Investigating the FR Dichotomy through Jet Evolutionary Tracks and Environmental Interactions

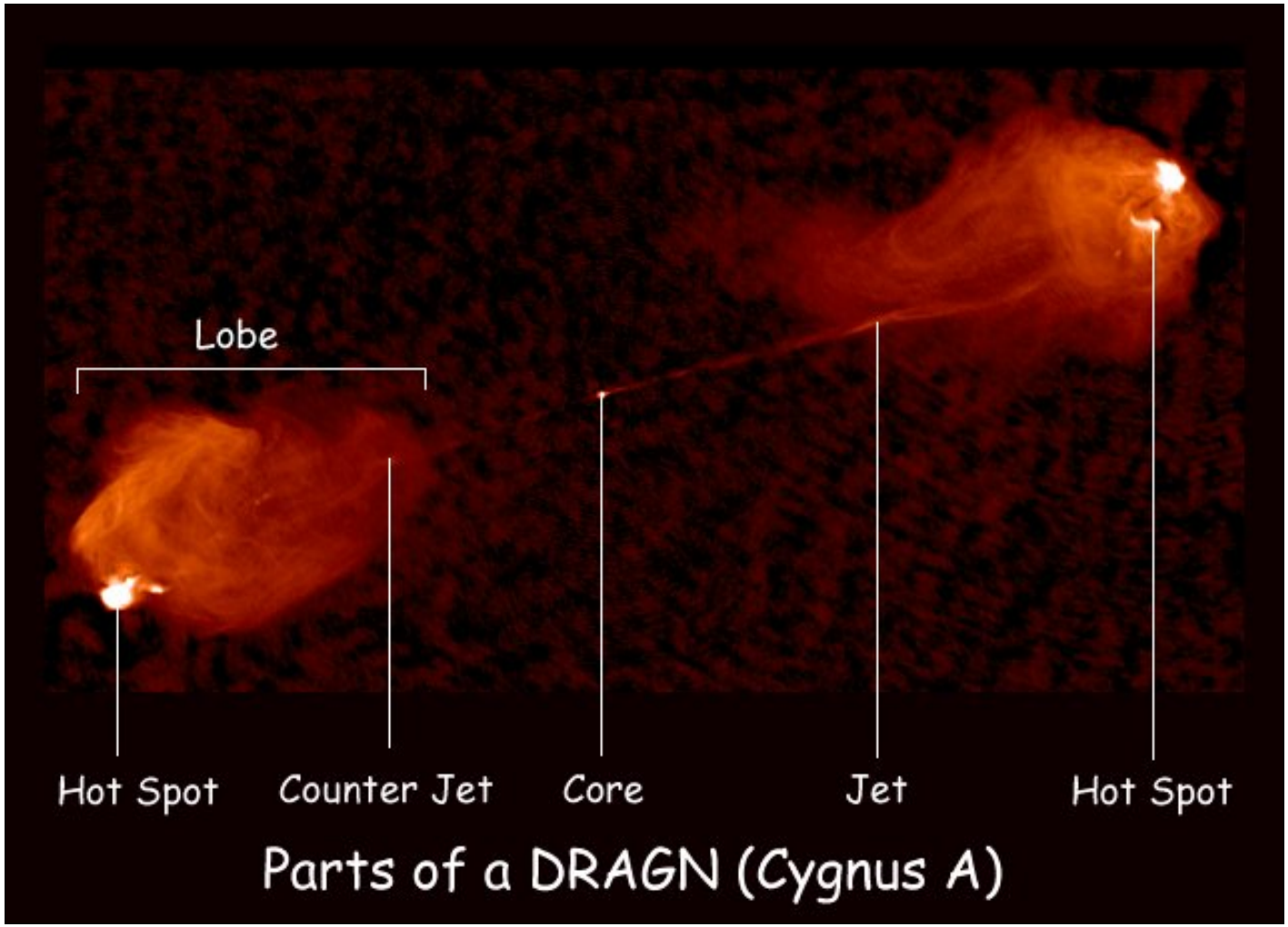
Tamela Maciel

University of Cambridge

Radio-Loud Galaxies

- $\mathrm{L_{1.4GHz}} > 10^{23}\ \mathrm{W\ Hz^{-1}}$
- Non-thermal, linearly polarized radio emission $\Rightarrow$ Synchrotron
- Giant elliptical host galaxy, often part of a galaxy cluster embedded in X-ray emitting ICM
- Two components: Extended and Core

Extended Morphology

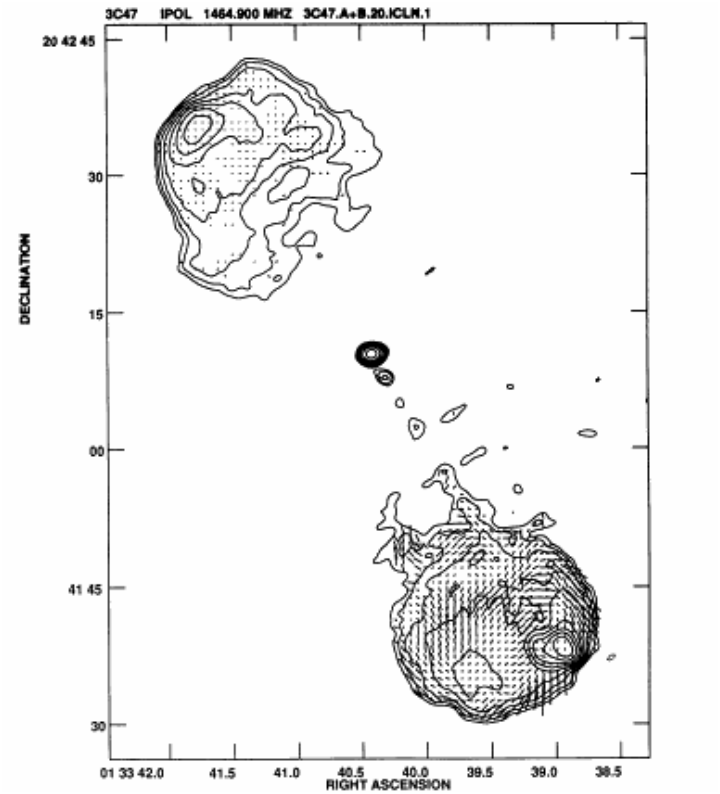


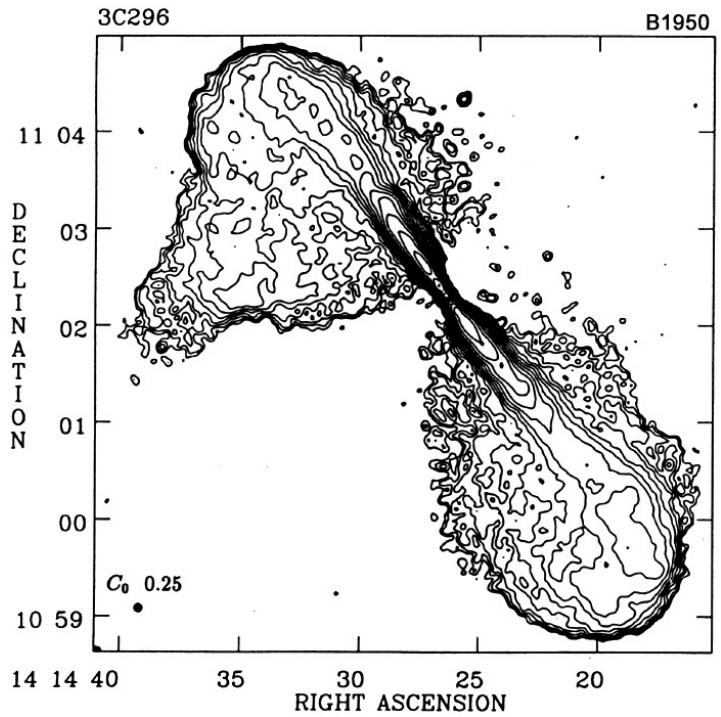
Feedback

- 'Cooling Flow Problem' $\Rightarrow$ Feedback necessary
- AGN winds, jets and induced shocks are an intriguing energy source
  - Thermal/Radiative heating
  - Mechanical removal of cold core gas
- But unclear how bipolar, collimated jets can efficiently couple to whole cluster

Need to study jet morphology in detail for clues to interaction processes

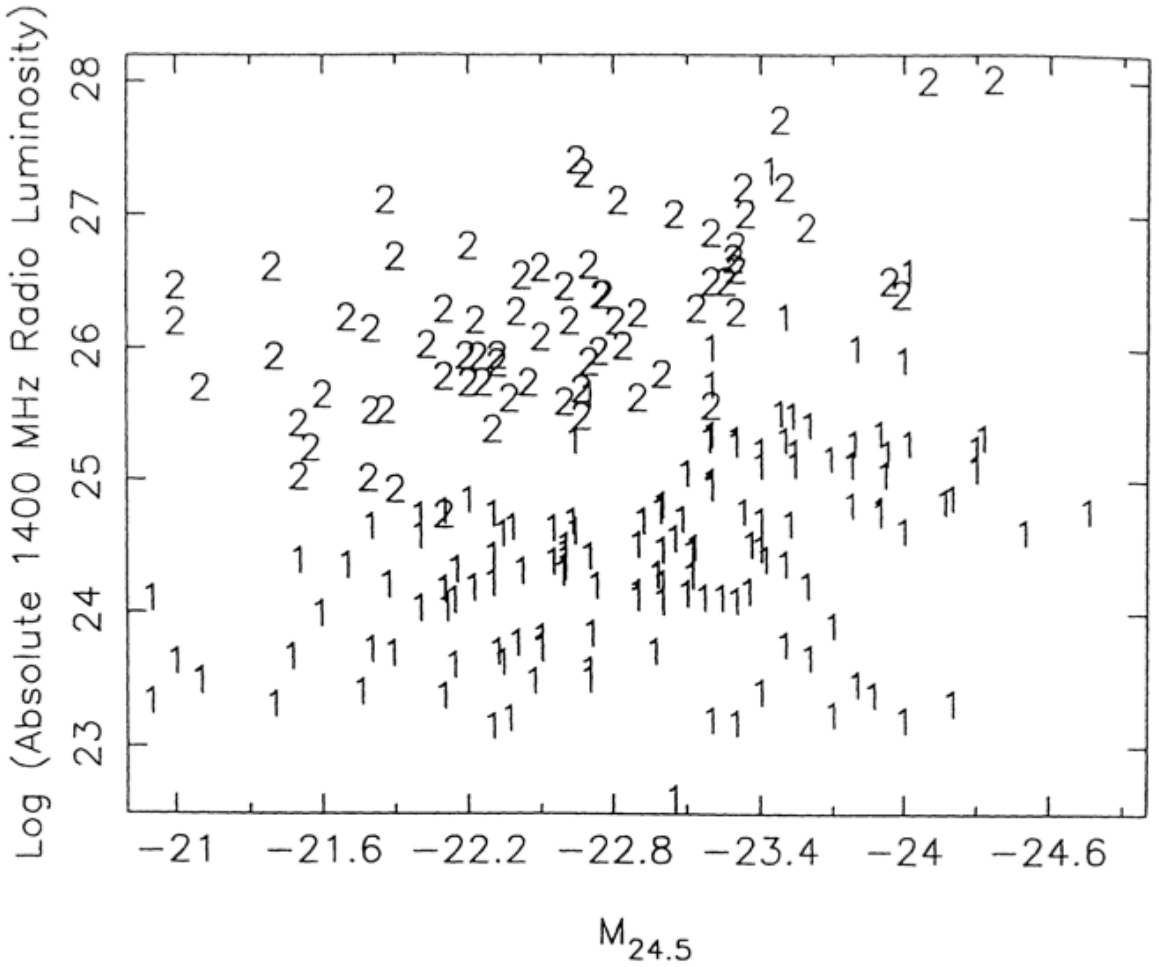
Fanaroff-Riley Dichotomy





FRII vs FRI
(3C 47 and 3C 296)

Fanaroff-Riley Dichotomy



Ledlow & Owen 96

Intrinsic Factors

- Different accretion rates leading to different black hole spins and thus different jet powers
  - But no clear relation between BH spin and jet existence (Fender+10 and Narayan presentation)
- Different accretion disk geometry (Maccarone 2003)
- Different jet opening angles (simulations by Krause 2011)

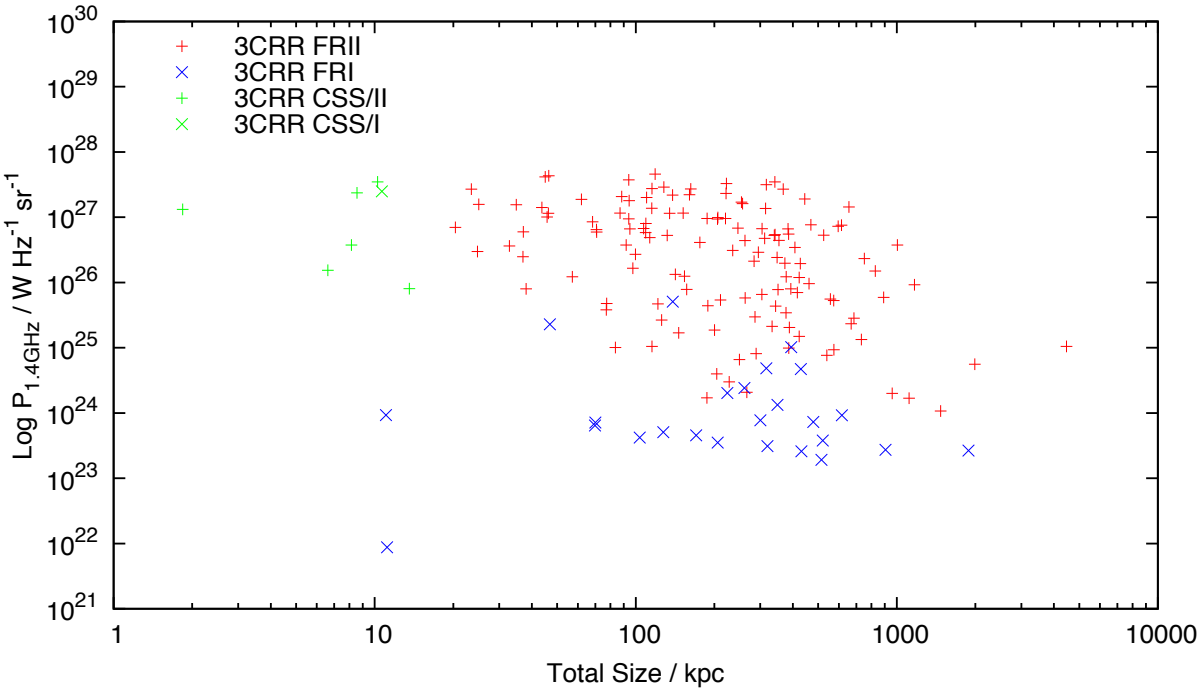
  $\theta > 24^o \Rightarrow$ FRI
- Correlation between radio luminosity and optical line emission in FRII sources, but no line emission in FRI (Baum 95, Hardcastle 07)

Extrinsic Factors

- Different ambient mediums
  - FRI sources found in richer environments (Wing 2011, Zirbel 1997)
- Hybrid FRII/FRI morphology - HYMORS (Gopal-Krishna & Wiita 00, 01)
  - Easily explained by an asymmetric environmental profile
- Ledlow-Owen: Correlation of radio luminosity with optical magnitude $\Rightarrow$ SFR $\Rightarrow$ the galactic environment

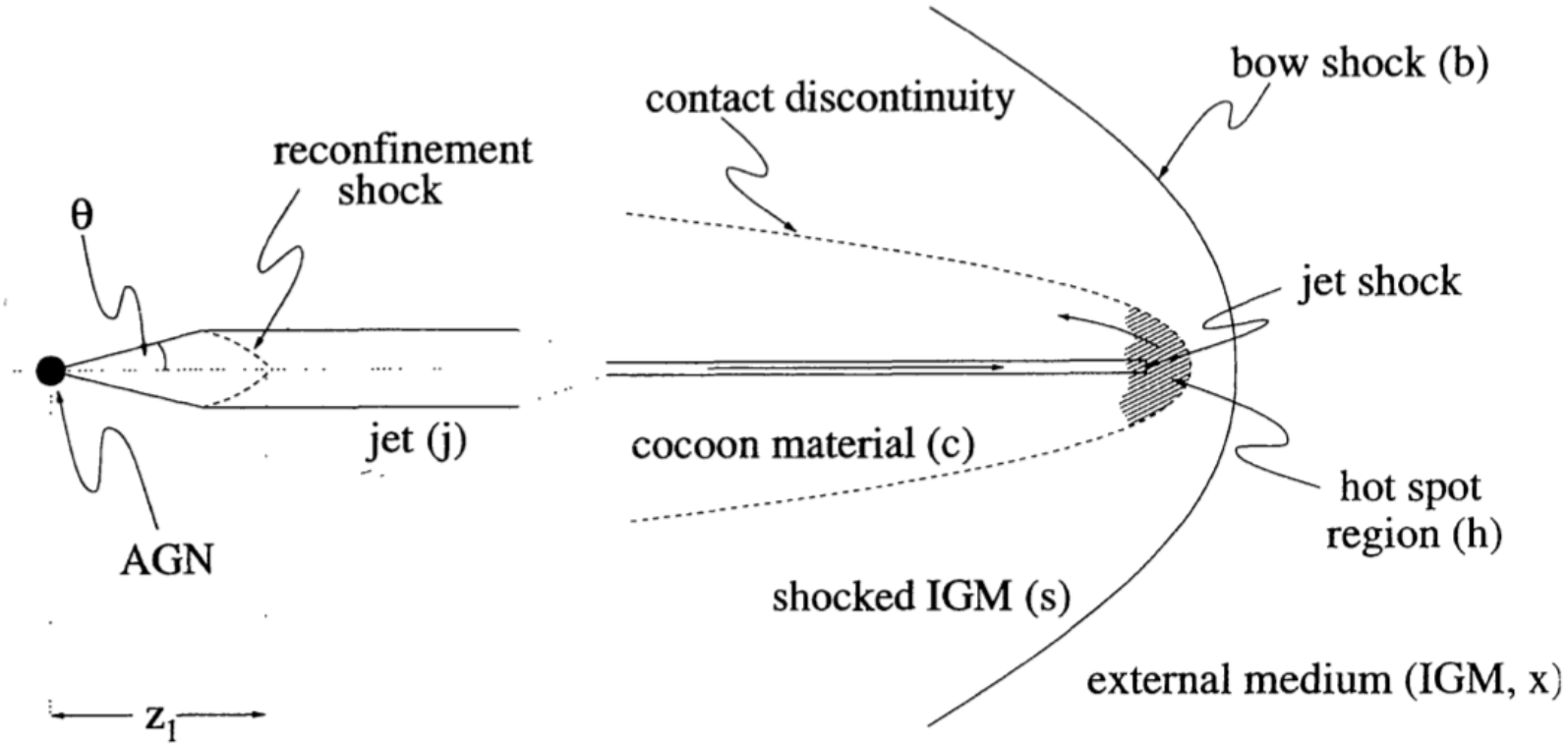
PD Diagram

- Dichotomy also apparent in the radio power vs jet length plane
- Diagram can help determine regimes where external factors may be significant



Self-Similar Model

Assume constant θ, Q_o, and $\dot{M}$. Jet expanding into a power-law falling atmosphere, parameter β



Kaiser & Alexander 97

Self-Similar Model

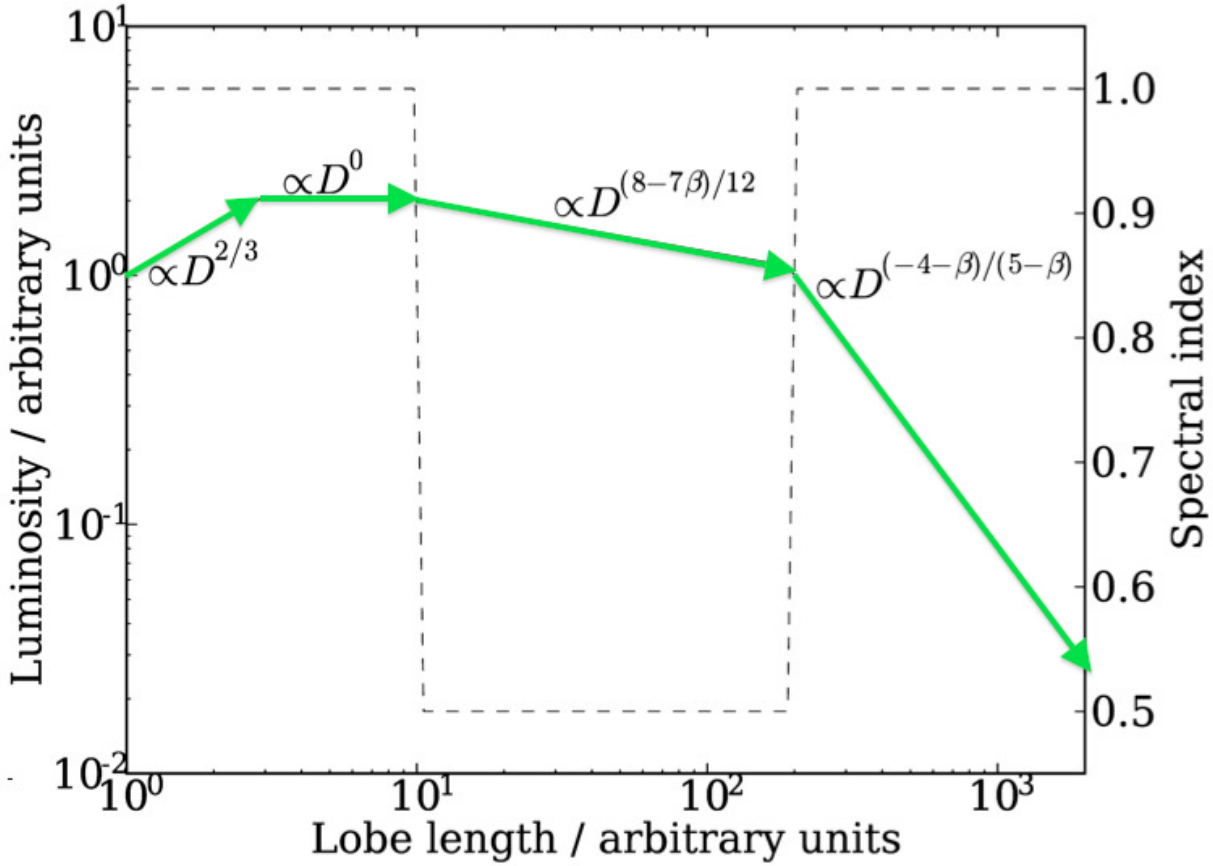
Radio synchrotron power from volume V,

$$P_\nu = \frac{\sigma\, c\, u_B}{6\pi\nu}\gamma^3 n\left[t,\, t_i\right] V\left[t,\, t_i\right]\ \mathrm{W\ Hz^{-1}\ sr^{-1}}$$

Allow γ to evolve with losses from adiabatic expansion, synchrotron emission, and inverse-Compton scattering on CMB photons. Assume equipartition.

$$\frac{d\gamma}{dt} = -\frac{a_1\gamma}{3t} - \frac{4\sigma}{3m_e c}\gamma^2\left(u_\mathrm{B} + u_\mathrm{CMB}\right)$$

Self-Similar Model



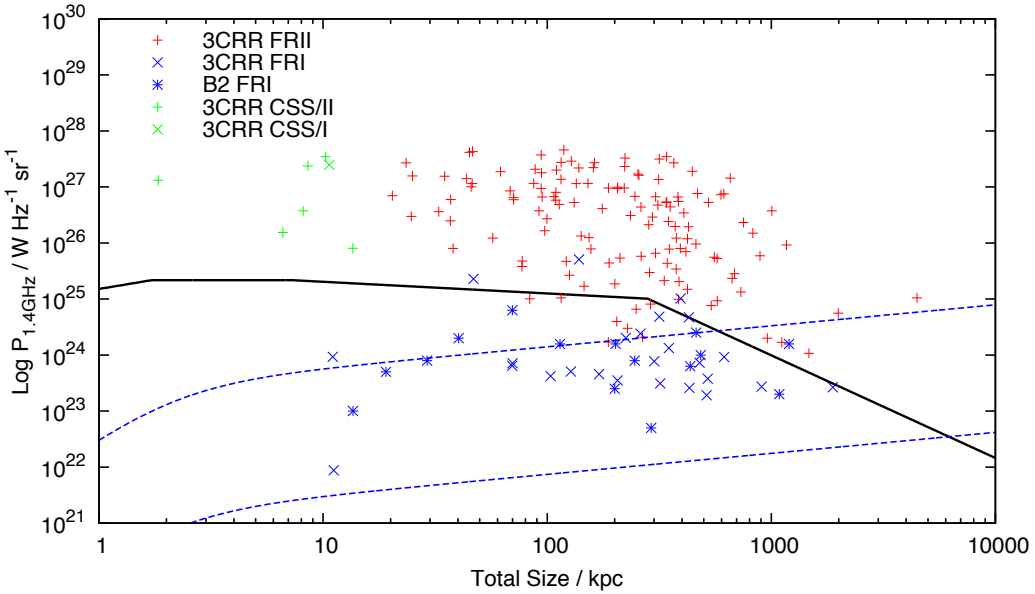
Kaiser & Best 07

External Pressure

$$p_x = p_{xo}\left[1+\left(\frac{r}{a_o}\right)^2\right]^{-\beta/2}$$

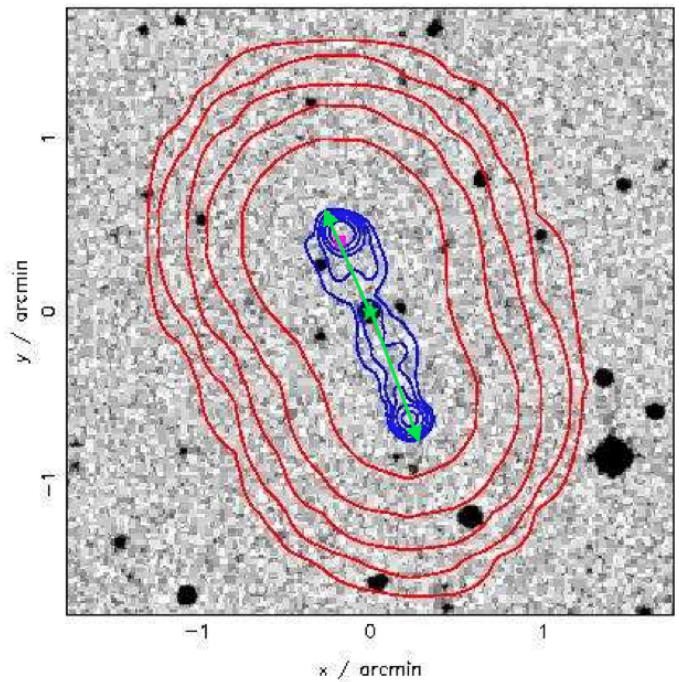
$$p_{xo}: \; 5\times10^{-13}-10^{-11}\,\mathrm{N\,m^{-2}}$$

Assume Q_o = constant and $\beta = 1.5$



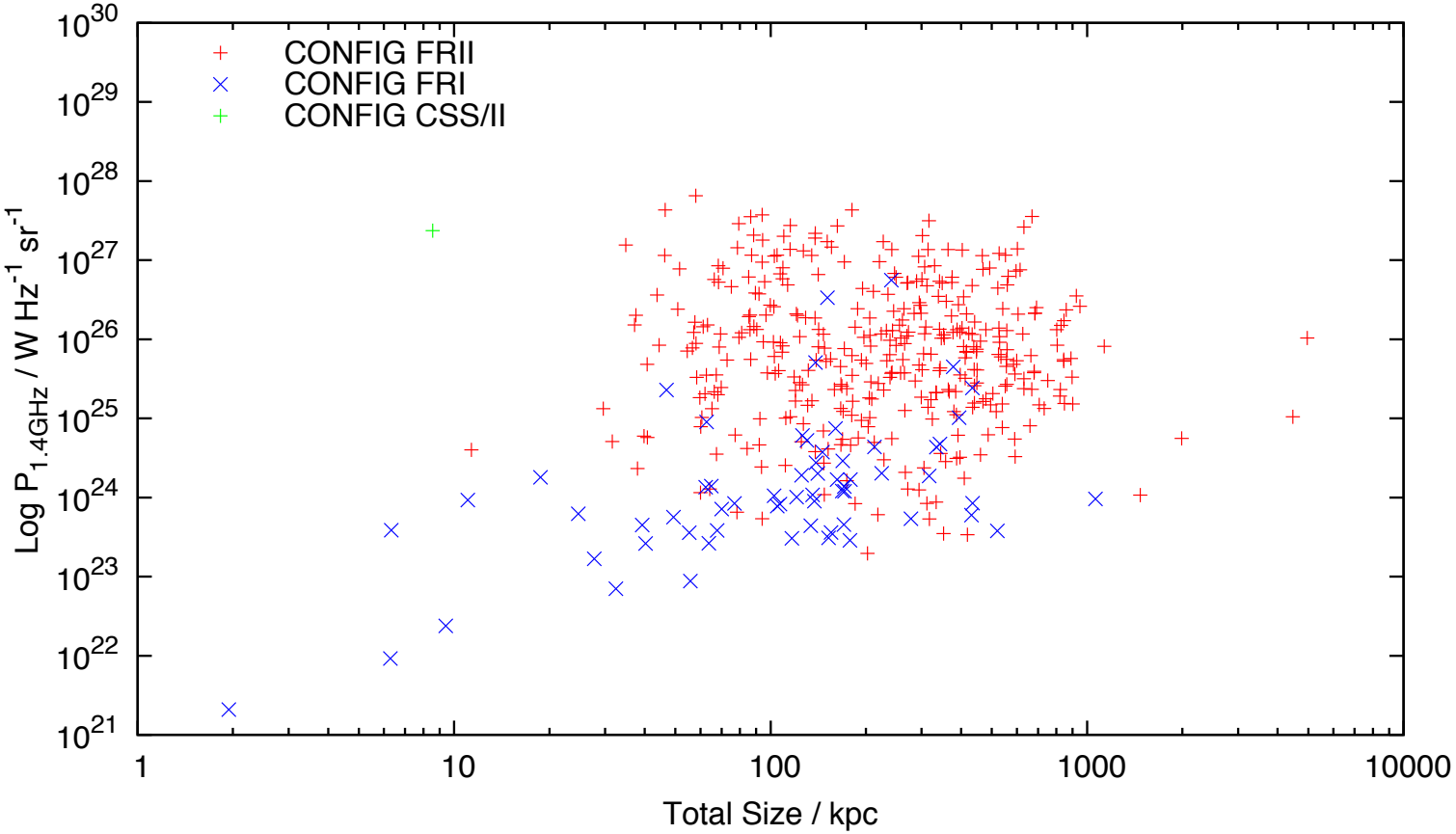
CoNFIG Sample

- Gendre+ 2008 and 2010
- Flux-limited (> 1.3 Jy) sample of 1.4 GHz sources from overlapping Northern region of NVSS and FIRST
- Measured linear sizes of the 433 FR classified galaxies

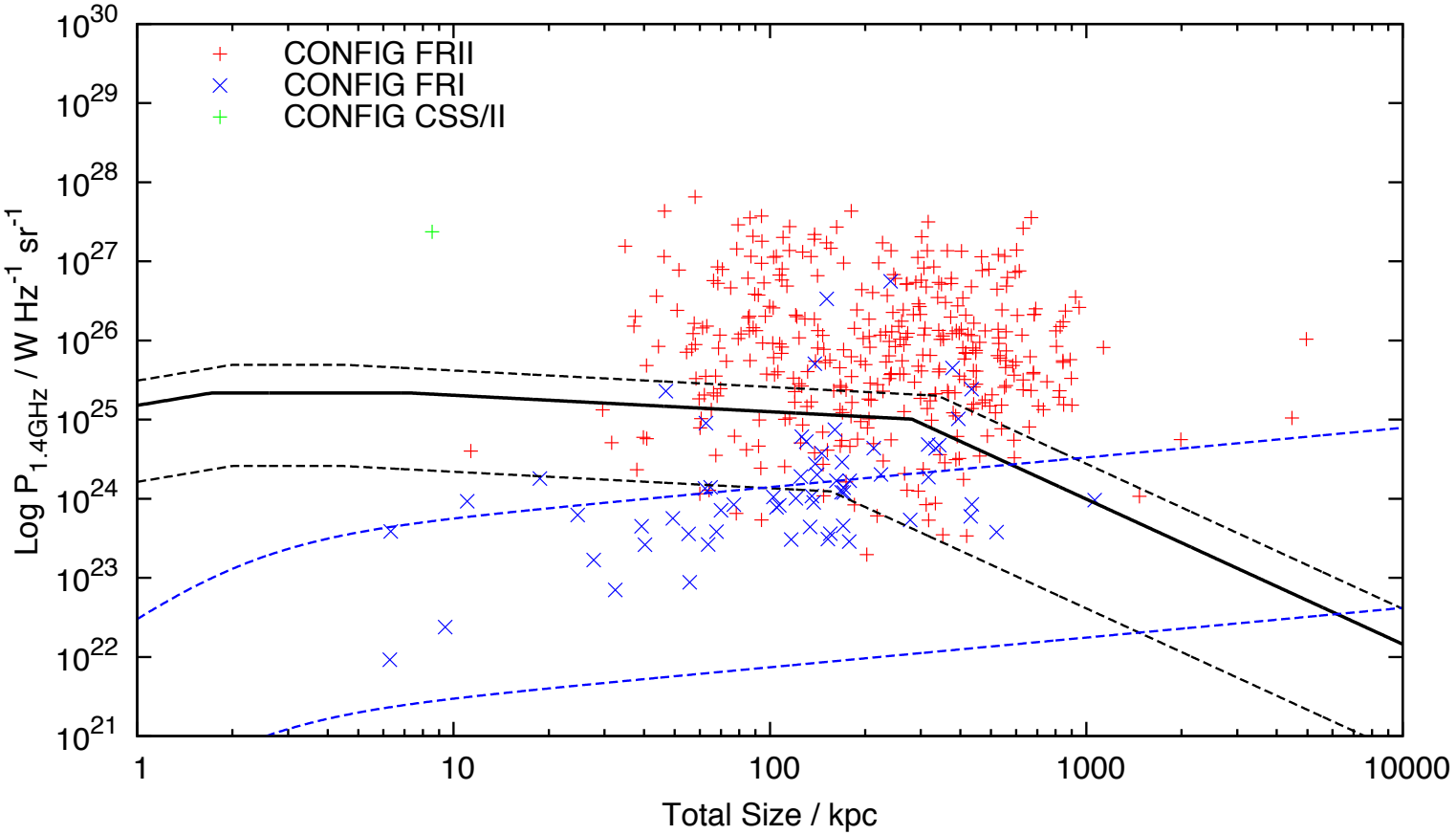


C1-226: 3C 323.1

CoNFIG Sample



CoNFIG Sample



Future Research

- Script to automate source measurements
- Investigate sub-sample of sources on border of FR divide
  - Optical line emission strength
  - Morphology of environmental interactions
  - Measure jet opening angle
- Additional observations of this subset?

Future Research

- Script to automate source measurements
- Investigate sub-sample of sources on border of FR divide
  - Optical line emission strength
  - Morphology of environmental interactions
  - Measure jet opening angle
- Additional observations of this subset?

Thank you