Summary: Jets, Outflows and Cosmic Structure Formation

- **Team members:**
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  - Tom Jones (UMN)
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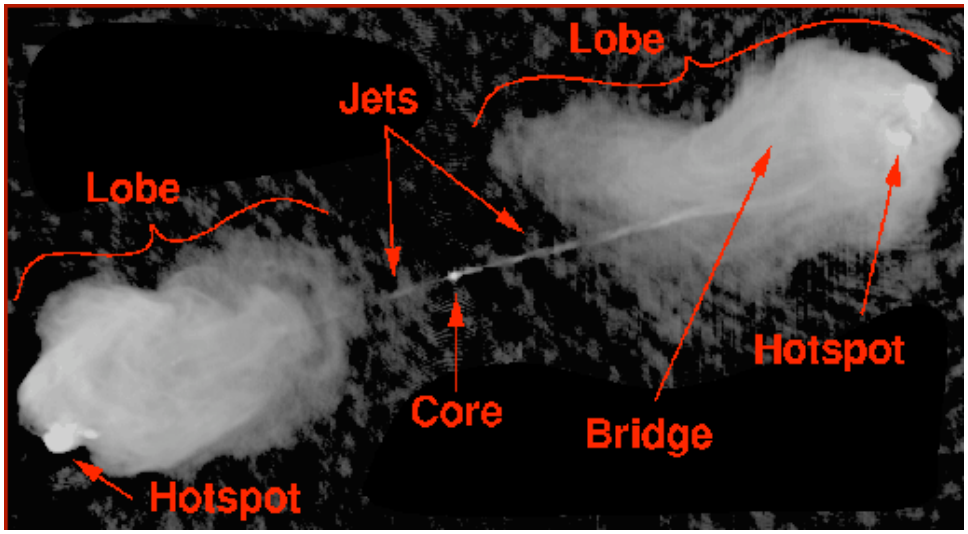
  - Sergey Lebedev (Imperial)
  - Hui Li (LANL)
  - Richard Lovelace (Cornell)
  - Sean Matt (NASA)
  - Pat Hartigan (Rice)
- Contacted about ~ 80 members in the community and got ~ 40 contributions

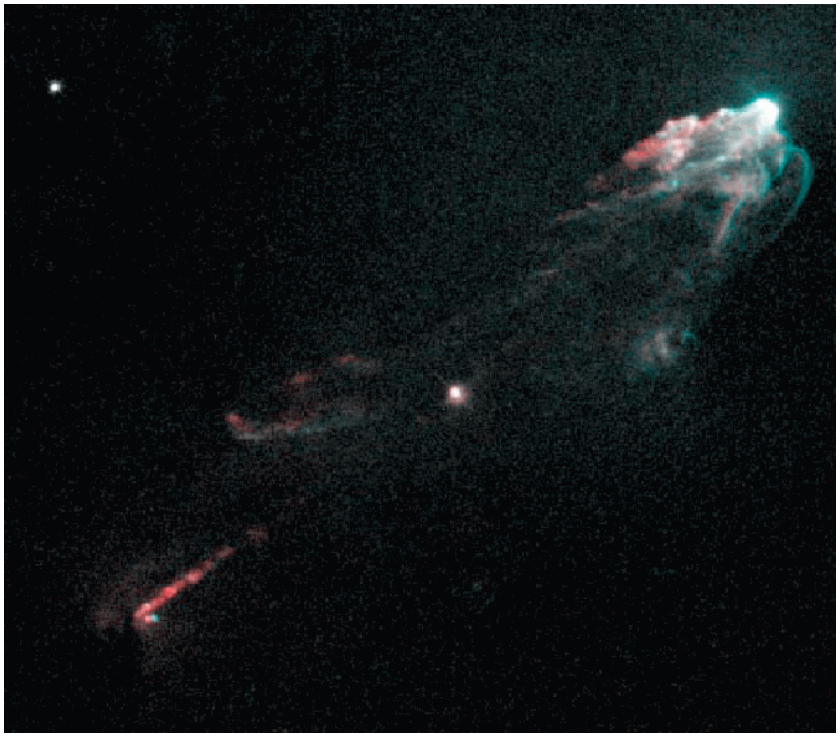
Challenge	Existing Research Capabilities	Gaps/what's needed	Opportunities
1) Understand the physics of astrophysical jets	Observation, lab experiments, theory/ simulations around the world	1) Better coordinated research efforts and information exchange among astro and plasma communities; 2) Different funding agencies with different priorities	1) Form a consortium with funding for research and regular workshops, bringing together interested astronomers and plasma scientists 2) Take advantages of recent breakthroughs in parallel numerical simulations (e.g., 3D GRMHD, PIC) and lab experiments producing jets
2) Physical conditions of AGN jets on all scales	EVLA (with 35 km baseline), VLBA, e-merlin, intercontinental VLBI	1) Angular resolution at least 10x insufficient to resolve jet transversely 2) Polarimetric capability limited	1) Propose coordinated funding between DOE, NSF and NASA for EVLA2 and VLBI enhancements.
3) Understand why jets are stable over such long distances	Observations, MHD simulations, Lab experiments	1) Lack of observational constraints of jet composition and properties; 2) Lack of good theory; 3) Extended parameter regime for lab experiments	1) Develop comprehensive theory of stability/instability of current carrying jets 2) Explain existing observations of radio jet and lobe morphologies 3) Funding for 3D simulations of lab

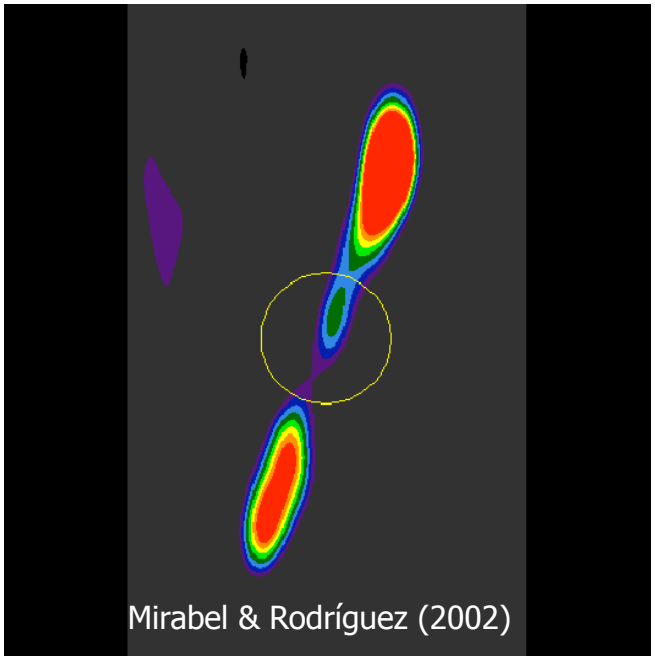
#1: Organizational/Infrastructure

- Existing: very active
  - Observations
  - Lab experiments
  - Theory/simulations
- Existing: high impact
  - Protostellar jets: impacting star formation and ISM
  - AGN jets: feedback on large-scale structure formation
  - AGN jets: multiwavelength radiation, UHECRs?
  - GRB jets: most explosive engines in the Universe
  -

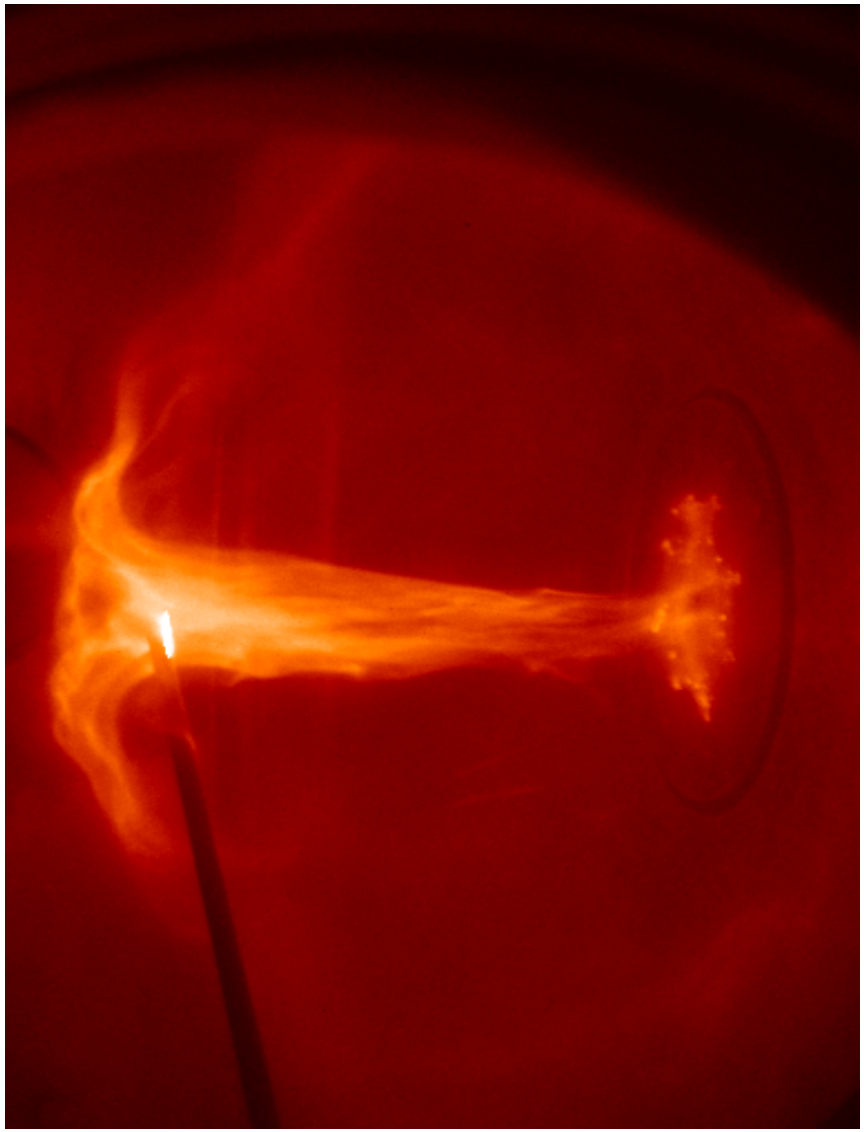
Observations

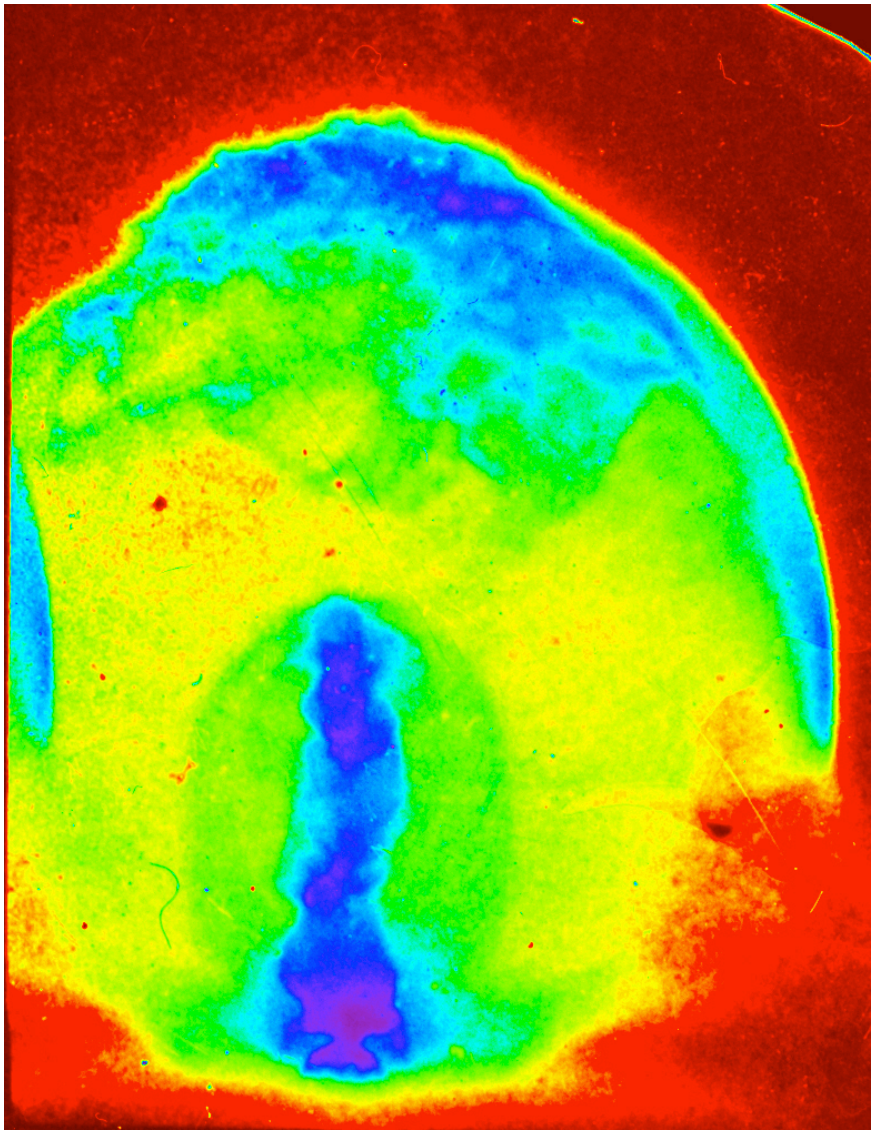




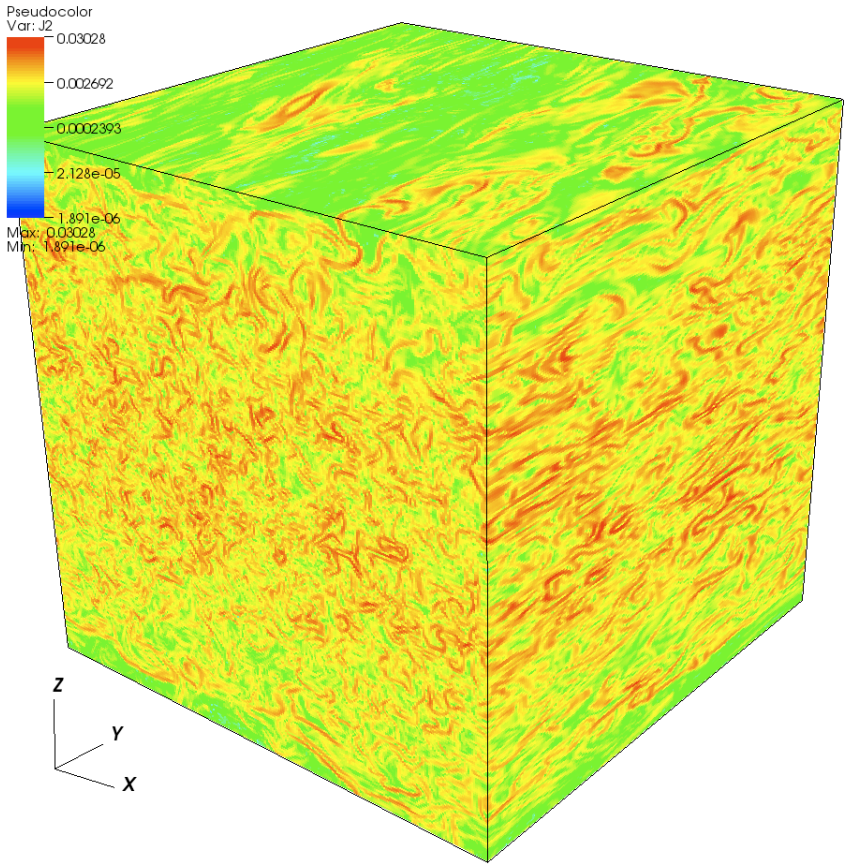


Lab Experiments

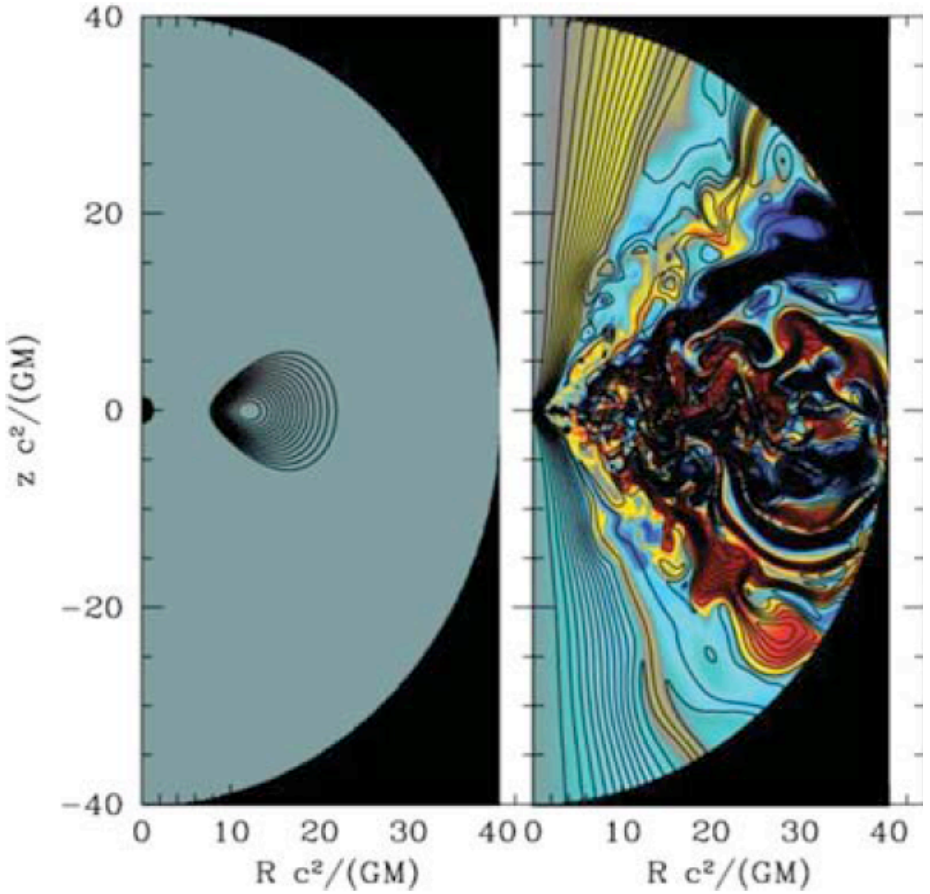




Disk Dynamo, Momentum Transport, Waves and Turbulence, Radiation Hydro

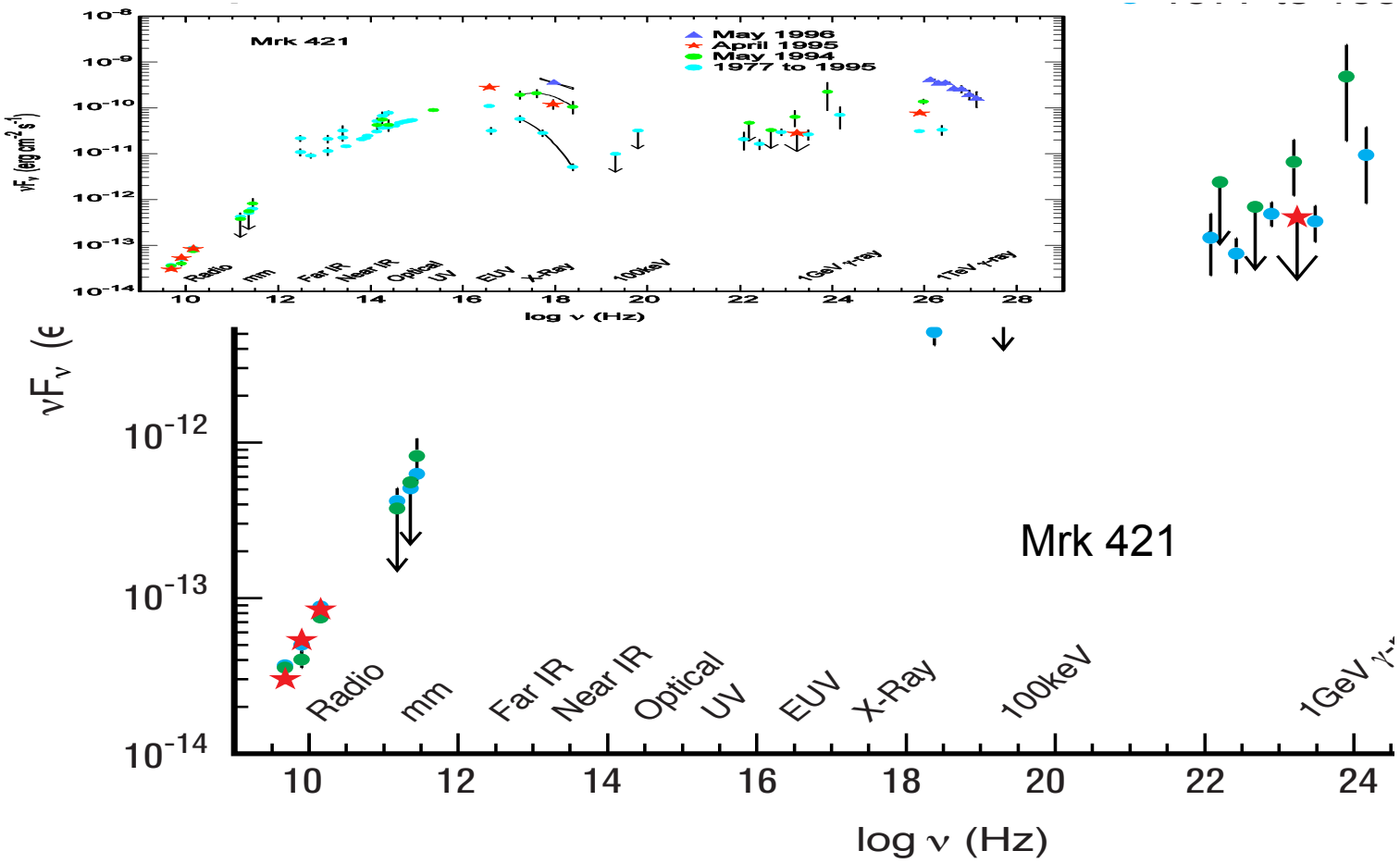


Courtesy: J. Stone



Courtesy: J. McKinney

Reconnection, Particle Acceleration, Relativistic Plasma, Interface Instability



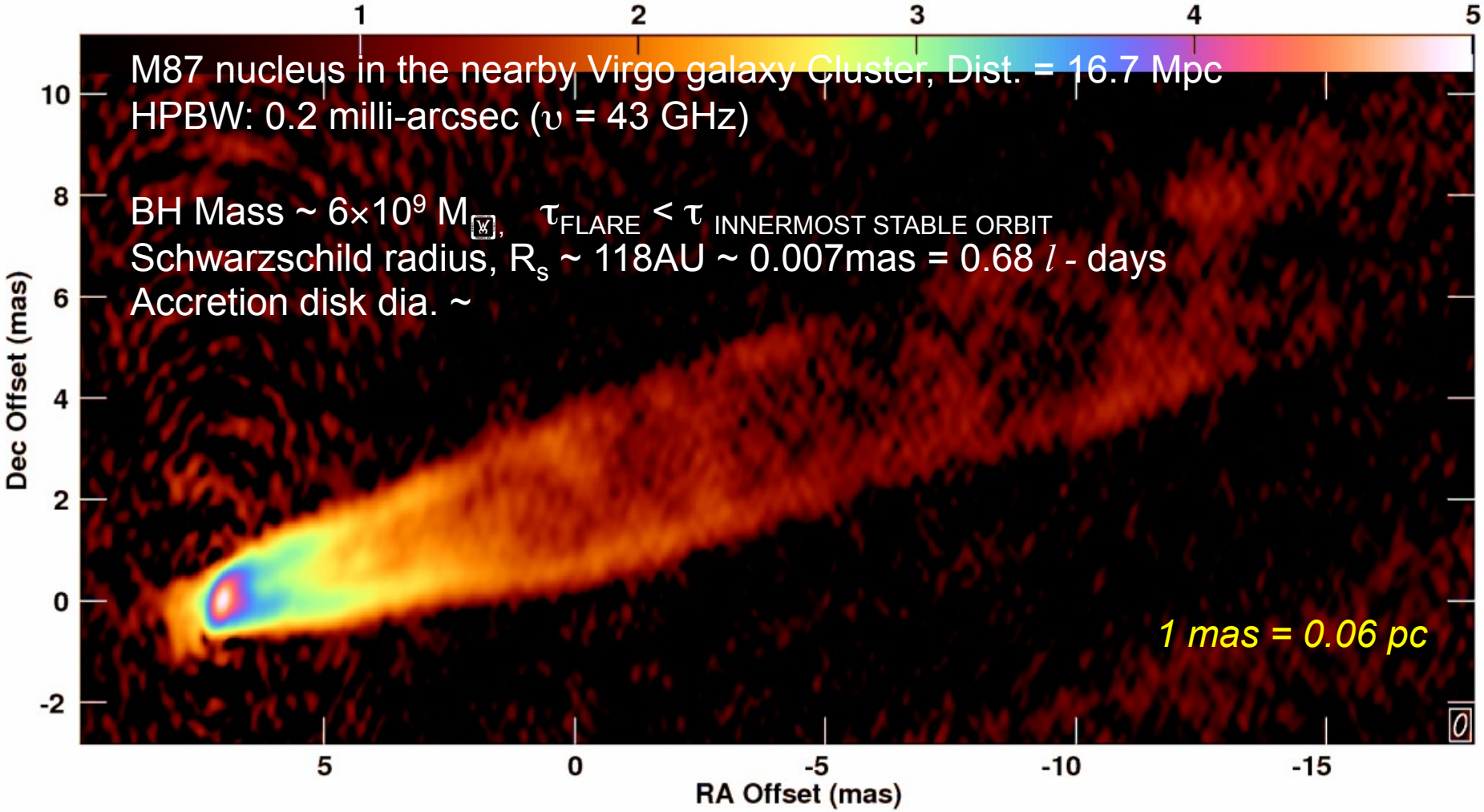
#1: Organizational/Infrastructure (cont'd)

- Gaps/Needs:
  - poor coordinated research efforts and information exchange among astrophysics and plasma communities (e.g., accretion disk physics community);
  - Different funding agencies with different priorities

#1: Organizational/Infrastructure (cont'd)

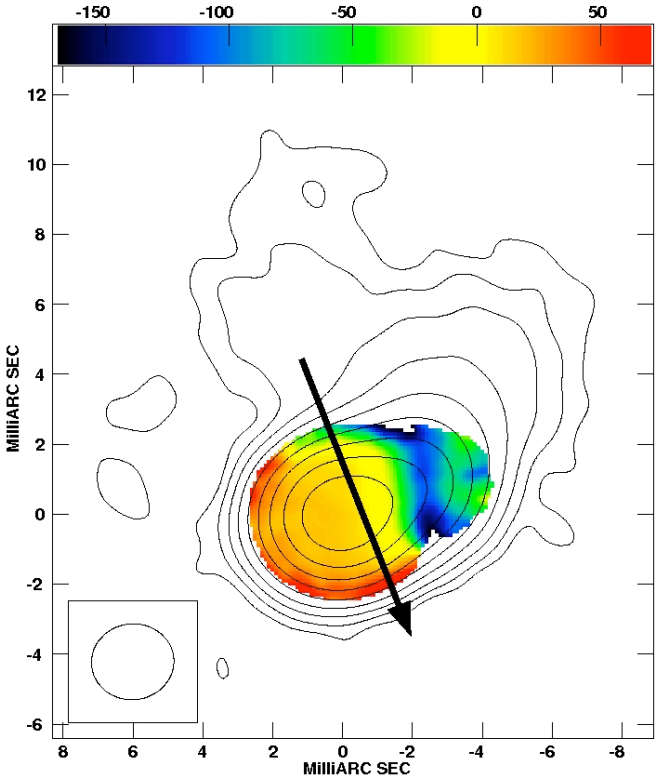
- Opportunities:
  - Form a national consortium with funding for research and regular workshops, bringing together interested astronomers and plasma scientists (e.g., EU/JetSet example)
  - Take advantages of recent breakthroughs in parallel numerical simulations (e.g., 3D GRMHD, PIC) and lab experiments producing jets

#2: Need significant Improvements in observations of AGN Jets



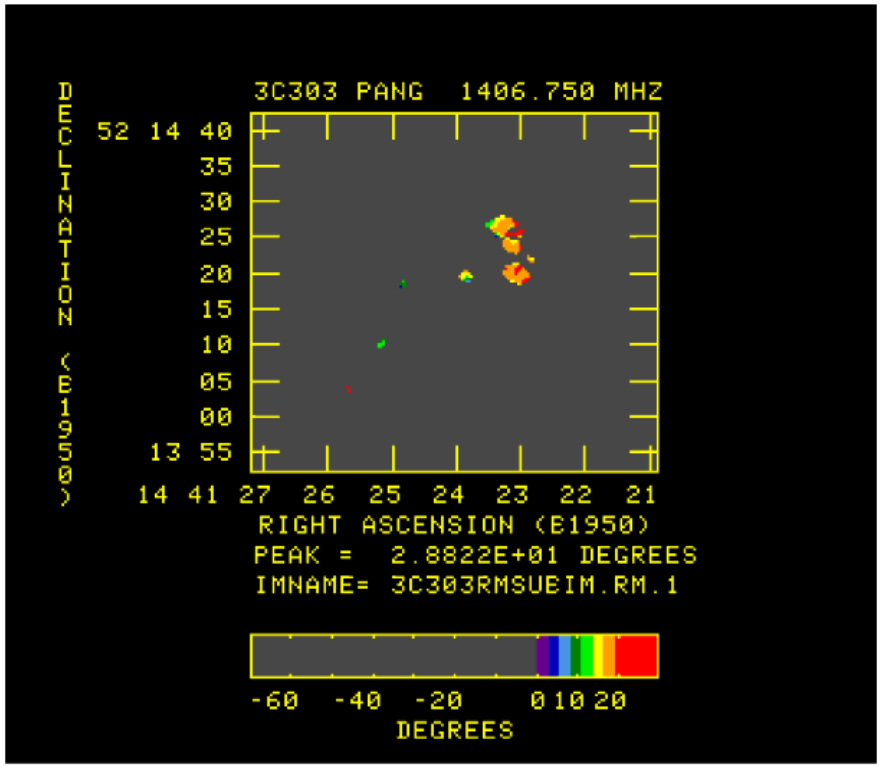
Faraday Rotation Measurement across jets

pc scale



Grey scale flux range= -170.0 70.0 RAD/M/M
Cont peak flux = 4.7375E-01 JY/BEAM
Levs = 2.000E-03 * (-0.500, 0.500, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024)

Kpc scale



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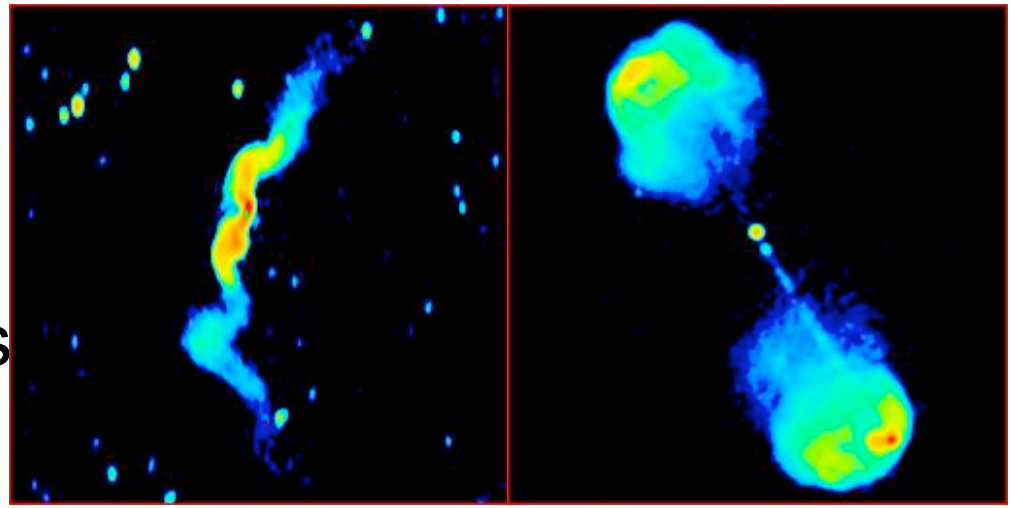
#2: Need significant Improvements in observations of AGN Jets (cont'd)

- Gaps/needs:
  - Angular resolution at least 10x insufficient to resolve jet transversely
  - Polarimetric capability limited
- Opportunities:
  - EVLA-2: in coordination w. NSF and NASA
  - VLBI enhancements

#3: Why are jets stable?

- Existing:
  - Observations
  - Lab experiments
  - Theory/simulations
- Gaps/needs:
  - Better constraints from observations
  - Parameter space in lab experiments
  - Good theory

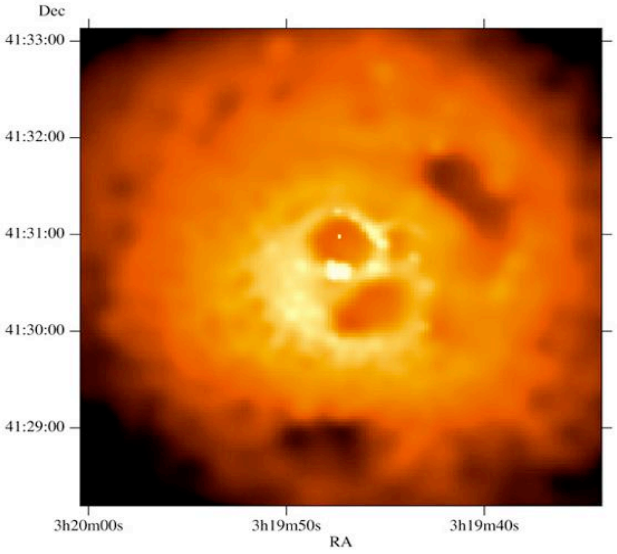


#3: Why are jets stable? (cont'd)

- Opportunities:
  - Explain existing observations of (large-scale) radio jet and lobe morphologies and YSO jets (e.g., modeling radio galaxies in galaxy clusters)
  - Develop comprehensive theory of stability/ instability of current carrying jets (e.g., relativistic kinetic MHD theory, particle acceleration)
  - Funding for 3D simulations of lab experiments

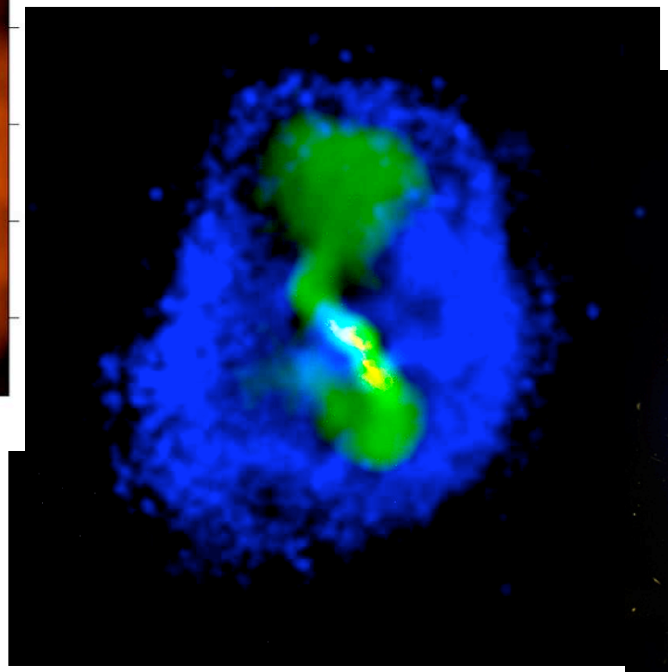
Jets and Lobes interacting with Galaxy Clusters

Perseus (Fabian et al.)



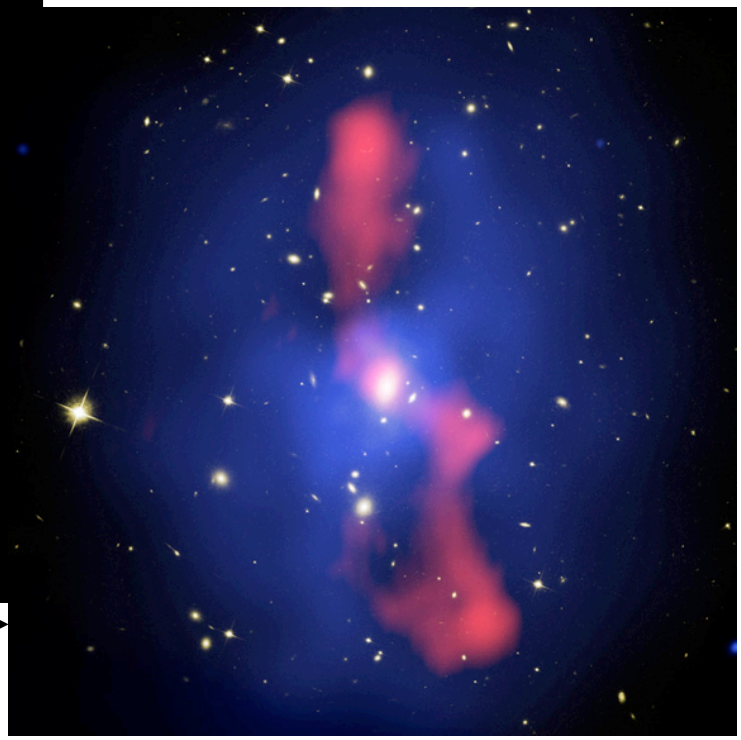
~ 200 Kpc

Hydra A (Wise et al.)



~ 400 Kpc

MS0735.6+7421
(McNamara et al.)



~ Mpc