... or what is someone who normally works on single objects doing in a survey meeting?
My work on radio surveys
Selected Topics

- Jet velocities and particle acceleration processes
- Magnetic fields in and around radio galaxies

What can we learn from the combination of deep single-object observations and surveys?
The Fanaroff-Riley Division

M84

30 arcsec

FRI

FRII

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FR Division and Environment

Need better radio imaging

Ledlow & Owen (1996)  
Heterogeneous

Best (2009)  
SDSS-FIRST/NVSS
FRI jet acceleration and deceleration

Proper motions in M87

Asada et al. (2014)

Mertens & Lobanov (2015)
Jet deceleration on kpc scales

(a) NGC 315

(b) Model

Velocity fields

Observations + model

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Approaching jets at high resolution

Jets brighten and start to expand more rapidly at the flaring point.
Flaring and Deceleration

(a) Geometry and velocity

- Flaring
  - Recollimation begins
  - Recollimation complete
- Subsonic shear layer
- Supersonic spine
- Subsonic shear layer
- Entrainment
- Dense corona

\[ \beta = 0.8 \]

- Deceleration
- Constant velocity
- Evolving profile
- Fixed transverse profile

\[ r_{\text{v0}} / \text{kpc} \]

Inflection point / kpc
Finding interesting sources

151 MHz
(Wagget, Warner & Baldwin 1977)

609 MHz WSRT
(Mack et al. 1997)

Jansky
VLA
4.5-6.5 GHz
Fine-scale structure in jets
Velocities from surveys

- How do the flaring and deceleration scales in FRI radio galaxies depend on:
  - jet power?
  - galaxy mass?
  - environment (field/group/cluster/hot gas density and pressure profiles)?

$s$ is the distance at which the jets become symmetrical (proxy for deceleration scale)

B2 sample, RL et al. (1999)
Velocities: open questions

- What are we measuring with proper motions?
  - components moving with the flow?
  - or at some other speed?
  - stationary features (e.g. shocks)?
- Is there bulk acceleration on pc scales, or are we seeing material entrained into a faster flow?
- How fast are FRII jets on kpc scales?
  - Probably need SKA2 for this
Where do jets light up?
Very close to the black hole

Core shift: measuring the position of the $\tau = 1$ surface as a function of frequency

3C270: Haga et al. (2015)

M87: Hada et al. (2011)
What keeps jets lit up?

Spectrum becomes **flatter** with increasing distance from AGN

Opposite to effect of synchrotron losses $S \propto \nu^{-\alpha}$

Velocity-dependent particle acceleration

Mildly relativistic shock network: close to Bohm diffusion?
Particle Energy Evolution

(c) Radiating particles

\[ \alpha = 0.66 \]

\[ \gamma_{\text{max}} \sim 10^7 \]

\[ \gamma_{\text{max}} \sim 10^5 \]

None

Particle acceleration

Flattening emissivity profile

\( M > M_{\text{crit}} \)

Complex non-axi-symmetric structure

High emissivity

Adiabatic evolution
Energy loss processes
The impact of jets on hot and cold gas

M84 (Finoguenov et al.; Hydra A (Mcnamara et al.); Cavagnolo et al.

IC5063
ALMA CO2-1 and 230GHz continuum
Morganti et al. (2015)
Jet entrainment

Velocity fits from Laing & Bridle (2014)
Conservation-law analysis following Laing & Bridle (2002)

3C31

NGC315

B2 0326+39

3C 296
Magnetic Field Strength and Geometry

- **kpc scales**
  - FRI jets: evolution from longitudinally to toroidally dominated; not a globally ordered helix; e.g. ordered toroidal + longitudinal with many reversals (Laing & Bridle 2014)
  - Field strength estimates from equipartition ~1-30 μG); inverse Compton constraints not very useful
  - FRII jets: integrated apparent field usually longitudinal; one resolved case: longitudinal + toroidal in boundary layer

- **pc scales**
  - Core shift method gives magnetic field strength at ~1 pc (and, with additional assumptions, the magnetic flux; Zamaninasab et al. 2014; Zdziarski et al. 2015) = Magnetically Arrested Disks
  - Field geometry debated: helical/toroidal + rms longitudinal/disordered and anisotropic. Likely to evolve with distance.
B-field geometry in FRI jets

Longitudinal

Toroidal

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Field Evolution

Ordered toroidal component preserved from pc scales

+ Longitudinal component with many reversals

?
Faraday rotation

3C31
θ ≈ 52°

RL et al. 2008

3C449
θ ≈ 90°

Guidetti et al. 2010
Faraday rotation geometry
Rotation Measure Bands

M84 in Virgo cluster

Guidetti et al. (2011, 2012)

3C353 on edge of rich cluster
Faraday Rotation Surveys

- Which radio galaxies show ordered RM patterns and why?
  - Actively driven lobes?
- What is the range of B-field power spectra in disordered RM distributions?
  - Flatter than Kolmogorov?
  - Inner and outer scales?
  - Scaling with $n_e$?
- Field strength? Energy density compared with thermal plasma?
- Resolution <500 pc
- Frequency range matched to the RM
Single-object dinosaurs can coexist with younger, faster survey mammals*

* at least until the extinction event.

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