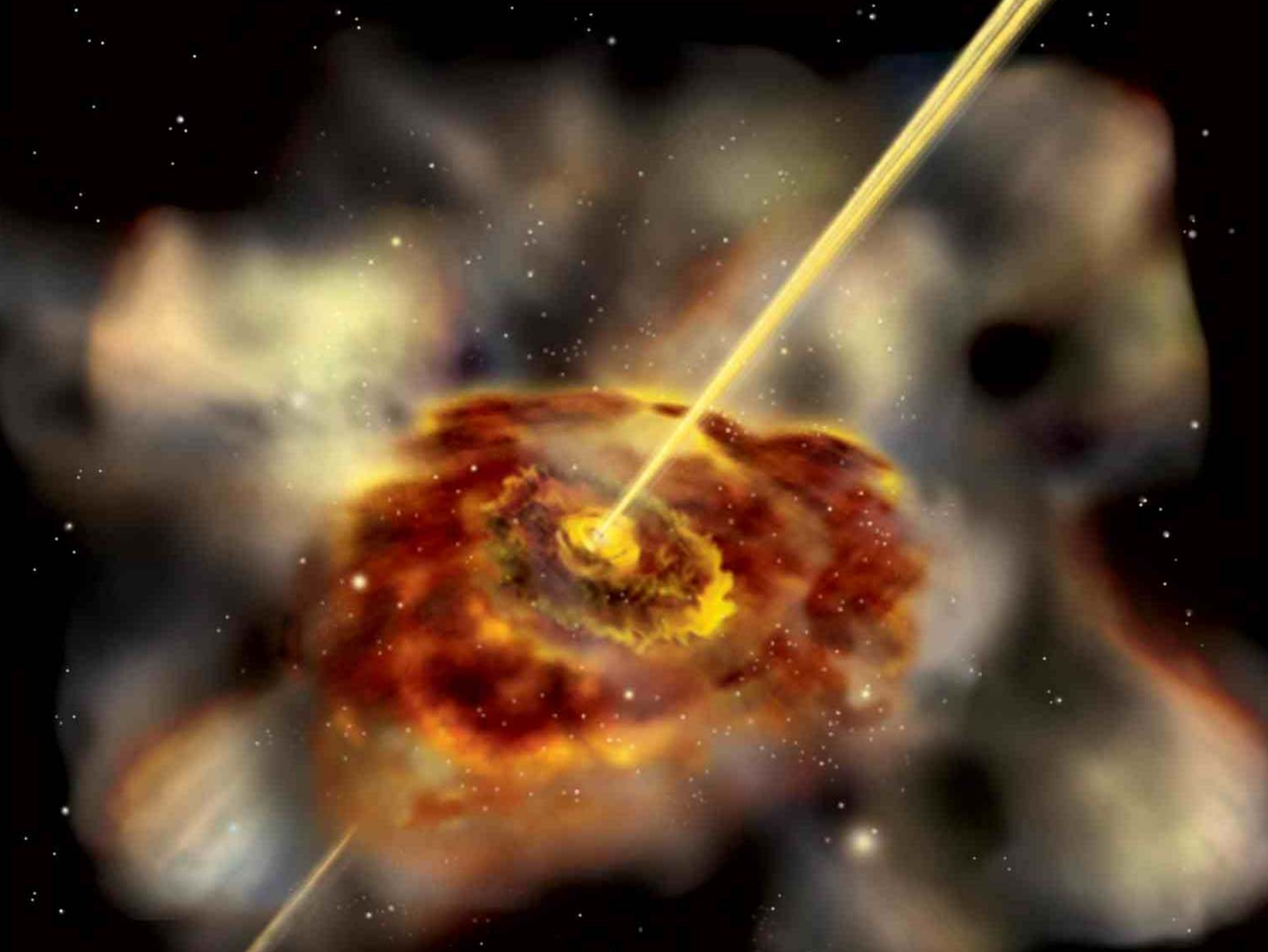
Blazars Overview

(...not a review!)

Esko Valtaoja
Tuorla Observatory, University of Turku
Finland

1978: BLAZARS (*Ed Spiegel*)

BISMARCK'S "AFTER-DINNER" SPEECH
"Gentlemen, there is *really* no more Turkey."



1979: JETS

THE ASTROPHYSICAL JOURNAL, 232:34–48, 1979 August 15

RELATIVISTIC JETS AS COMPACT RADIO SOURCES[1]

R. D. BLANDFORD AND ARIEH KÖNIGL
W. K. Kellogg Radiation Laboratory, California Institute of Technology
Received 1978 December 26; accepted 1979 March 1

ABSTRACT

Variable extragalactic radio sources, associated with the nuclei of galaxies and quasars, are interpreted in terms of a supersonic relativistic jet. It is proposed that radio emission originates both from the quasi-steady jet itself and from behind strong shock waves which either propagate in the jet, or which are formed behind dense condensations (clouds) that are accelerated to relativistic speeds by the flow. In this way the source could display apparent superluminal expansion in which the moving component (associated with a shock) and the stationary component (associated with the optically-thick core of the jet) would have comparable, Doppler-boosted fluxes. Specific models for the dynamical and radiative properties of the jet and of individual shocks are presented. Kinematical consequences of the relativistic motion are described for flux and polarization measurements, as well as for VLBI observations of superluminal sources. It is argued that the majority of bright compact sources are observed along lines of sight making small ($\lesssim 10°$) angles to the jet velocity. This hypothesis has important consequences for the interpretation of low-frequency variable sources, optically-violent variable quasars, Lacertids, and extended double sources. These are briefly outlined, and some specific observational tests are proposed.

Subject headings: BL Lacertae objects — galaxies: nuclei — quasars — radio sources: galaxies — radio sources: variable

1982: ESKO MEETS DEBORAH!

Nature **314, 146 - 148 (14 March 1985); doi:10.1038/314146a0**

Periodicity in the BL Lac object OJ287

L. Carrasco, D. Dultzin-Hacyan & I. Cruz-Gonzalez

Instituto de Astronomia, National University of Mexico,
Apartado Postal 70-264, Mexico D.F. 04510, Mexico

Nature **314, 148 - 149 (14 March 1985); doi:10.1038/314148a0**

A 15.7-min periodicity in OJ287

E. Valtaoja[*], H. Lehto[*†], P. Teerikorpi[*†], T. Korhonen[*], M. Valtonen[*],
H. Teräsranta[‡], E. Salonen[‡], S. Urpo[‡], M. Tiuri[‡], V. Piirola[§] & W. C. Saslaw

[*]Turku University Observatory, University of Turku, 20520 Turku 52, Finland
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[§]Astronomical Observatory, University of Helsinki, 00130 Helsinki 13, Finland
University of Virginia, Department of Astronomy, Charlottesville, Virginia 22903, USA
[†]Present addresses: University of Virginia, Department of Astronomy, Charlottesville, Virginia 22903 USA (H.L.); University of Leningrad

1984: QUESTIONS!

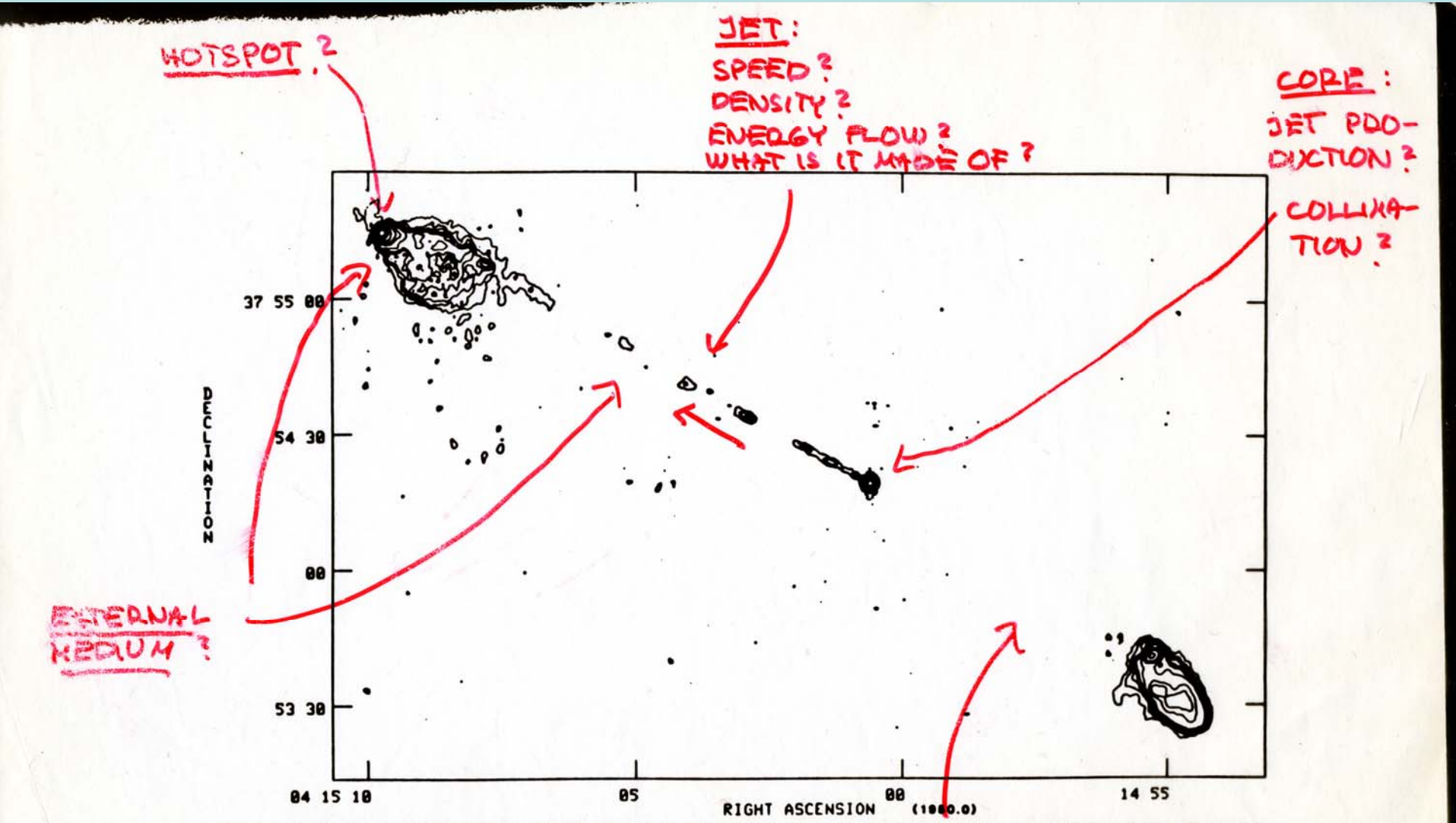

FIG. 1.—Total intensity map of 3C 111 at 1.4 GHz, with 1".34 × 1".20 resolution. The bright central component is coincident with the nucleus of the optical galaxy. The contour levels are −3.7, −1.2, 1.2, 2.5, 3.7, 4.9, 6.1, 9.8, 22, 37, 86, 220, and 470 mJy per beam.

NO COUNTER-JET:
- ONE-SIDED ?
- RELATIVISTIC ?
- FLIP-FLOP ?

1985: SHOCKED JETS

THE ASTROPHYSICAL JOURNAL, **298**:114–127, 1985 November 1

MODELS FOR HIGH-FREQUENCY RADIO OUTBURSTS IN EXTRAGALACTIC SOURCES, WITH APPLICATION TO THE EARLY 1983 MILLIMETER-TO-INFRARED FLARE OF 3C 273

ALAN P. MARSCHER
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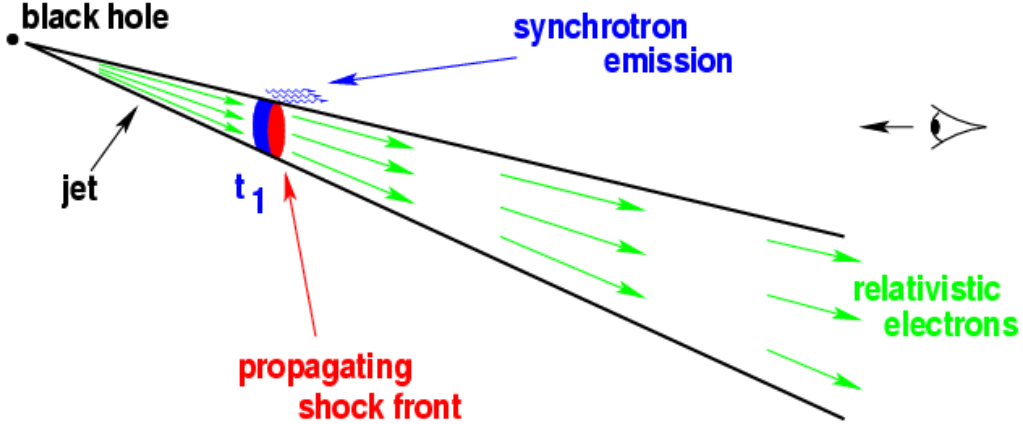
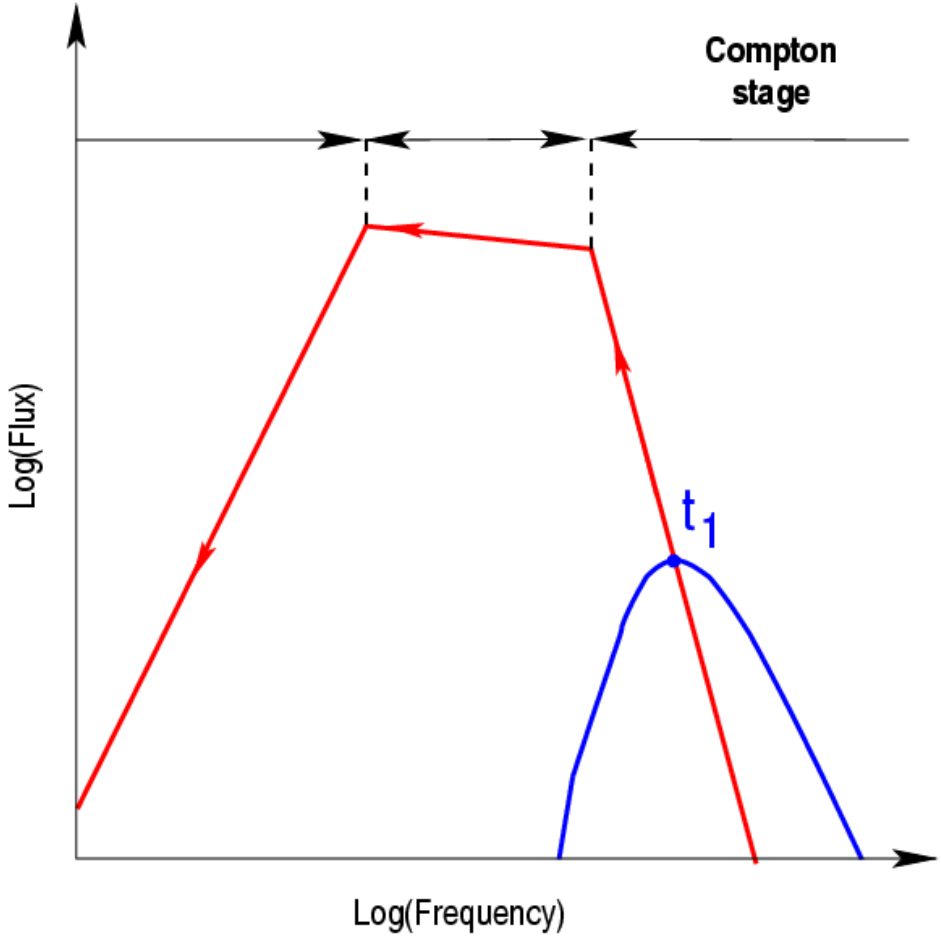
AND

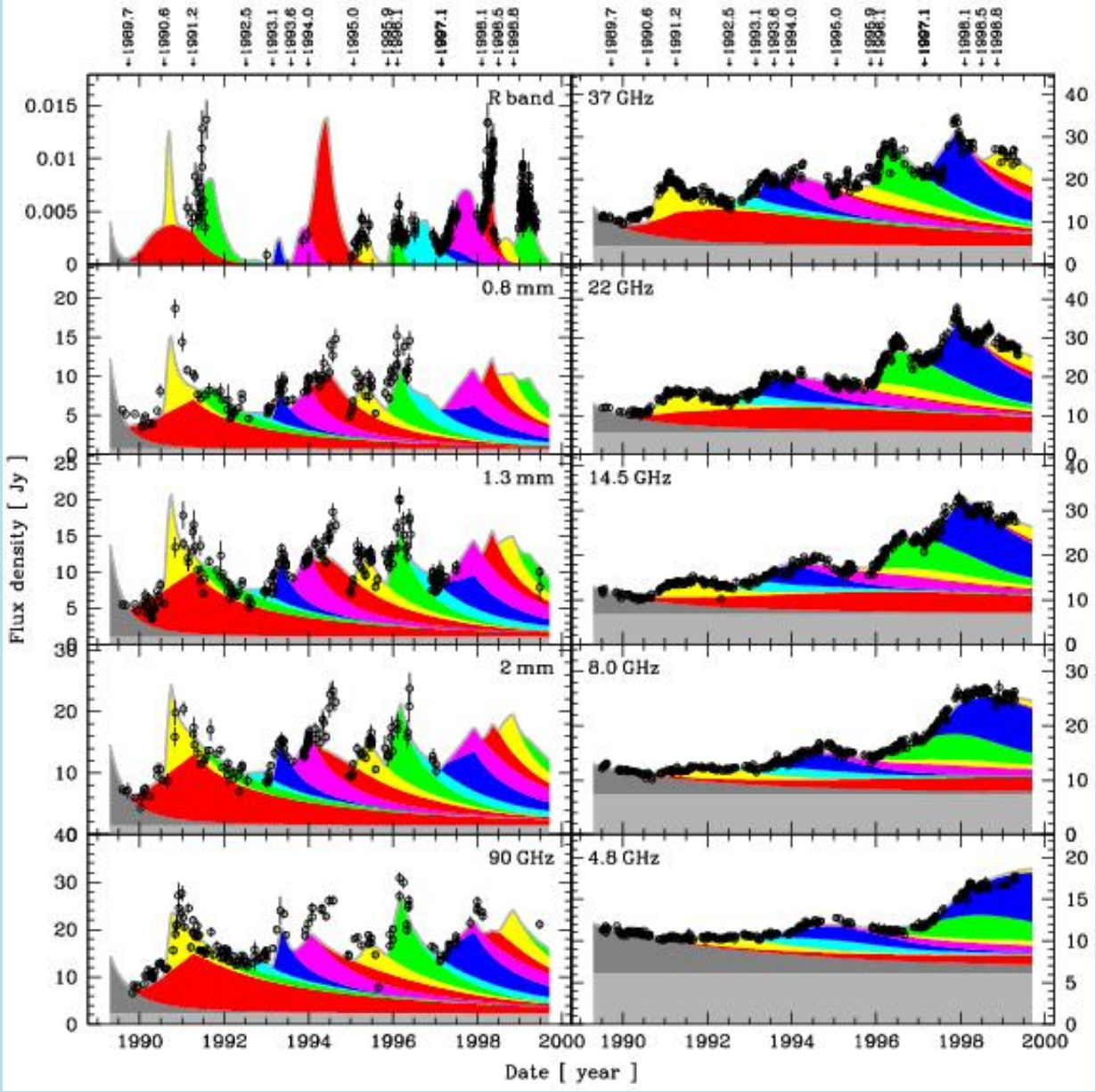
WALTER K. GEAR
School of Physics and Astronomy, Lancashire Polytechnic
Received 1984 December 3; accepted 1985 April 26

ABSTRACT

We present models for the variability of compact radio sources with specific application to the early 1983 millimeter-to-infrared flare of the quasar 3C 273. We show that the early evolution of the outburst spectrum is most readily explained if the flaring component is expanding. In our models the effects of individual events are first detected in the millimeter-to-infrared region of the spectrum, as observed in 3C 273. The models include the effects of synchrotron, Compton, and expansion losses as well as variable injection of relativistic electrons and magnetic field. We find that a model based on a uniform expanding source requires rather artificial variations of particle injection with source radius if it is to explain the 3C 273 flare data presented by Robson *et al.* The observed behavior is obtained in a more natural way by a second model in which the outburst is due to a shock wave passing through an adiabatic, conical, relativistic jet. We extend the application of this model by showing that it can reproduce many of the characteristics of general radio source variability. The model can also naturally explain the production and evolution of superluminal knots on VLBI maps and their tendency to collectively form relatively flat radio spectra, as well as the variable X-ray emission observed from 3C 273 and other similar sources. The minimum time scale of variability can be as short as ~ 1 day, despite the rather large distance ($\gtrsim 1$ pc) of the shock from the central energy source of the quasar.


black hole
synchrotron
emission
jet
t 1
relativistic
electrons
propagating
shock front


Compton
stage
Log(Flux)
t 1
Log(Frequency)



Ten years of 3C 279 cm-to-optical variations modelled as ”M & G” shocks in a jet (*Lindfors et al., 2006)*

1989: ORIENTATION

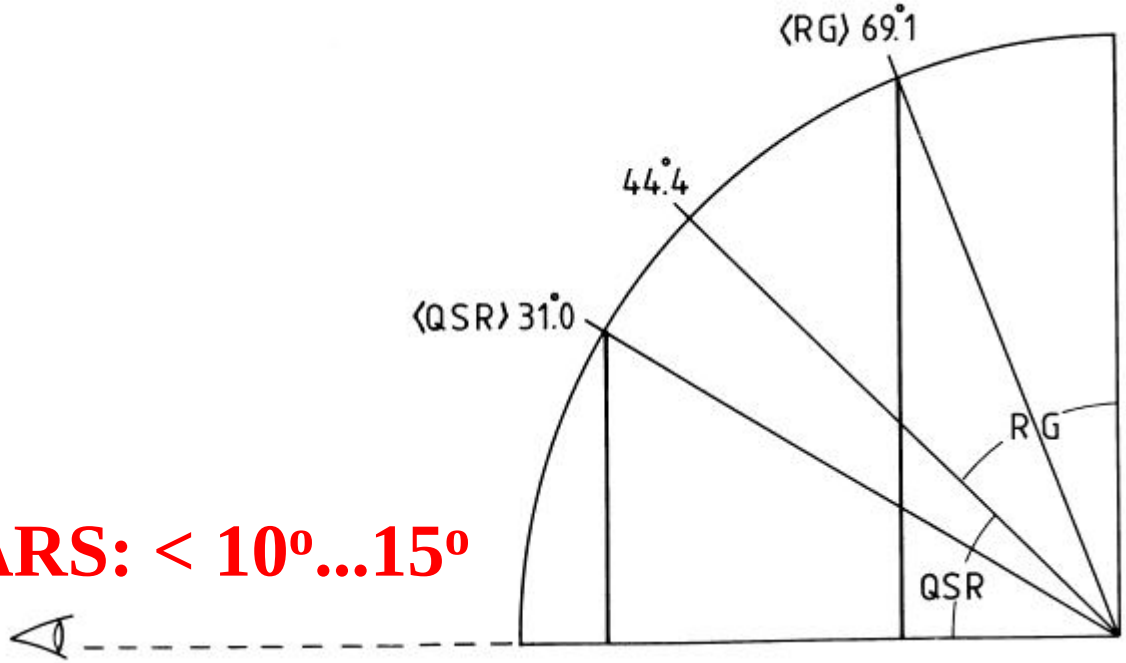
THE ASTROPHYSICAL JOURNAL, 336:606–611, 1989 January 15

IS EVERY QUASAR BEAMED?

PETER D. BARTHEL
Owens Valley Radio Observatory, California Institute of Technology
Received 1988 April 12; accepted 1988 June 23

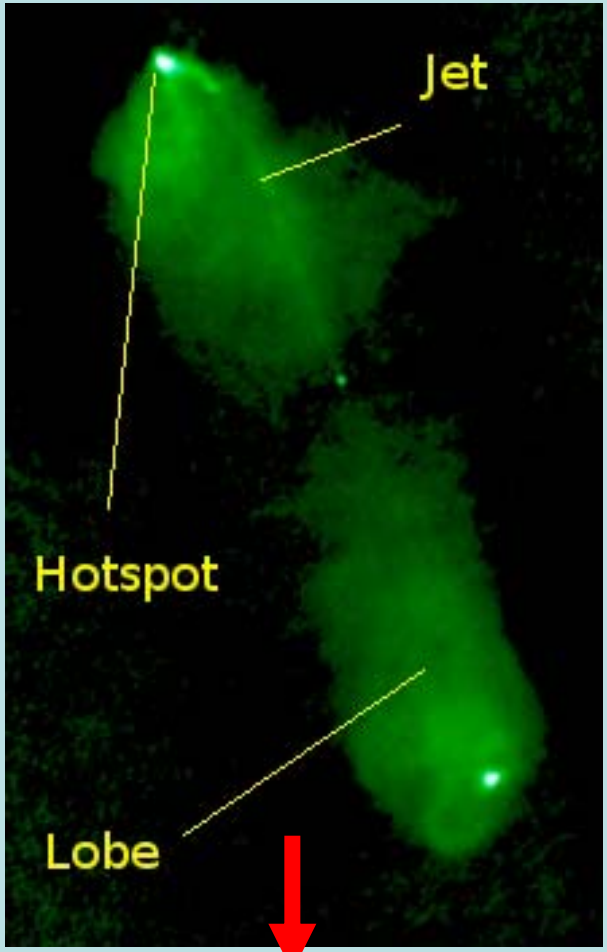
ABSTRACT

A companion paper (Barthel *et al.*) reports the discovery of superluminal motion in the core of 4C 34.47, the largest known quasi-stellar rad
large-scale one-sided radio jets, and
find a natural explanation in the eff
model the available data imply tha
may well form the unbeamed parer
unified using similar orientation effec
Subject headings: quasars — radio s

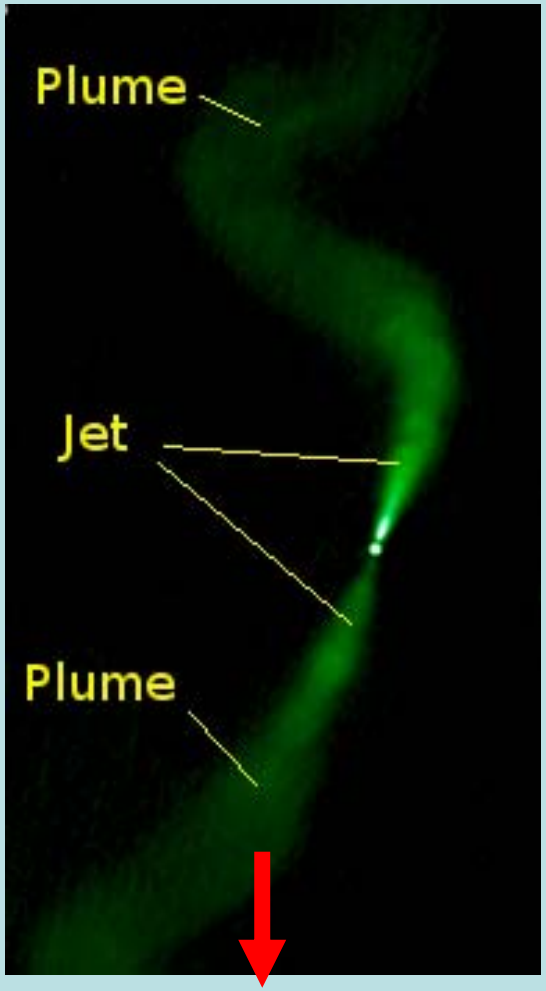


BLAZARS: < 10º...15º

FR II



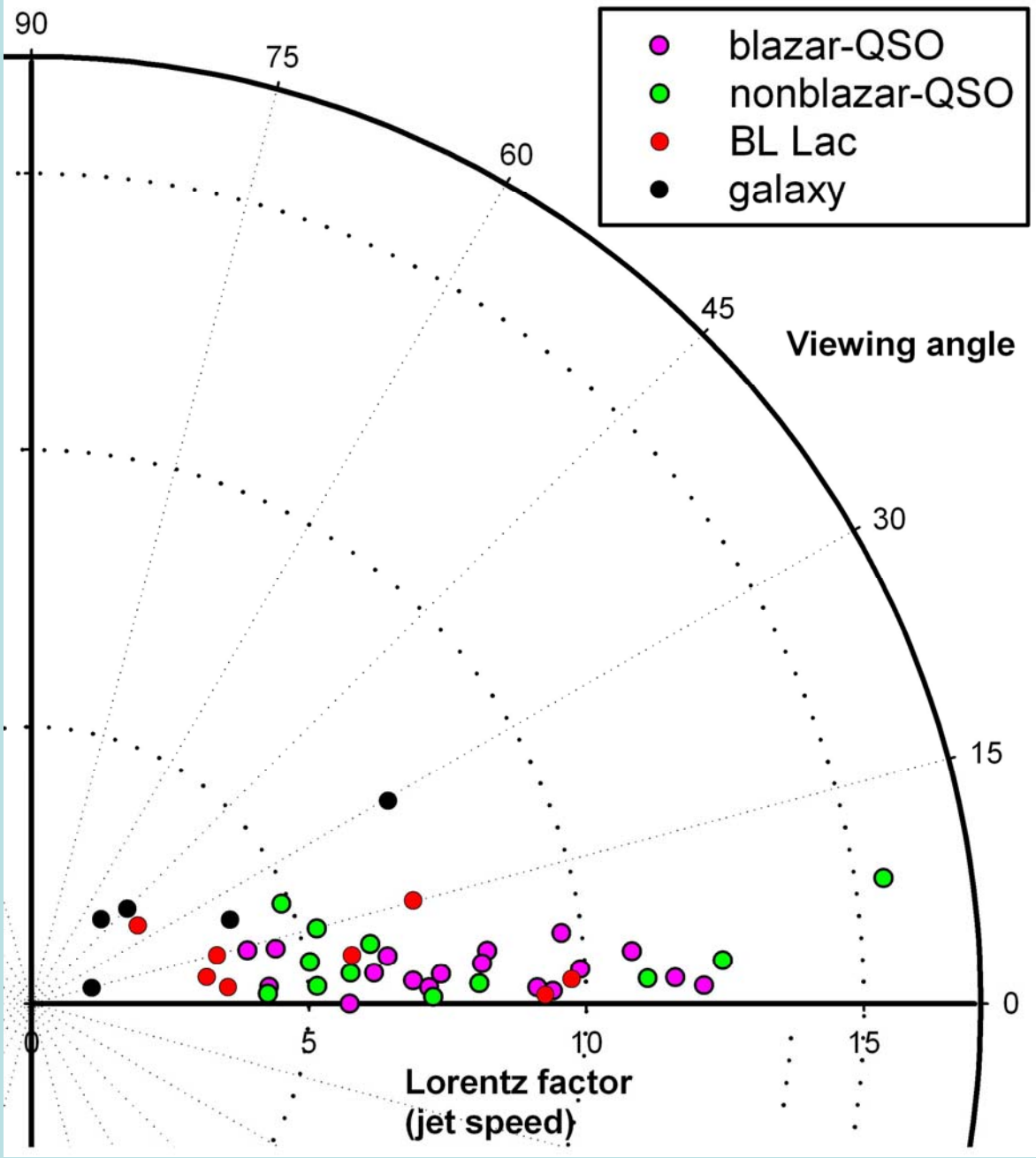
FR I



QUASAR

BL LAC

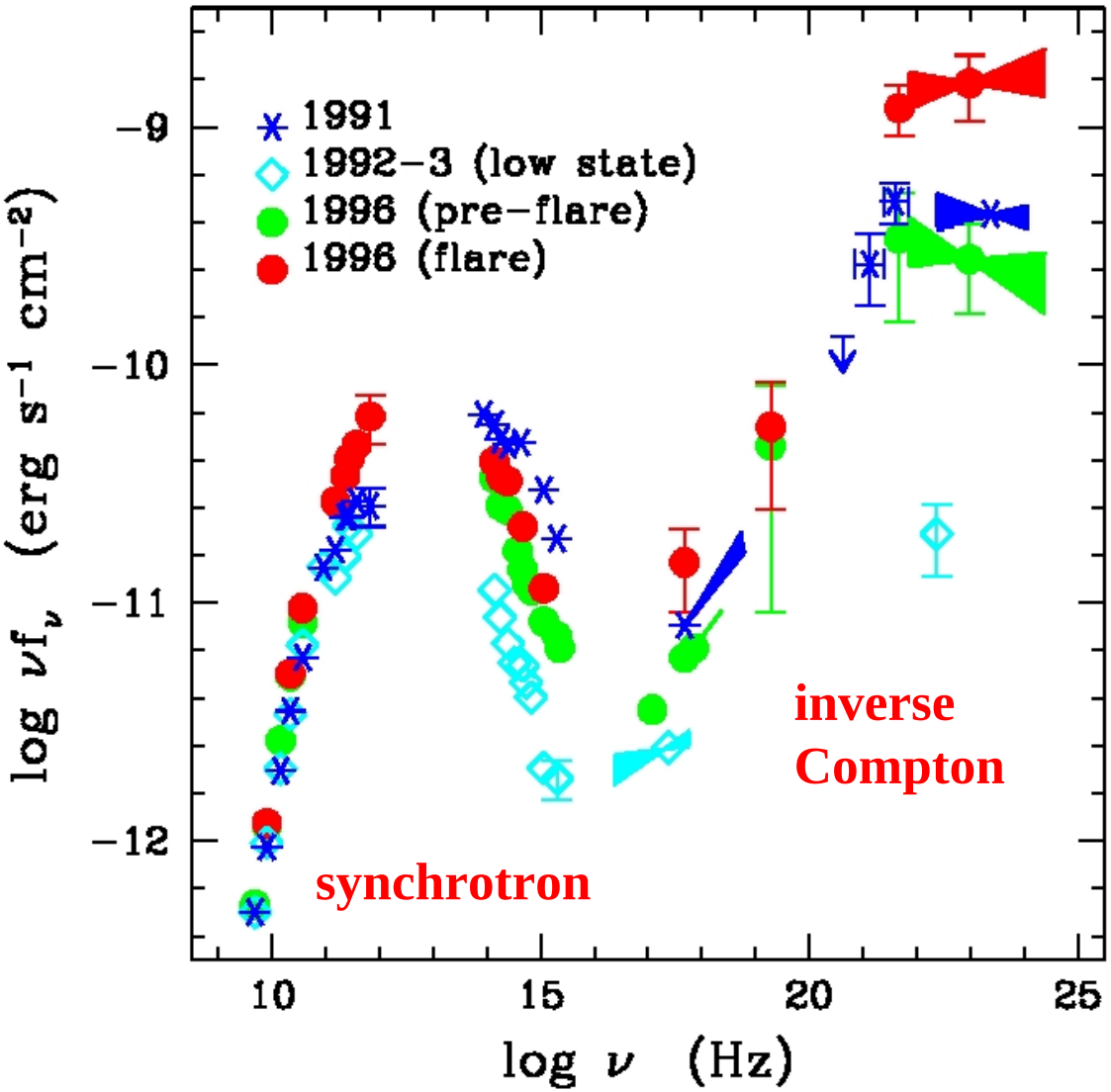
BLAZAR



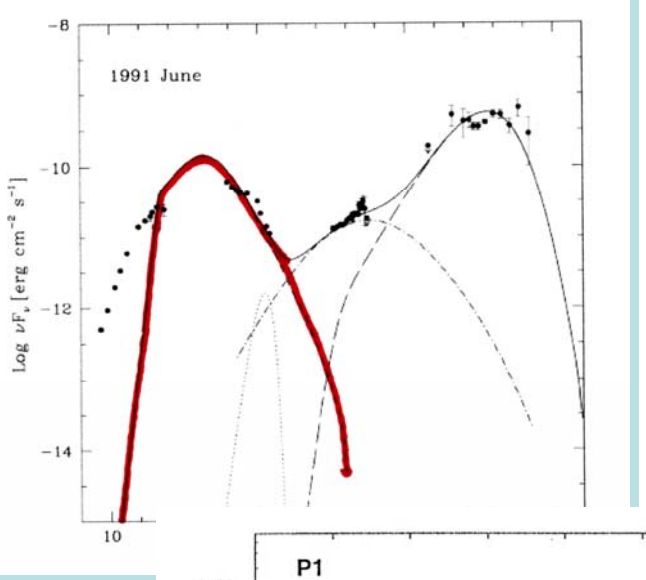
Γ, θ from flux variations and VLBI

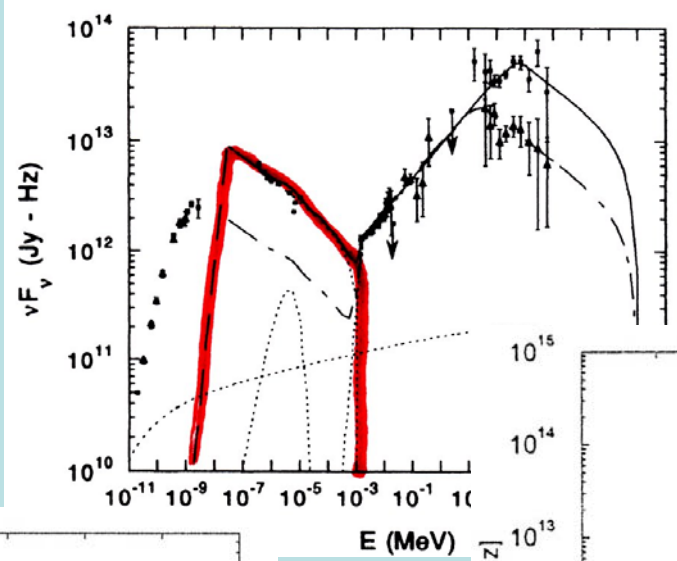
Data from Lähteenmäki & Valtaoja 1999

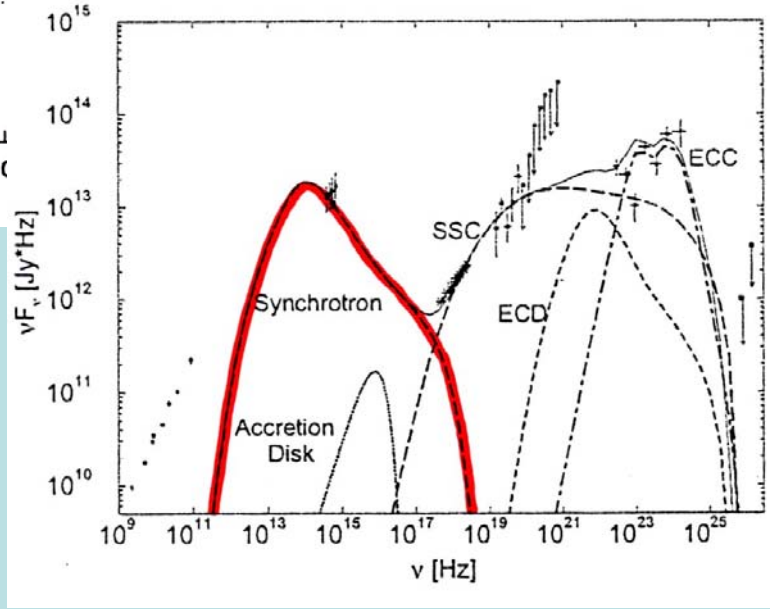
1991: EGRET AND GAMMA-RAYS

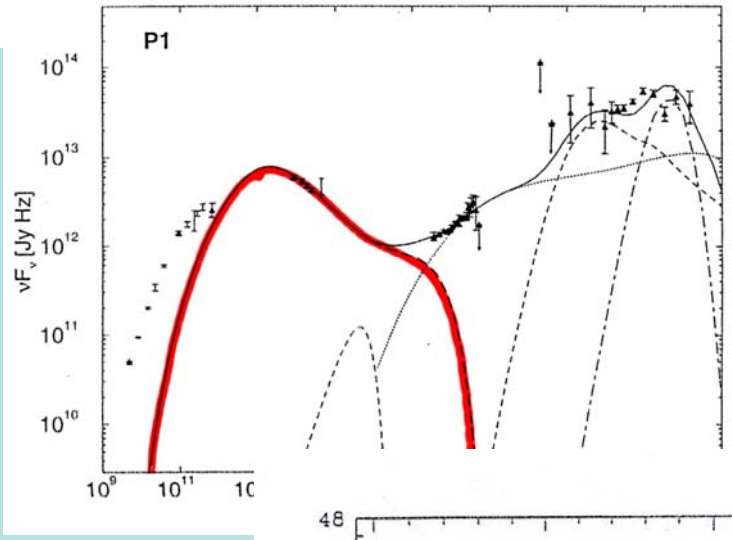


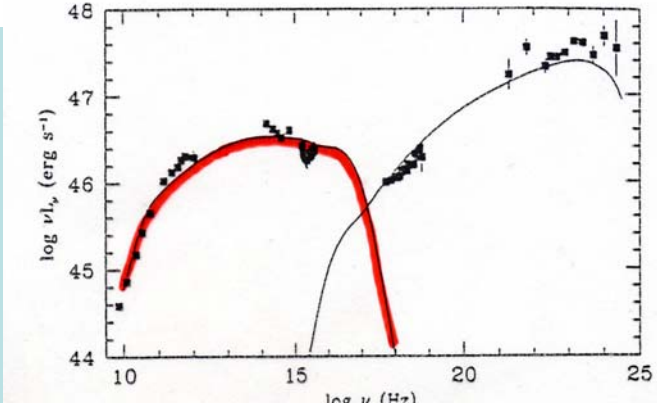
Six times 3C 279, June 1991

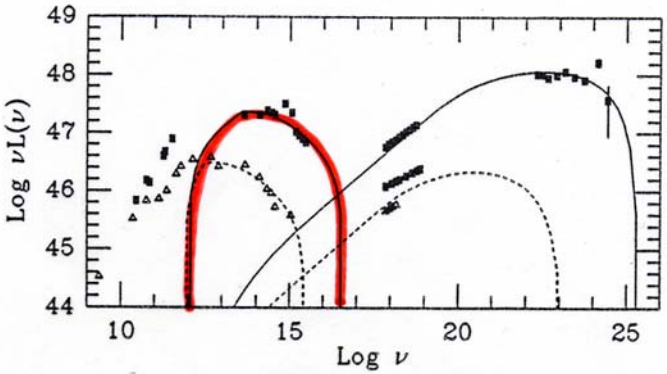






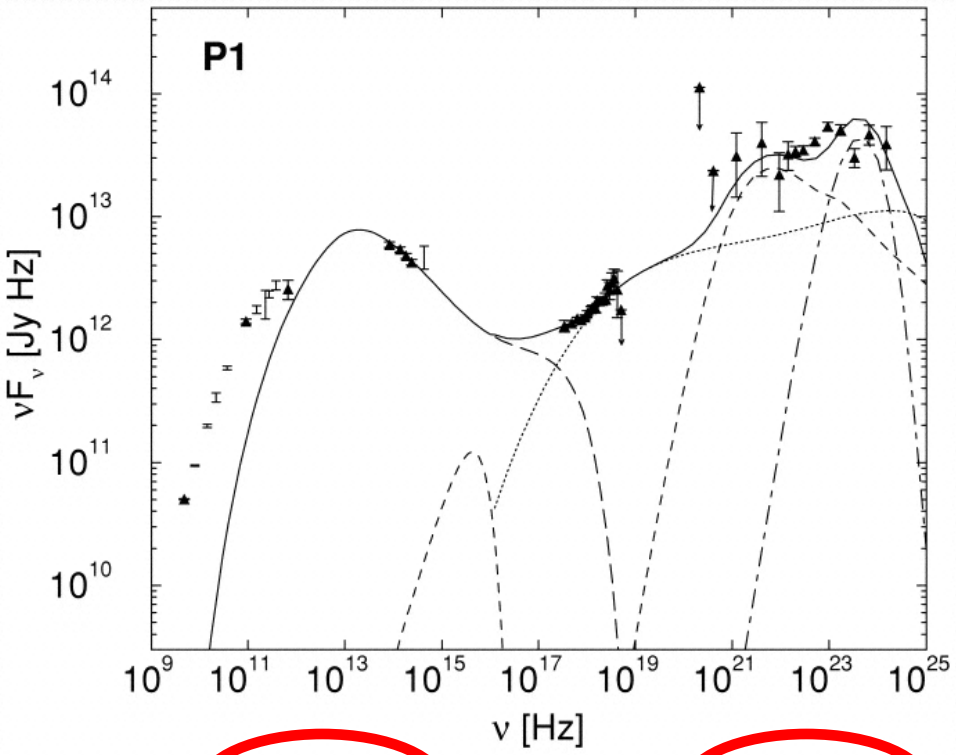


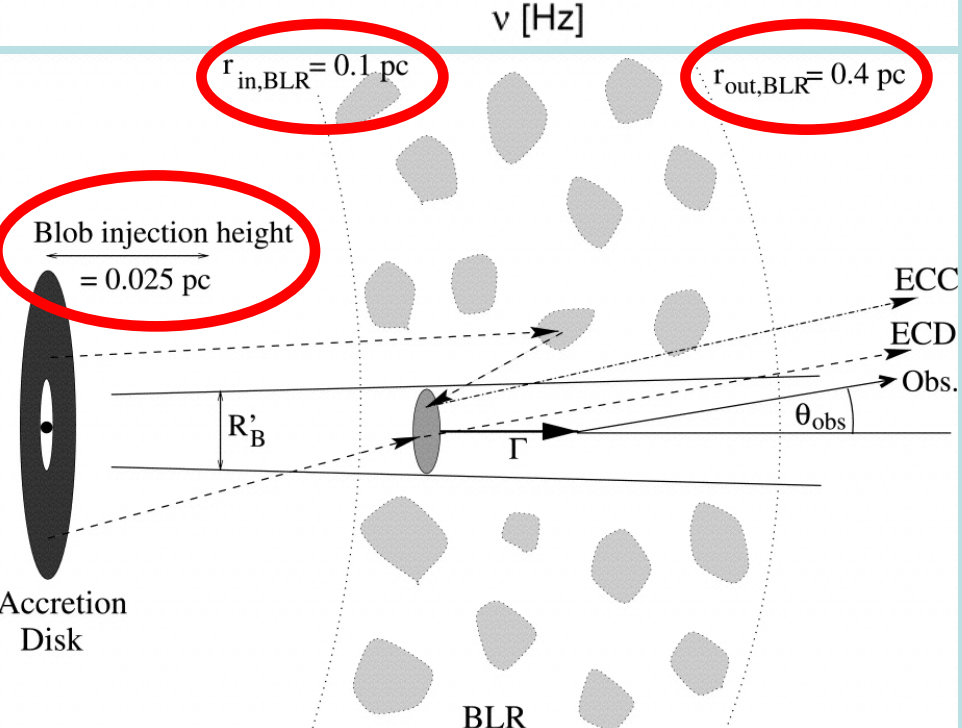


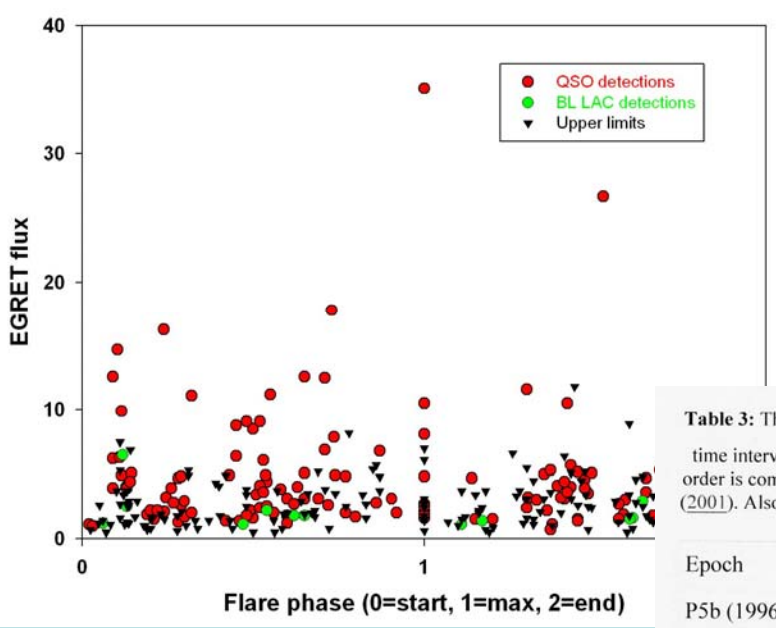


State-of-art in IC modelling
(Hartmann et al. 2001)

BUT...







P = 99,9 %

EGRET vs continuum sample: radio flare starts ~2 months before the gamma flare

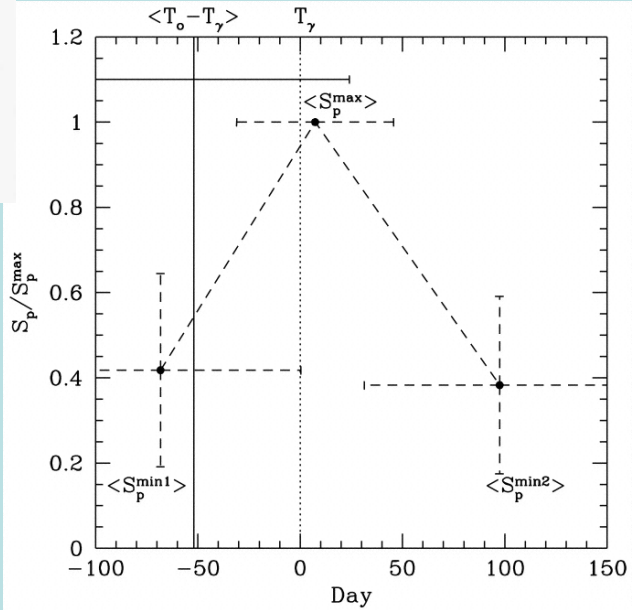
[Valtaoja & Teräsranta 1995; Lähteenmäki & Valtaoja 2003]

Table 3: The EGRET epochs ordered by increasing Δt_{obs} [years], the time interval since the start of the last outburst as derived here. This order is compared to the gamma-ray state adopted from Hartman et al. (2001). Also an estimate of the distance, L, of these shock components from the apex of the jet is given (see text).

Epoch	Shock No.	Δt_{obs}	gamma-ray state	L [pc]
P5b (1996.092)	10	0.006	very large flare	0.12
P8 (1999.070)	15	0.195	high	3.88
P5a (1996.063)	9	0.206	high	4.10
P1 (1991.47)	3	0.225	high	4.48
P3a (1993.858)	6	0.288	moderate	5.74
P6b (1997.470)	12	0.328	moderate	6.53
P3b (1993.979)	6	0.409	moderate	8.15
P2 (1993.004)	4	0.49	low	9.76
P6a (1997.010)	10	0.924	low	18.41
P4 (1994.970)	7	0.99	low	19.72

P = 99,98%

3C 279: the more distant the shock, the weaker the gamma flare **[Lindfors et al. 2006]**

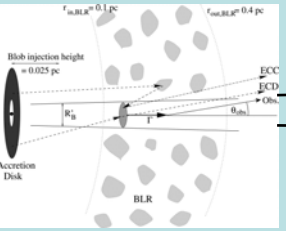


EGRET vs VLBI sample: new component emerges ~2 months before the gamma flare

[Jorstad et al. 2001]

P = 99,999%

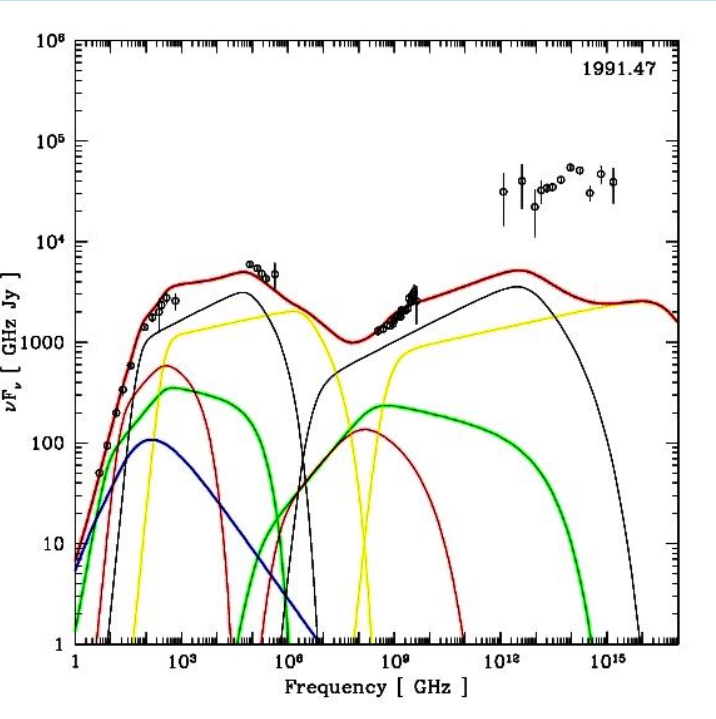
2 months equals parsecs, so External Compton fails...



EC photons are here!

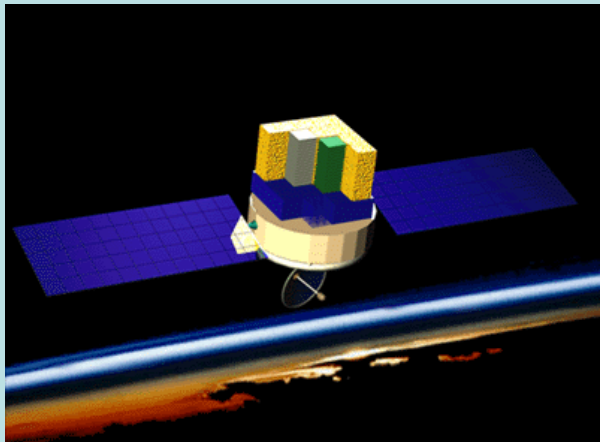
radio

gamma



...but the only alternative, synchrotron-self-Compton also fails *(Lindfors et al. 2005, 2006)*

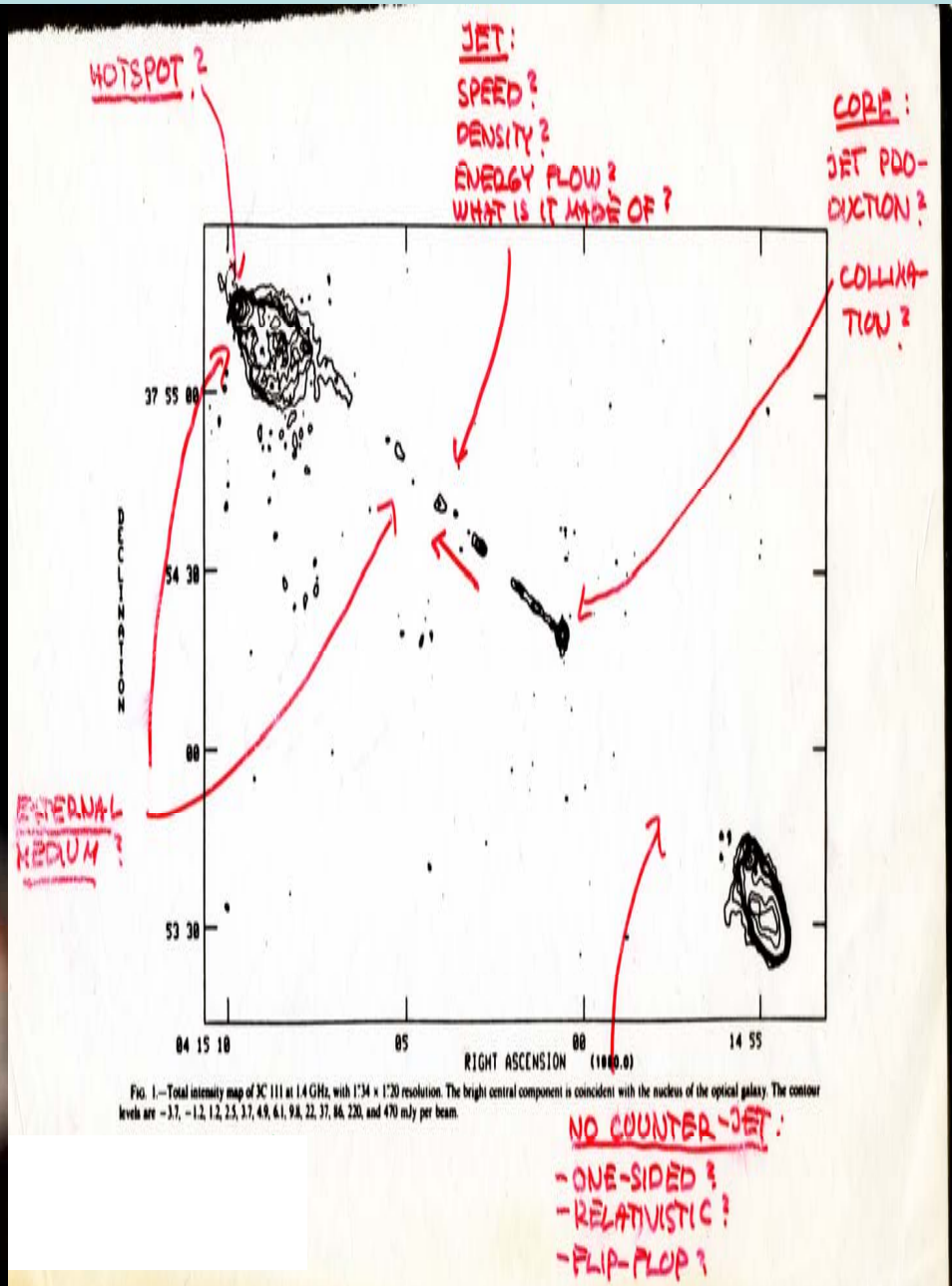
Heh.



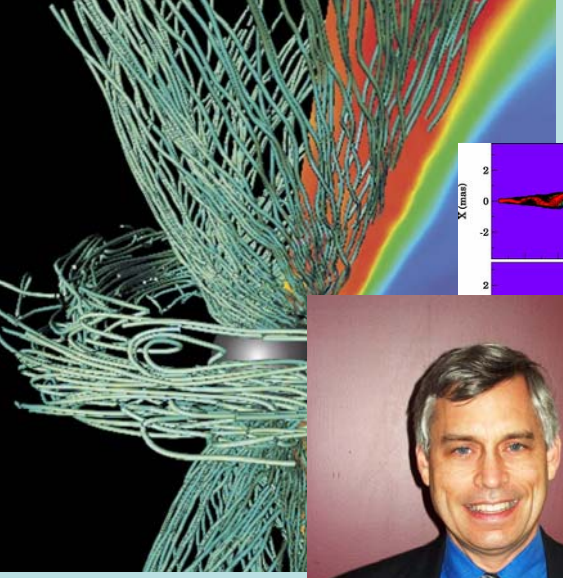
From basic parameters to observed phenomena?

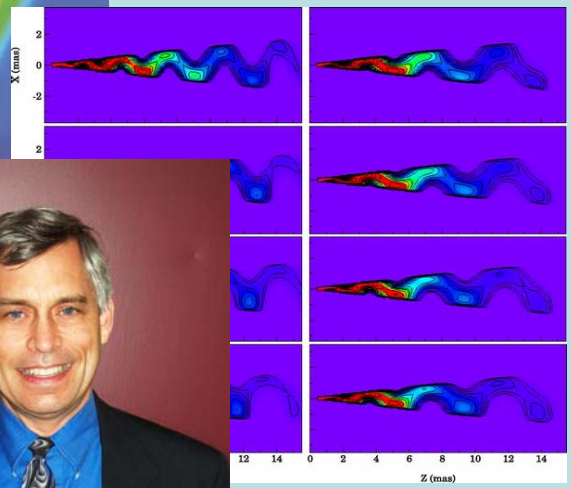
jet speed
collimation
turbulence
luminosity
maximum e energy
magnetic field strength
p/e$^+$/e$^-$ density
...

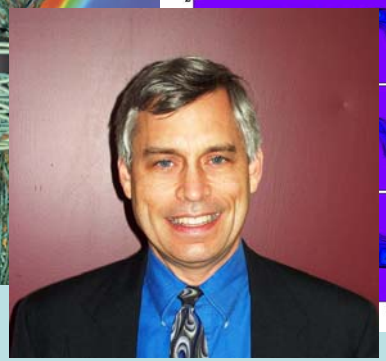
BH mass
BH spin
accretion rate
parent galaxy

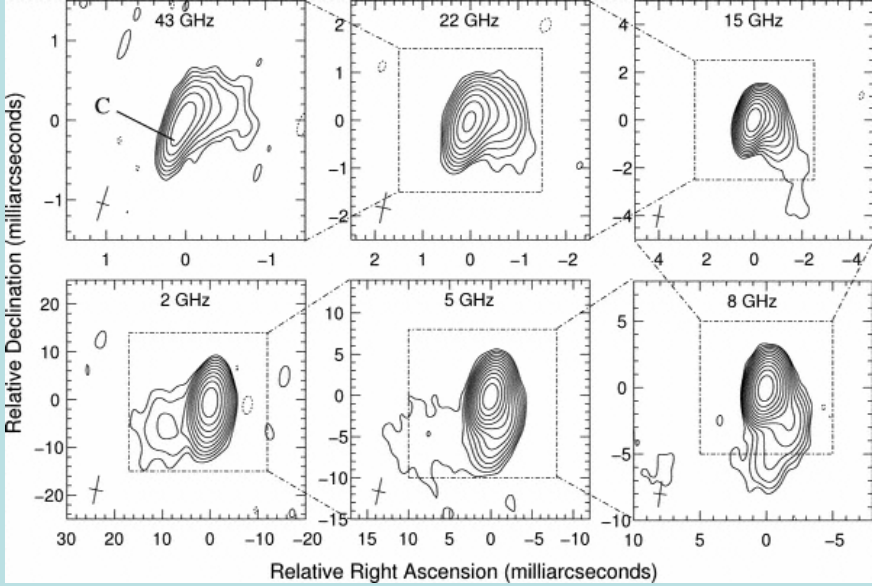


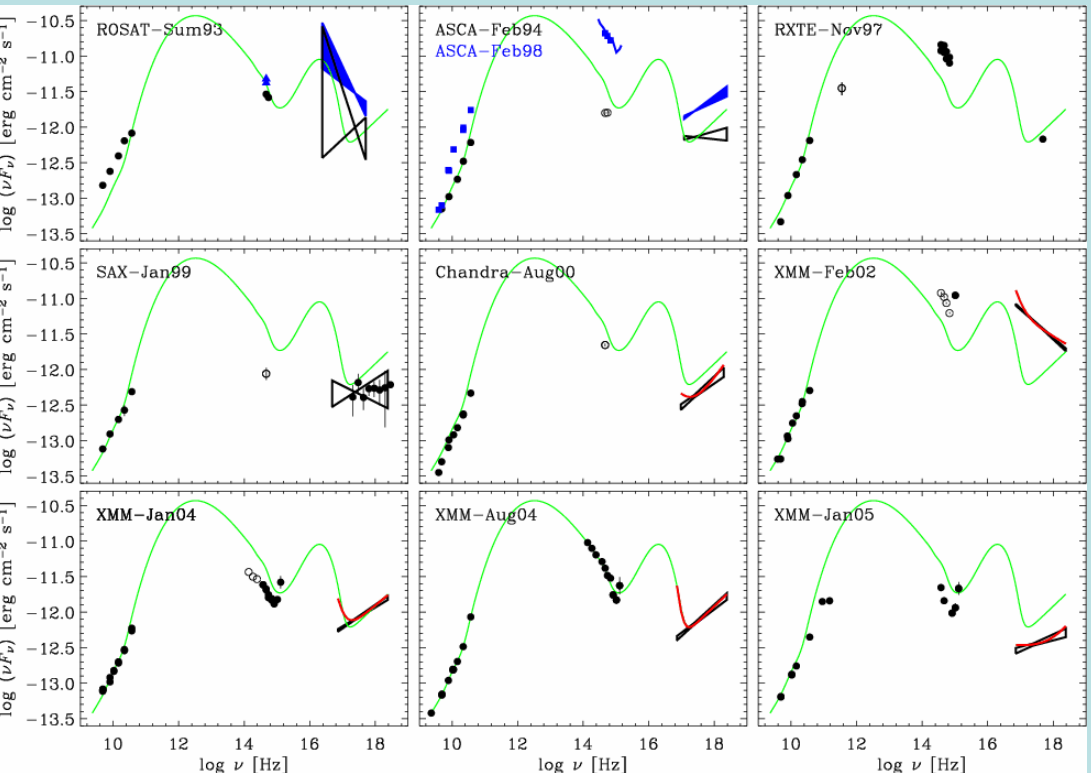
DATA:

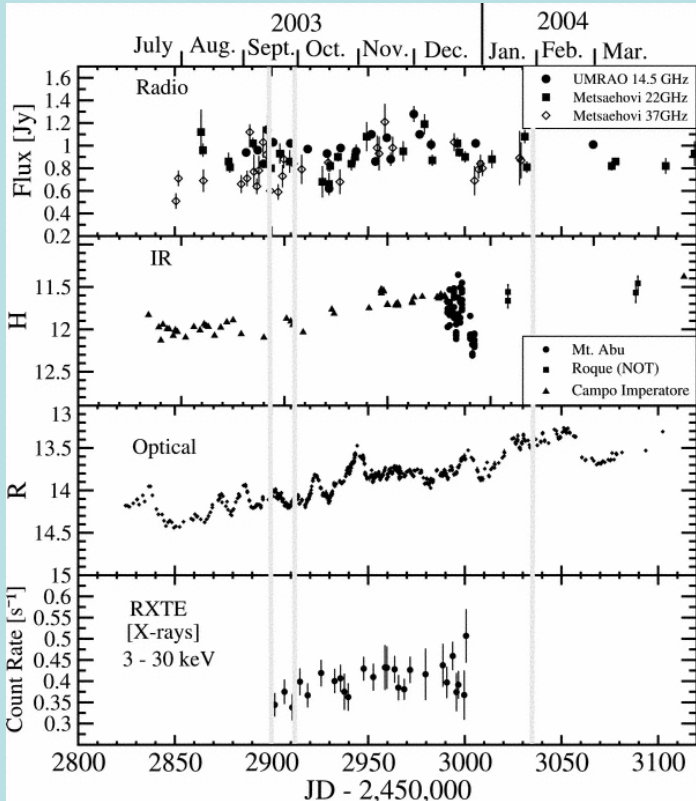


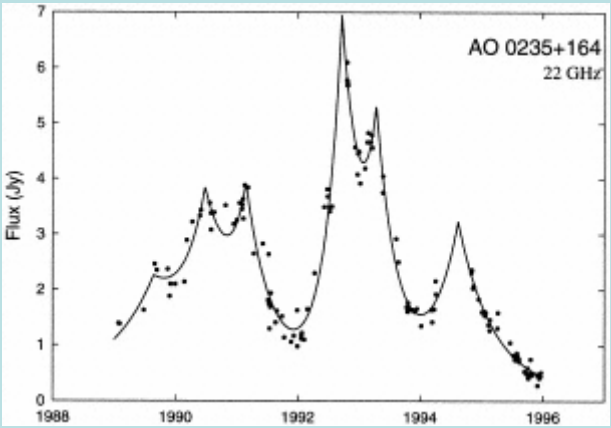

X (mas)
Z (mas)

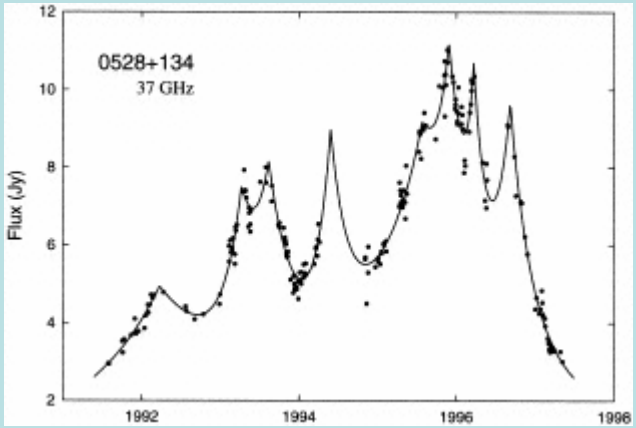


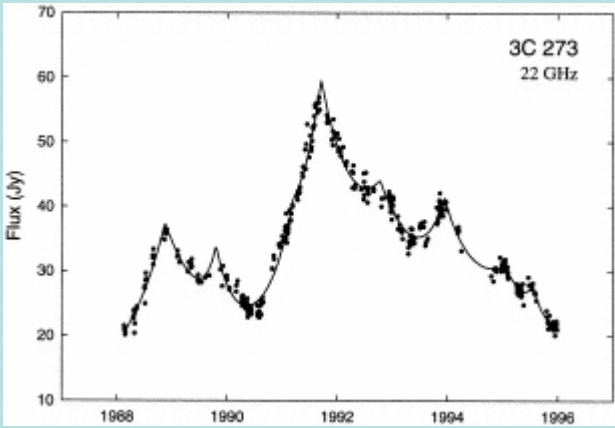

43 GHz
22 GHz
15 GHz
2 GHz
5 GHz
8 GHz
C
Relative Declination (milliarcseconds)
Relative Right Ascension (milliarcseconds)


ROSAT−Sum93
ASCA−Feb94
ASCA−Feb98
RXTE−Nov97
SAX−Jan99
Chandra−Aug00
XMM−Feb02
XMM−Jan04
XMM−Aug04
XMM−Jan05
log (νF_ν) [erg cm⁻² s⁻¹]
log ν [Hz]

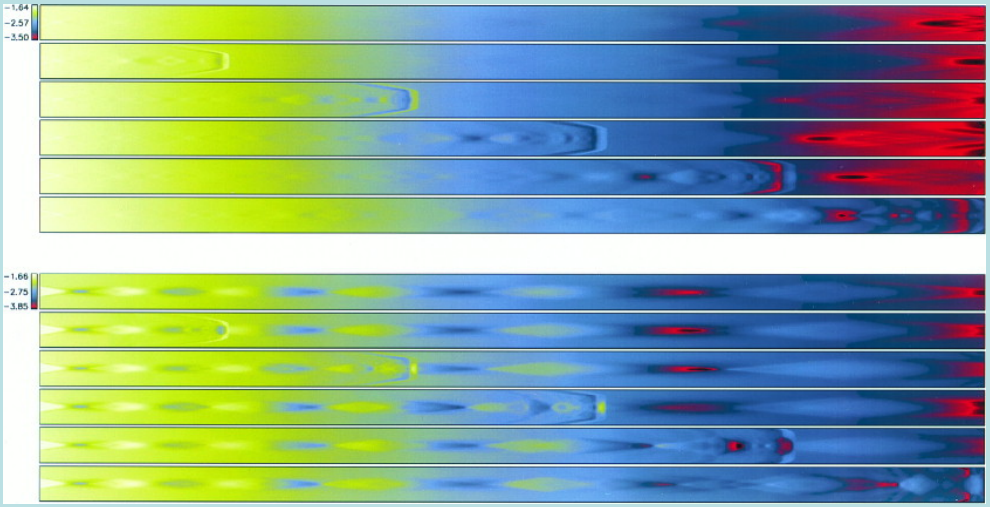

2003
2004
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Radio
UMRAO 14.5 GHz
Metsaehovi 22GHz
Metsaehovi 37GHz
Flux [Jy]
IR
H
Mt. Abu
Roque (NOT)
Campo Imperatore
Optical
R
RXTE
[X-rays]
3 - 30 keV
Count Rate [s⁻¹]
JD - 2,450,000

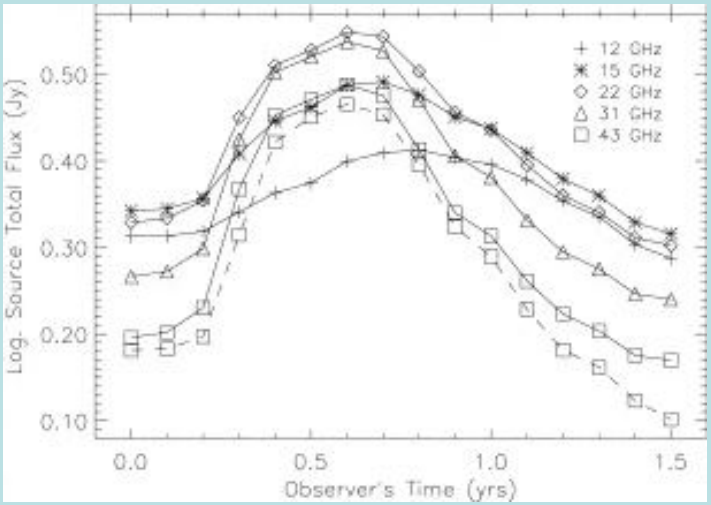






Exponential, sharp flares *(Valtaoja et al. 1999)*

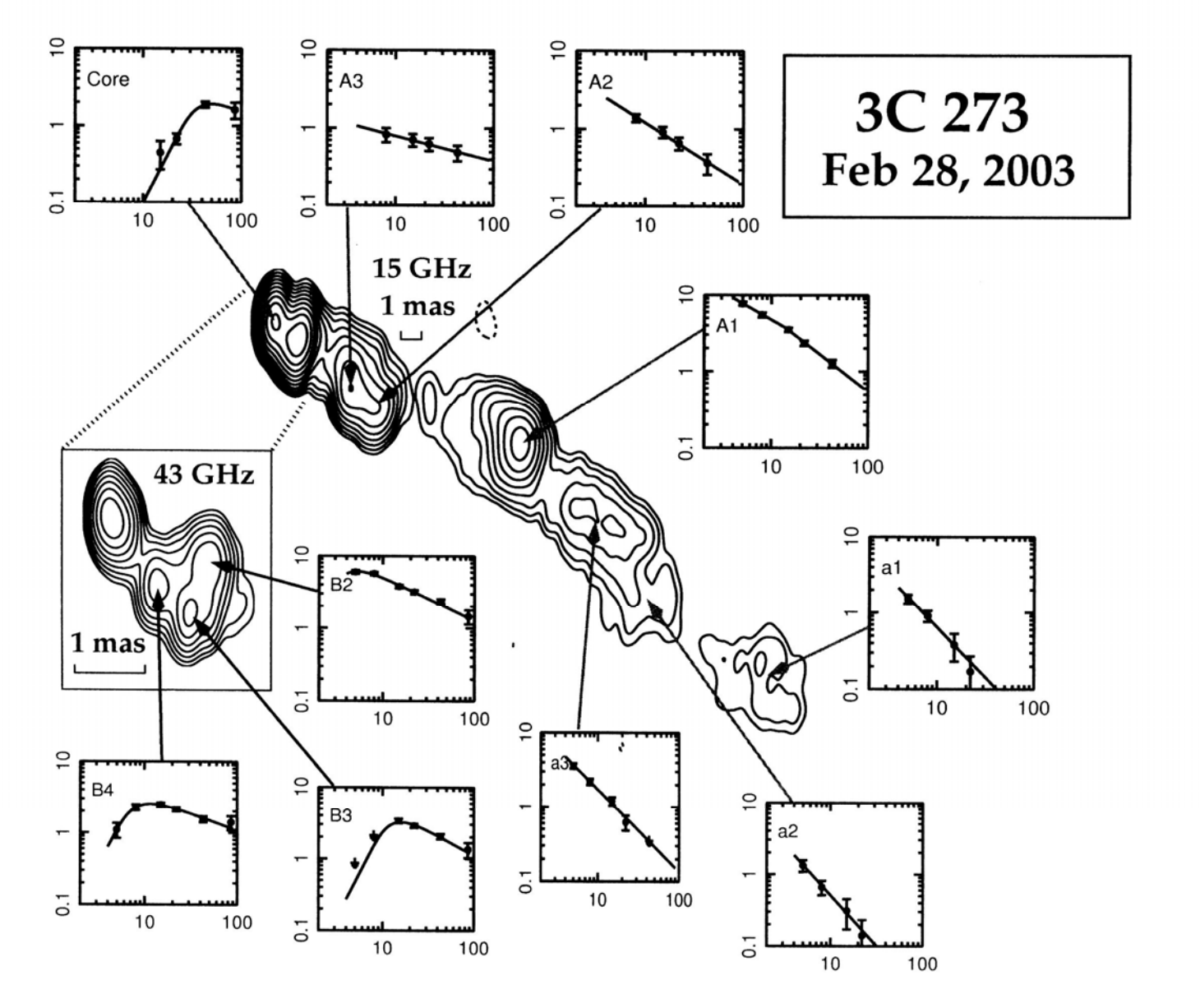




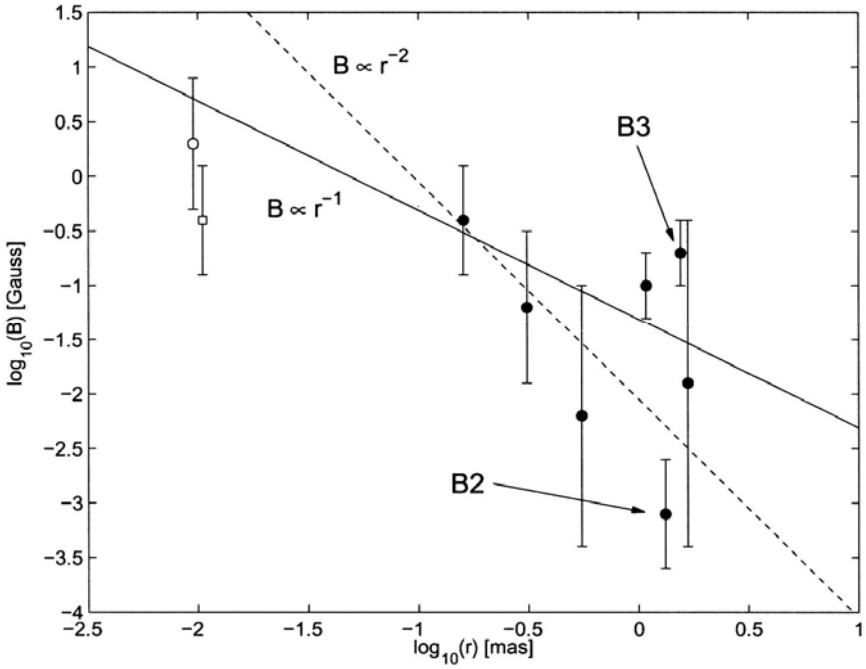
Theory and simulations: quite different flare shapes *(Gomez et al. 1997)*

VLBA with all frequencies and polarization...

(Savolainen et al., 2006, 2007)

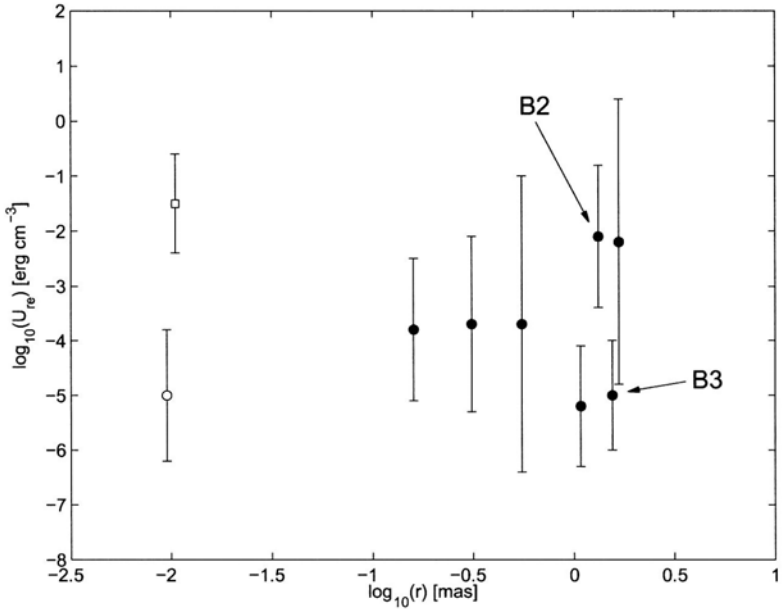


...gives us basic information of jets!



magnetic field vs. distance

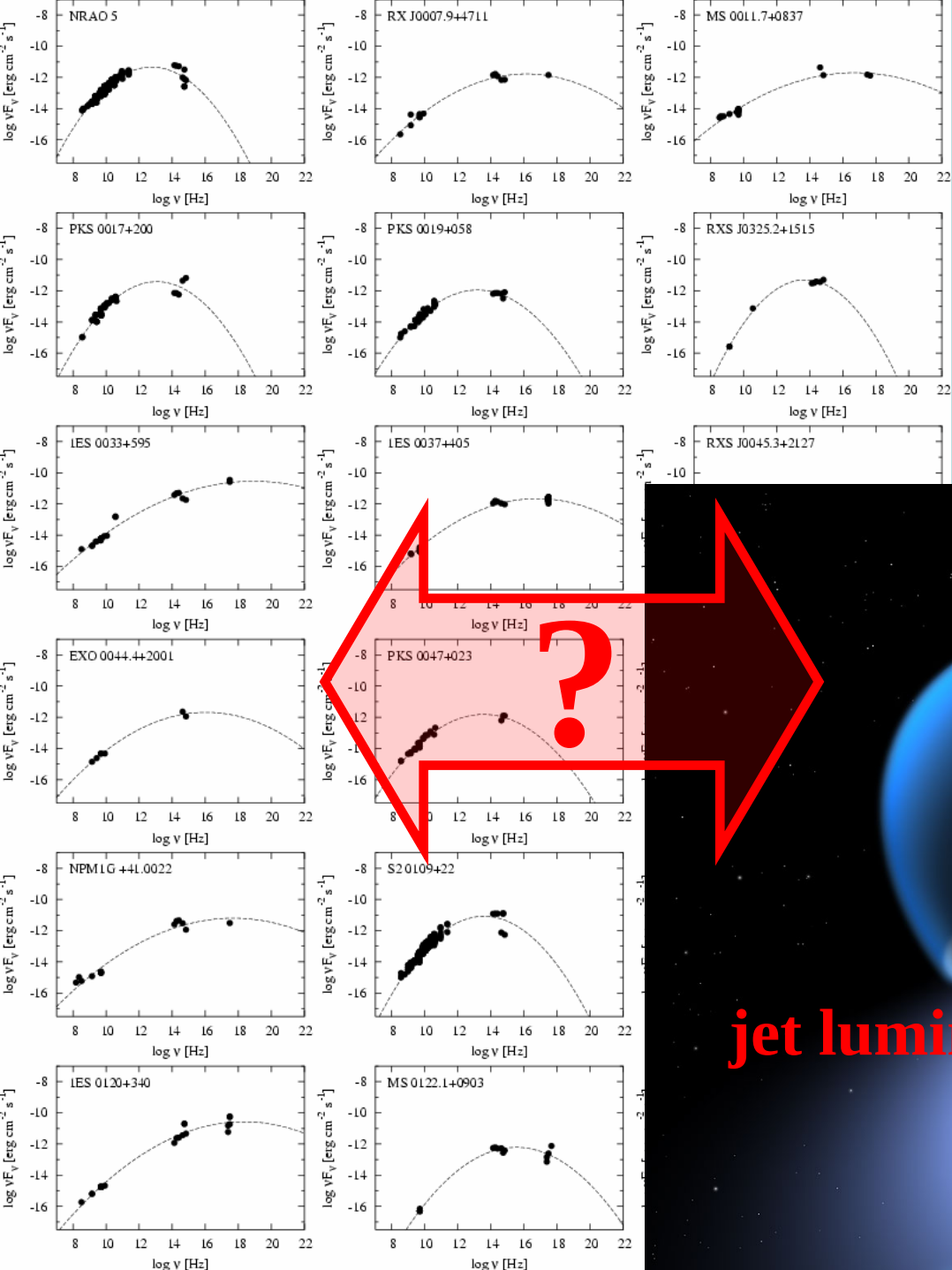
electron energy density vs. distance

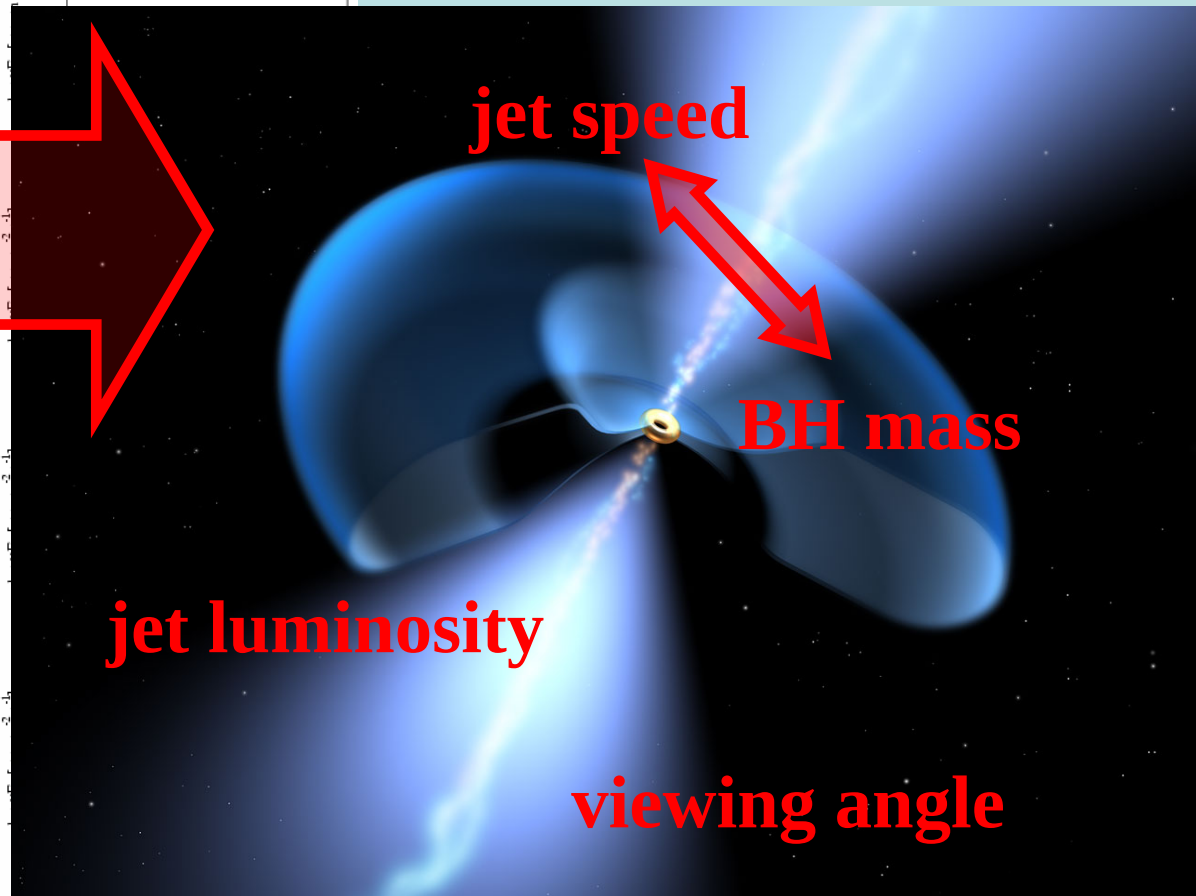


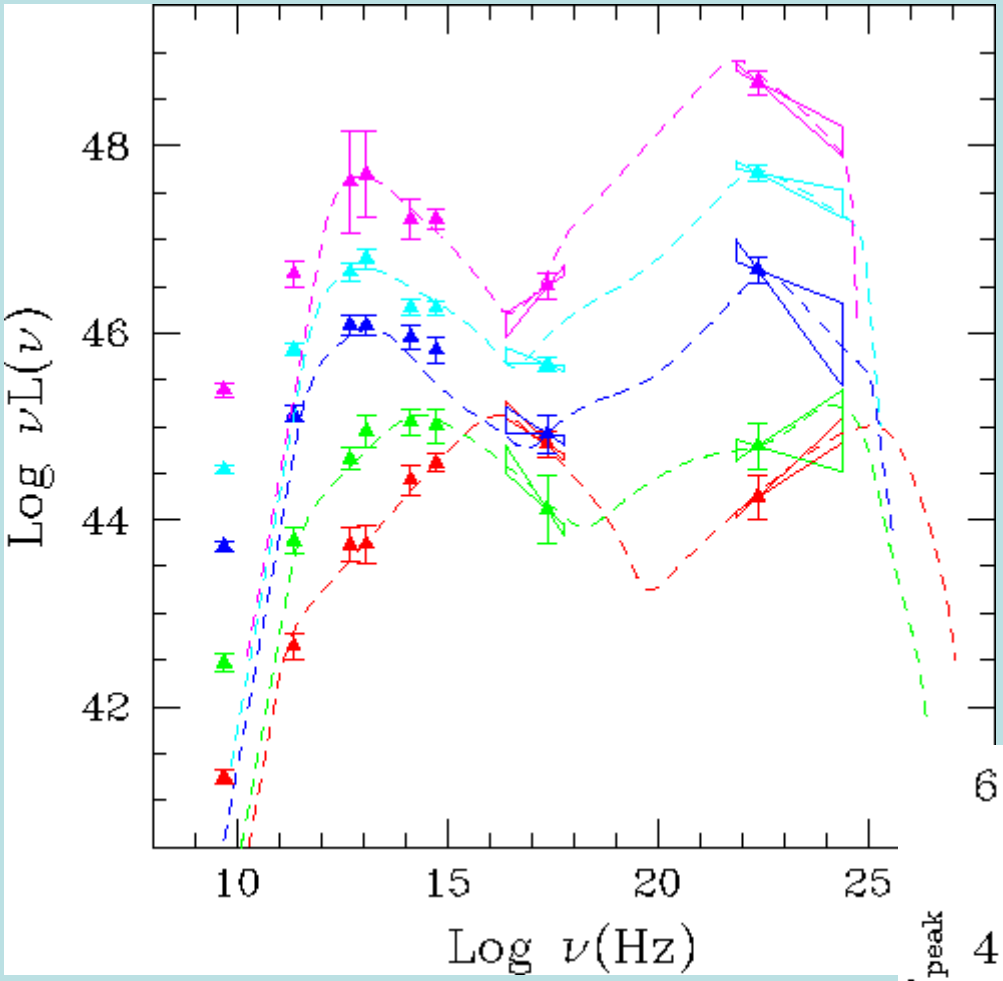
+ jet/mf structures, instabilities, nonrelativistic plasma, speeds, IC fluxes, ...

Spectral energy distributions

(Nieppola et al. 2006)

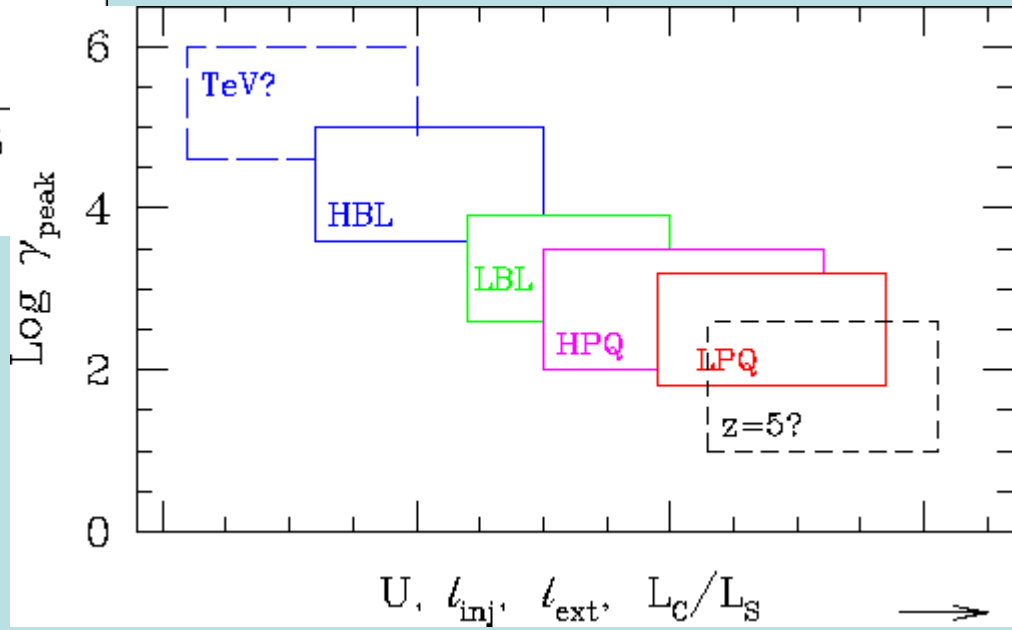




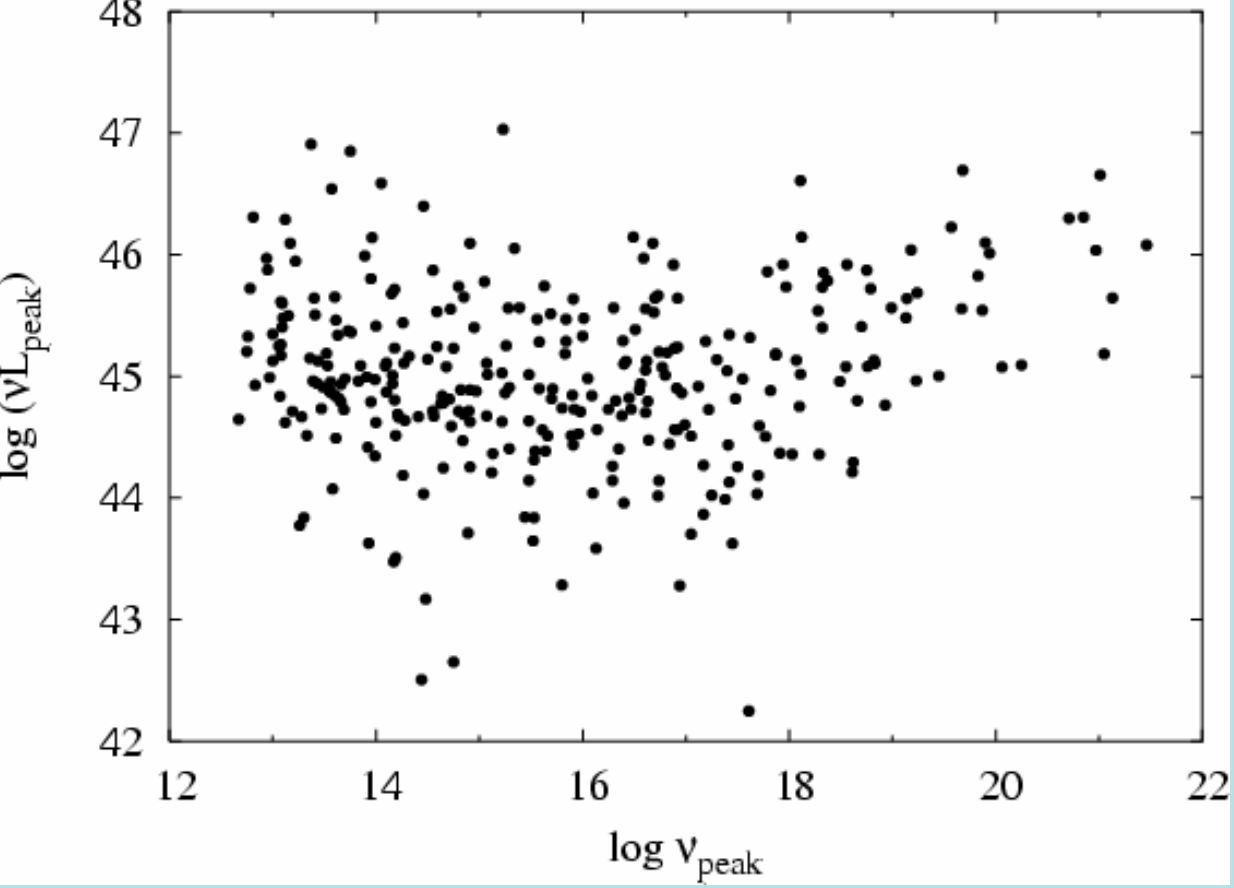


Blazar sequence?
(Ghisellini et al. 1998)

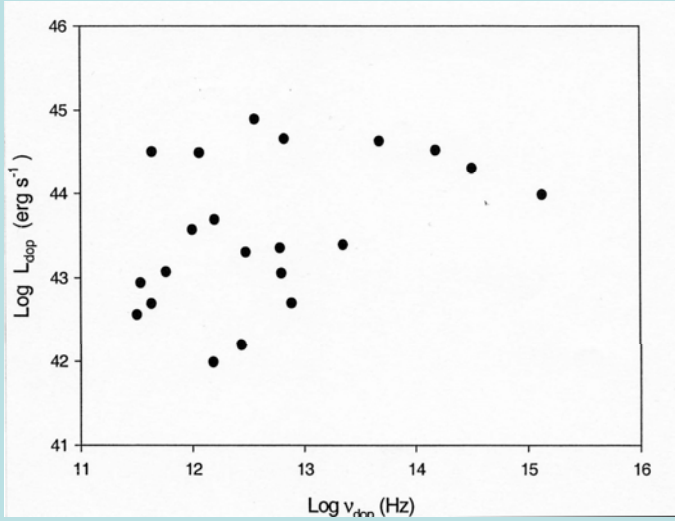
Most powerful sources have lowest synchrotron peak frequencies



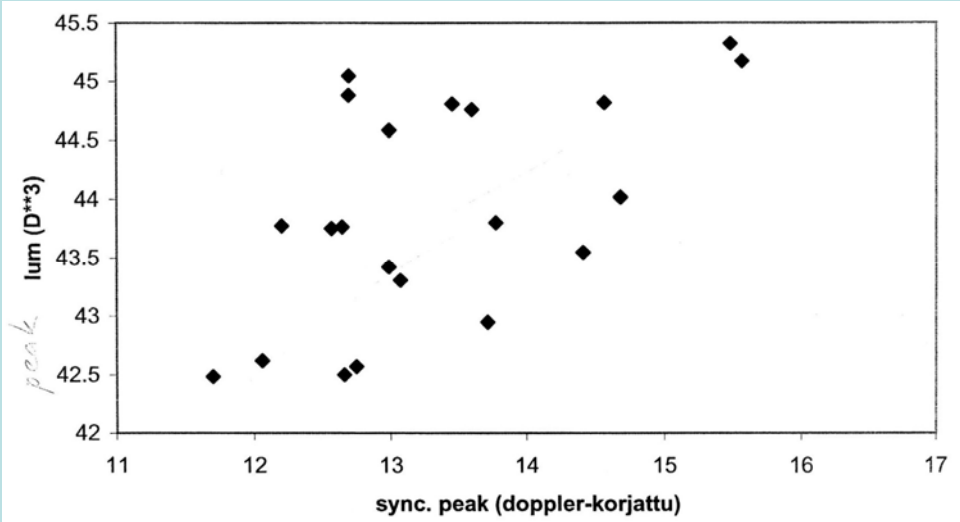
One-parameter (total power) family:



...but no predicted luminosity – peak frequency dependence?
(Nieppola et al. 2006)



...or even the opposite when corrected for Doppler boosting?
(Saloranta, Nieppola, unpublished)



BH MASS as the fundamental parameter?

(work in progress, Tuorla & Metsähovi:

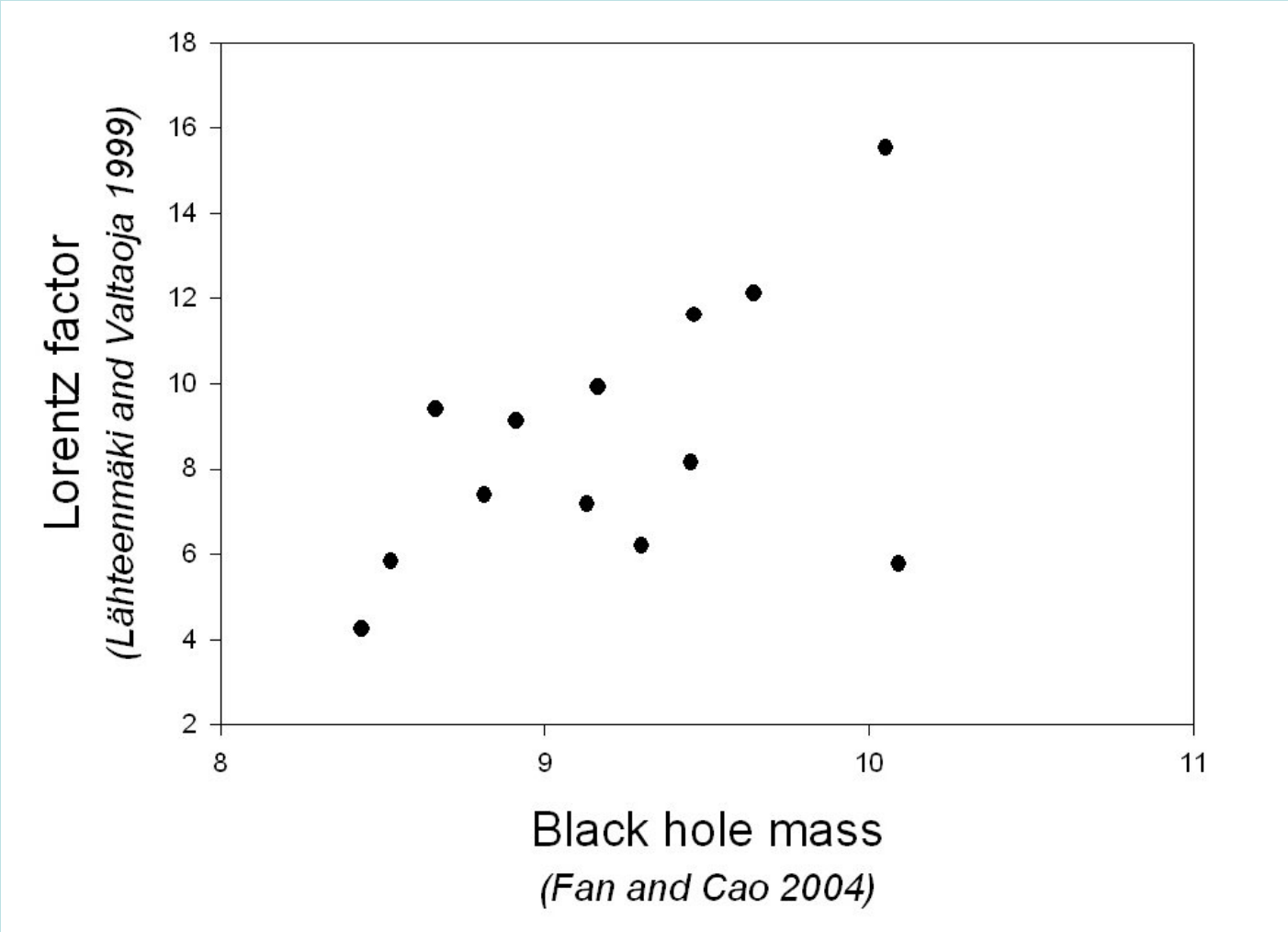
BH MASS

2 main observables:

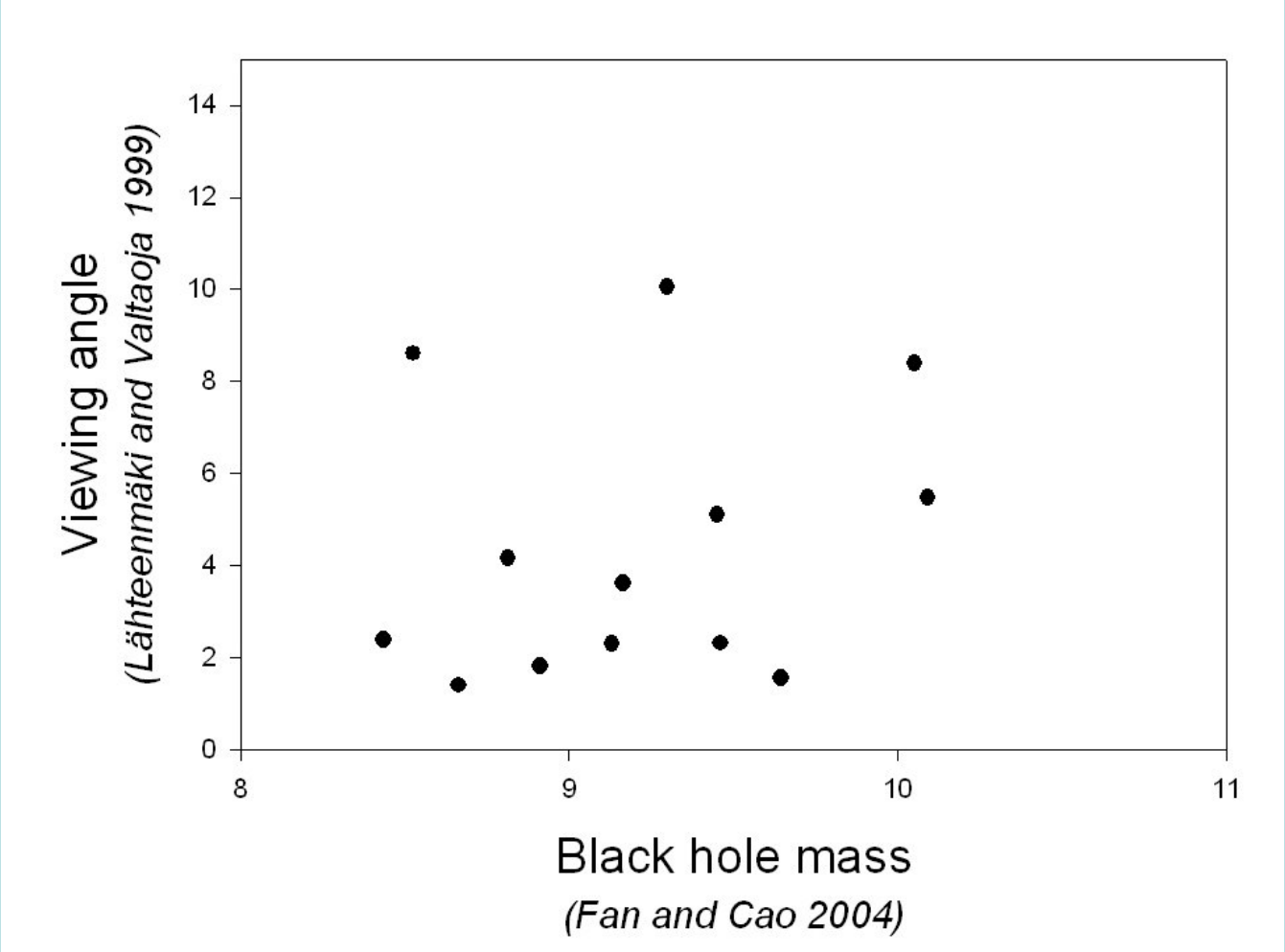
L(peak) | **DOPPLER**
ν(peak) | **CORRECTIONS!**

2 main jet parameters:

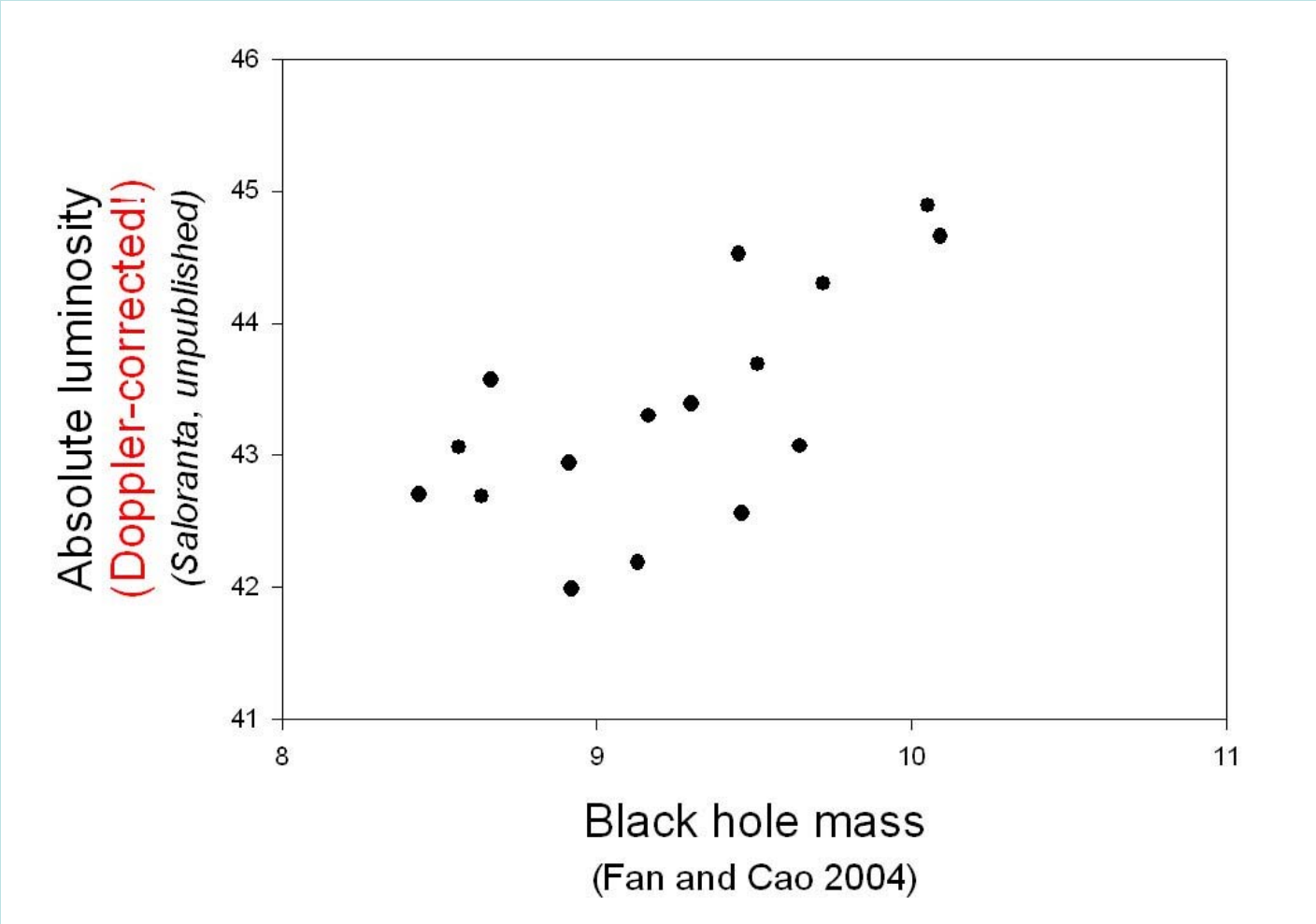
Γ (jet speed)
θ (viewing angle)



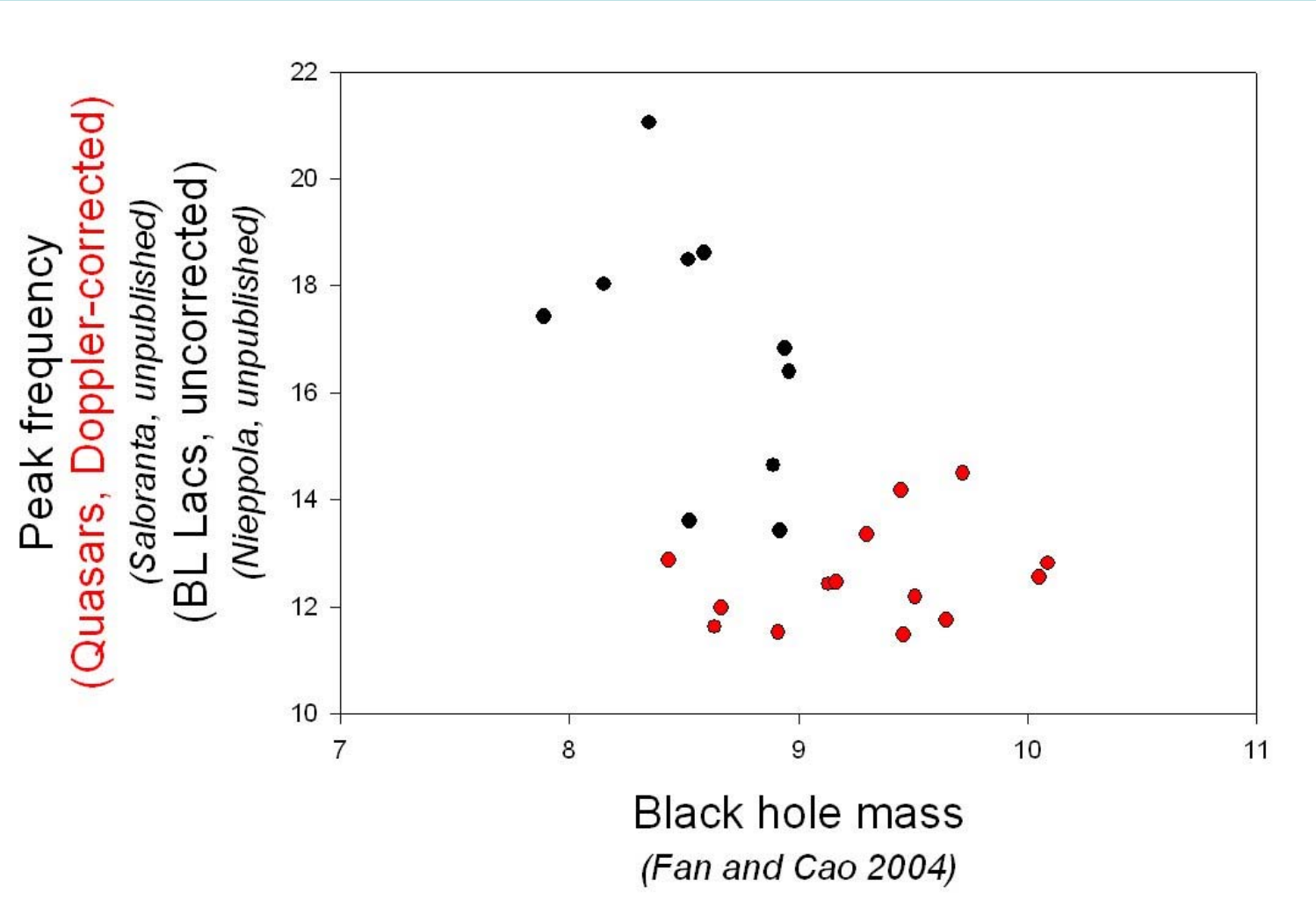
Big BH mass → fast jet



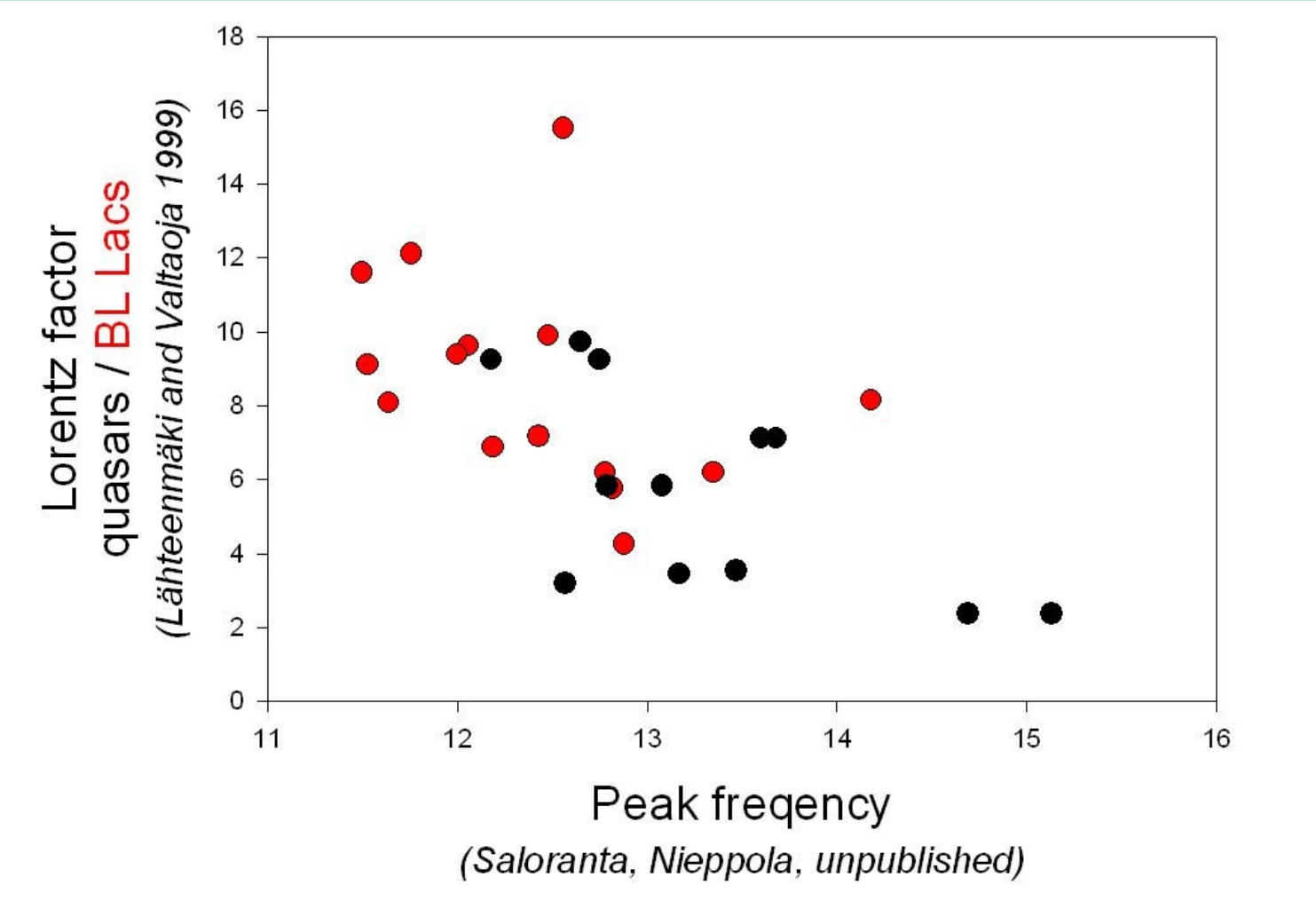
Check: viewing angle does not depend on mass



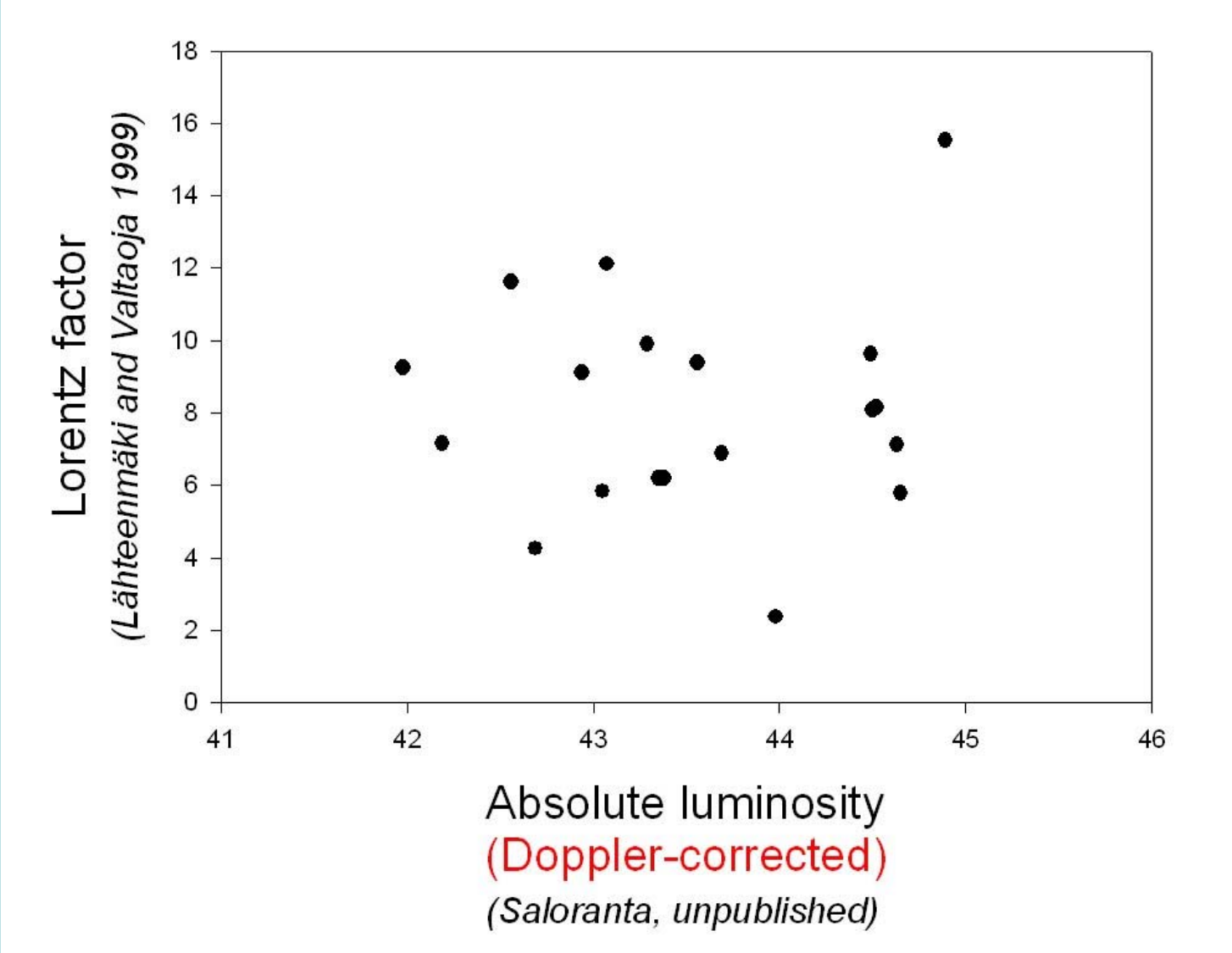
Big BH mass → high absolute luminosity



Peak frequency depends (also?) on other parameters than just black hole mass



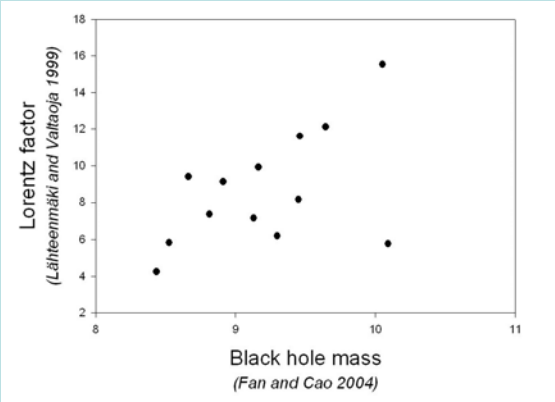
Fast jets have low peak frequencies



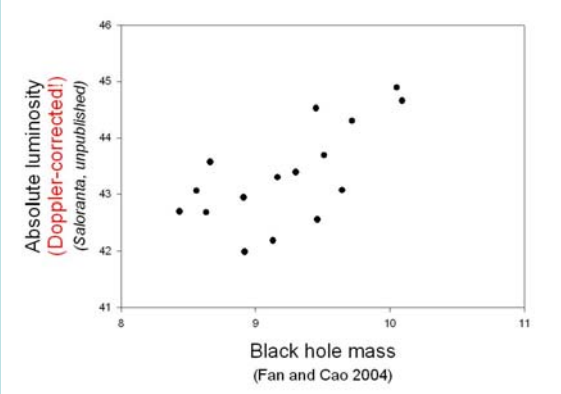
Jet speed does not depend on jet luminosity

BH MASS correlates with:

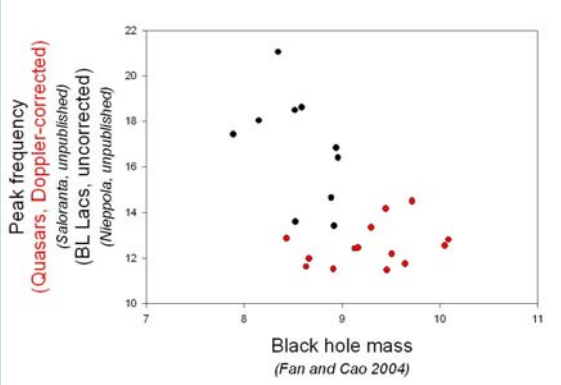
jet speed



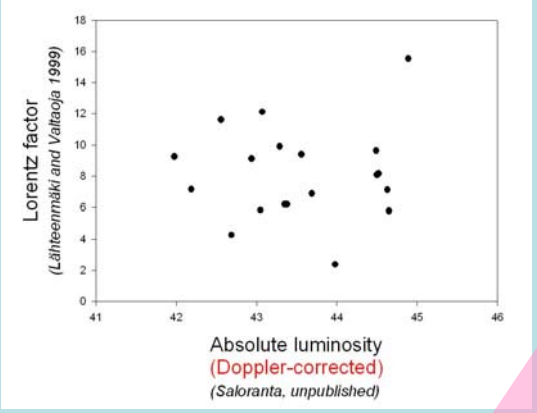
jet luminosity

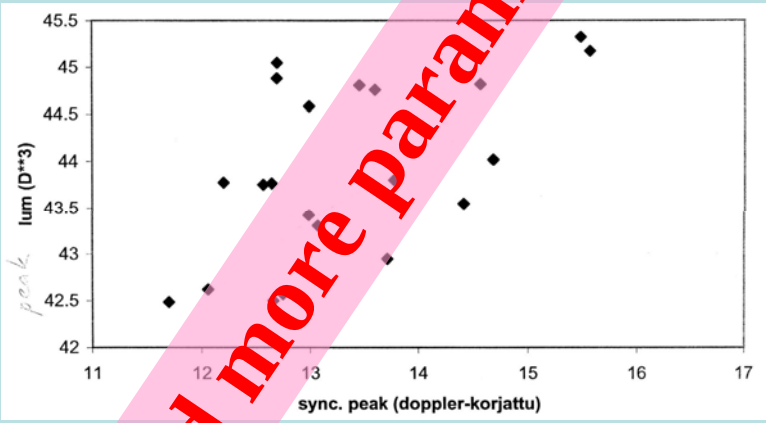


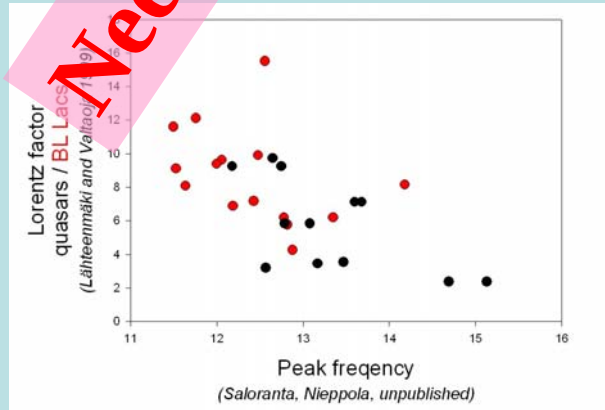
peak freq (inversely)



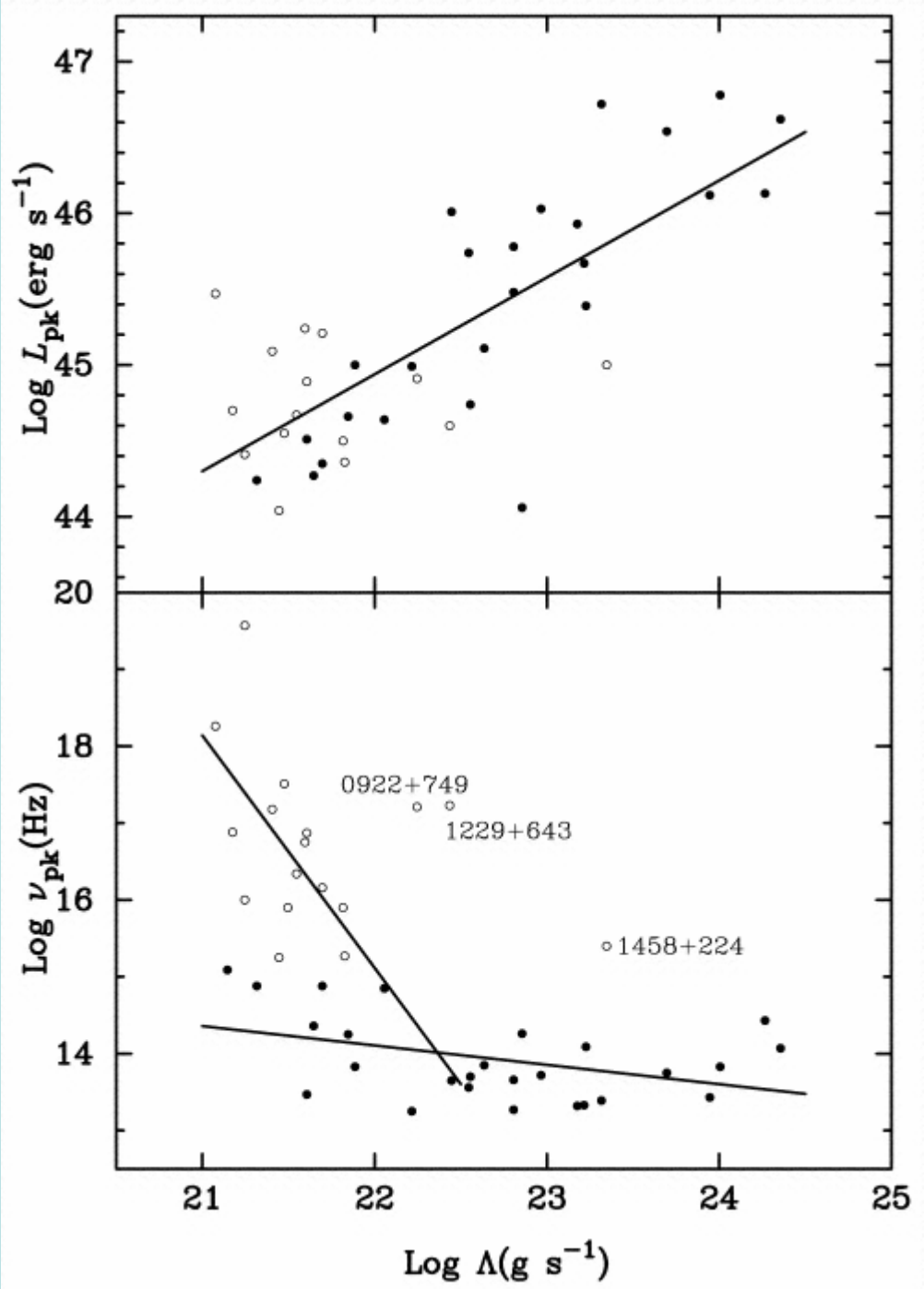
cross-correlations (or not):







Need more parameters!



LUMINOSITY and PEAK FREQUENCY depend on <u>accretion rate</u>
(Wang et al. 2002)

PEAK FREQUENCY depends on <u>viewing angle</u>
(Saloranta, Nieppola, unpubl.)