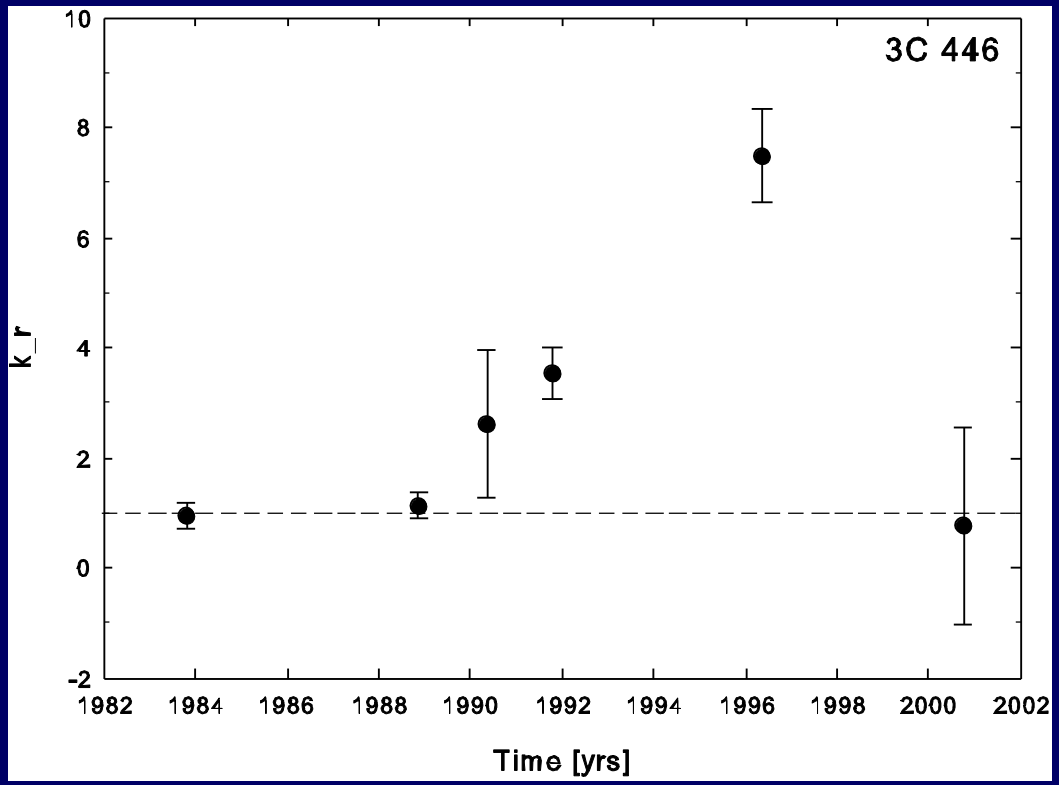


Based on 57 flares

K_r values from 0.3 to 17.2 – the highest k_r values are for the brightest flares

43 % of the flares are [0.5,1.5] – so almost in equipartition

Magnetic fields



From $k_r = 1$, then a bright outburst, then coming back to $k_r = 1$ (equipartition)

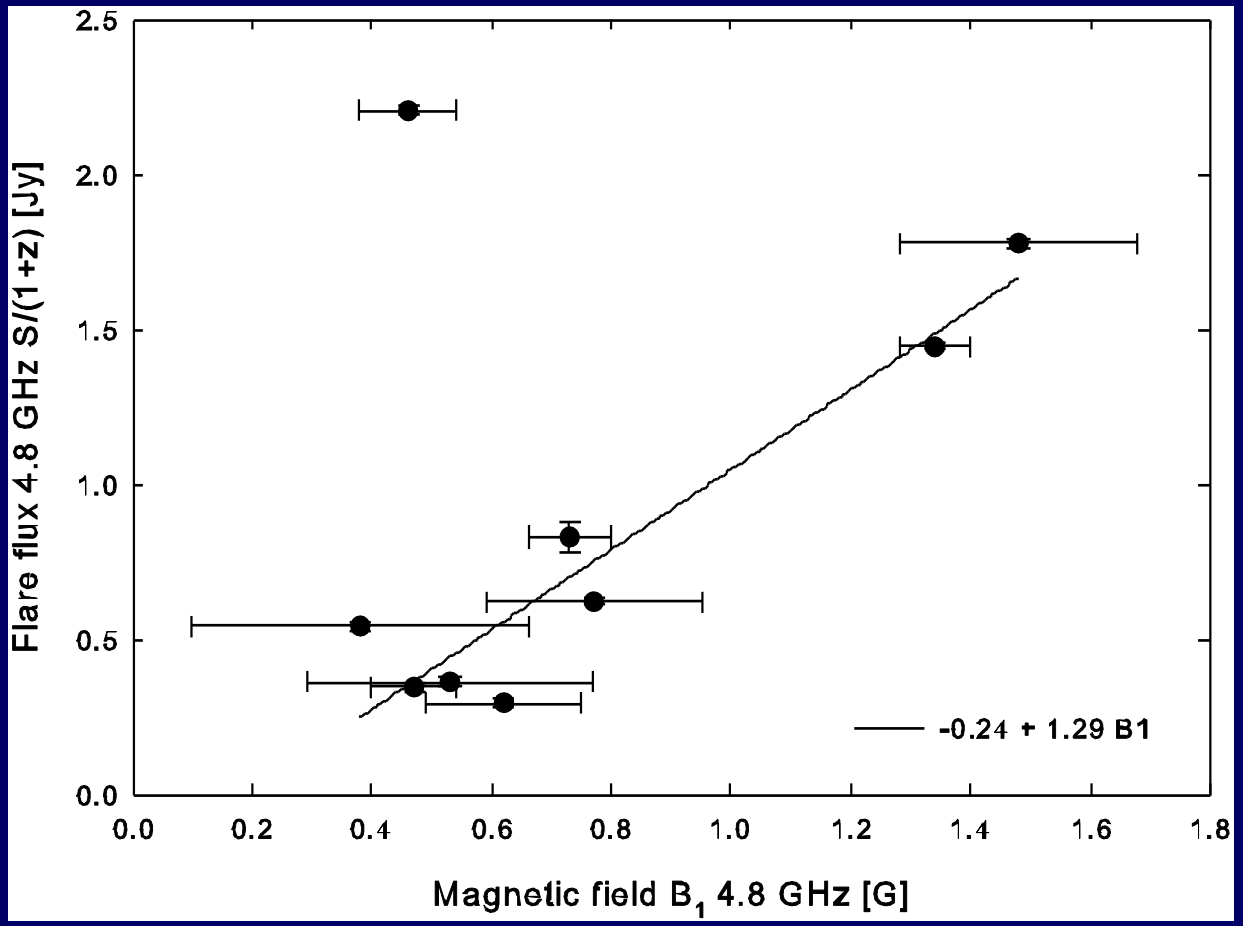
Magnetic fields at 1 pc distance

Magnetic fields in the core

B1 : 1.1 – 2.7 G

B core: 0.02 – 0.3 G

Flux / Magnetic field



$$S_\nu = \tau^2 x K B^{(s+1)/2} \delta^{(s+3)/2} \nu^{-(s-1)/2},$$

Linear dependence → s=1

$$N(E) = K E^{-1}$$

Summary

→We can use multi-frequency radio single-dish observations for calculating magnetic fields (using opacity and time lags)

→Opacity and core shifts have significant time variability which is probably mostly caused by changes in the electron density and magnetic field

→ Half of the flares are in the equipartition (K_r values are about 1)

→ We do not have equipartition during the most brightest outbursts (Found correlation between k_r values and flux of the flares)