

# AGN Jets as Probes of Intracluster Media Dynamics and Physics

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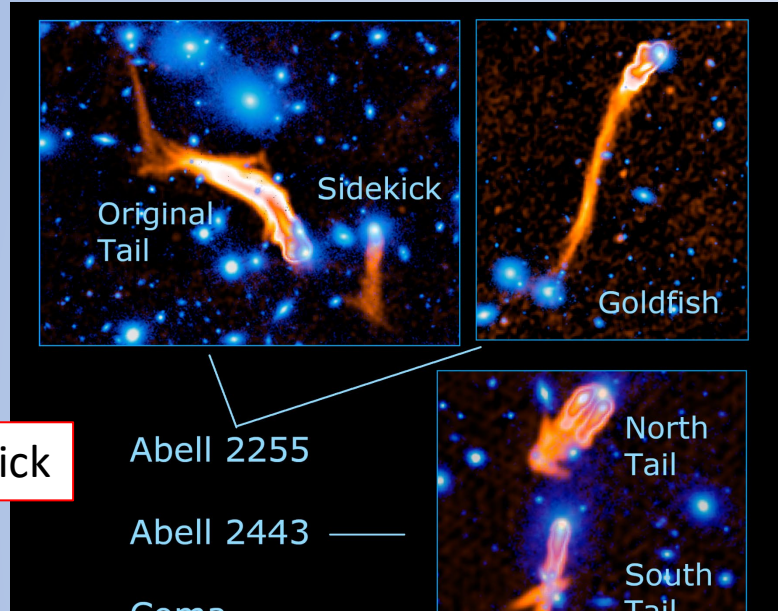
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# Outline:

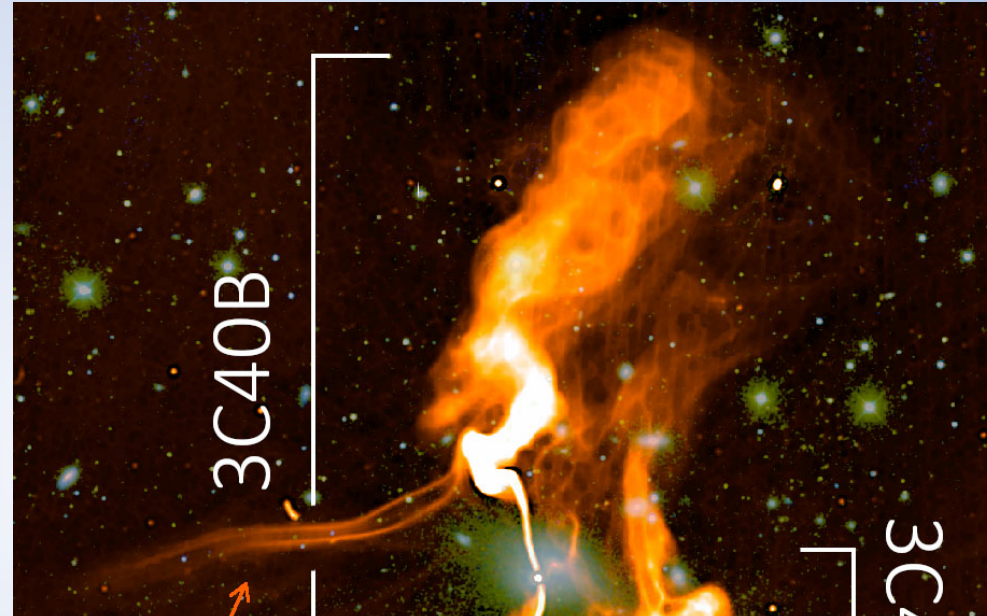
- 1) Brief Introduction to the Observational Scene
- 2) Example Simulated AGN/ICM Interaction Scenarios  
(Idealized)
- 3) Lessons & Next Steps Forward

# Growing Array of Complex Structures Clearly Revealing A Rich Zoo of “ICM Dynamical Structures” in Association with RGs

## Some Examples:

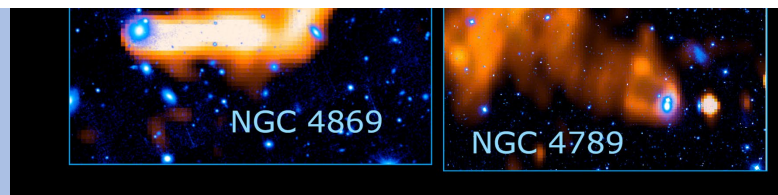


Rudnick

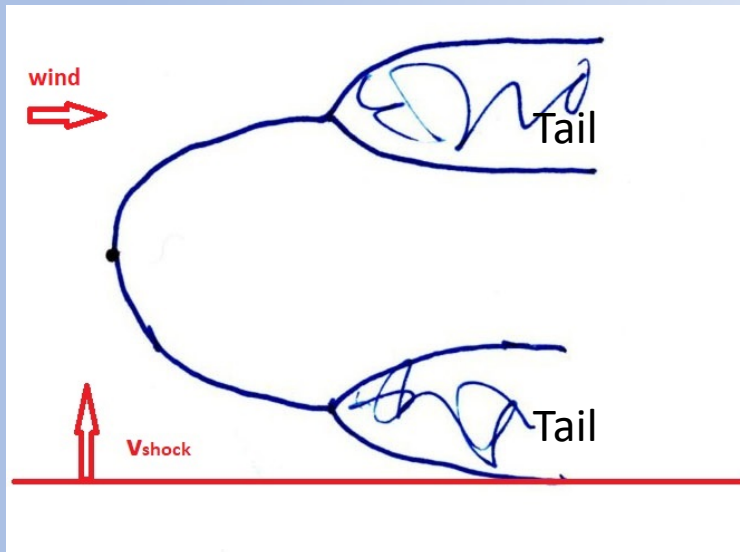


Rudnick + '21

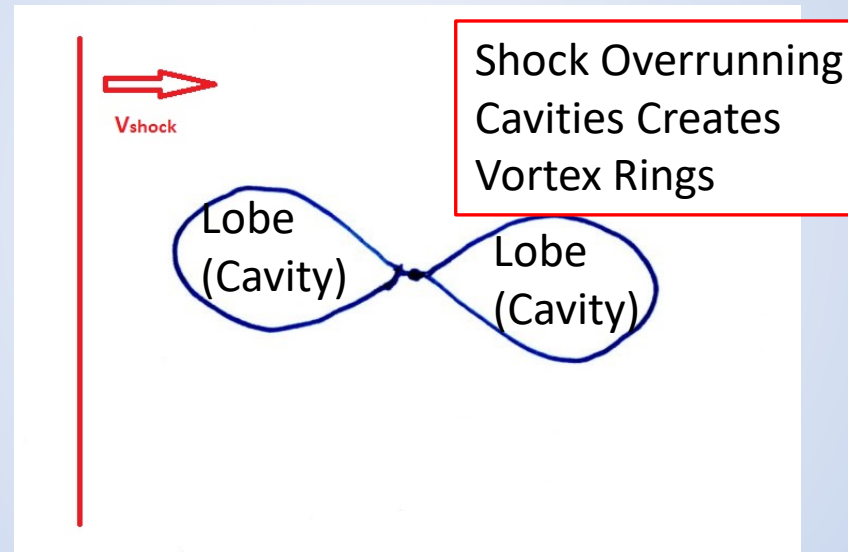
- Provide Opportunities to Identify and Decipher ICM Dynamics & RG Interactions:
  - Improve understanding of interaction physics & ICM physics
  - Improve Cluster Dynamical Models
- => MHD+CR Simulation Studies



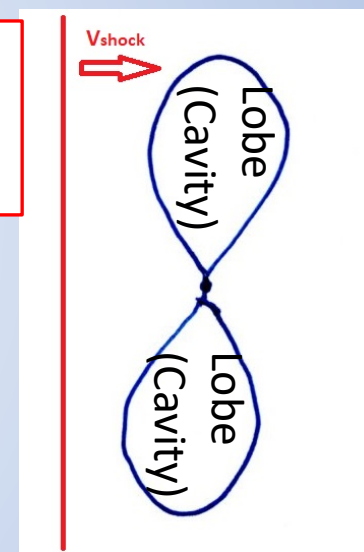
- Some Initial Numerical Experiments: Plane ICM Shock/RG interactions,  $M_s = 2, 3, 4$
- Dual AGN jets: e.g.,  $V_{jet} = 0.08 c$ ,  $\rho_{jet} = .01 \rho_{ICM}$ ,  $P_{jet} = P_{ICM}$ ,  $\beta_{jet} = 75$ ,  $M_{jet} = V_{jet}/c_{sjet} = 3.5$
- CRE: embedded in jets from AGN with  $N(E) \sim E^{-2.3}$ , tracks adiabatic, radiative, DSA
- ICM: typically,  $\rho_{ICM} = 5 \times 10^{-27} \text{ g/cm}^3$ ,  $T_{ICM} = 4.6 \text{ keV}$ , mostly  $B_{ICM} = 0$
- Code: WOMBAT Ideal, Eulerian MHD, 2<sup>nd</sup> order, TVD version



Shock crosses previously evolved NAT  
(Shock Enhances Tail Turbulence)



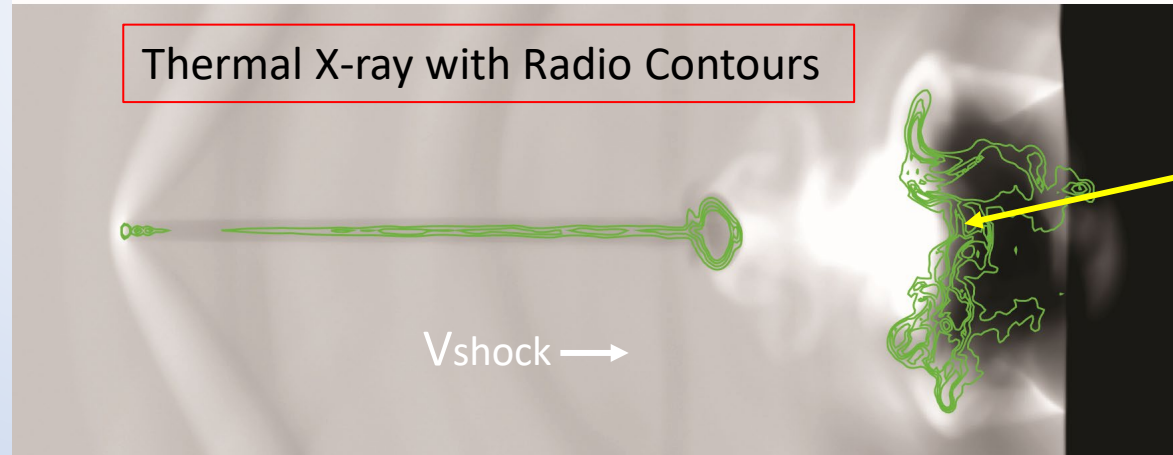
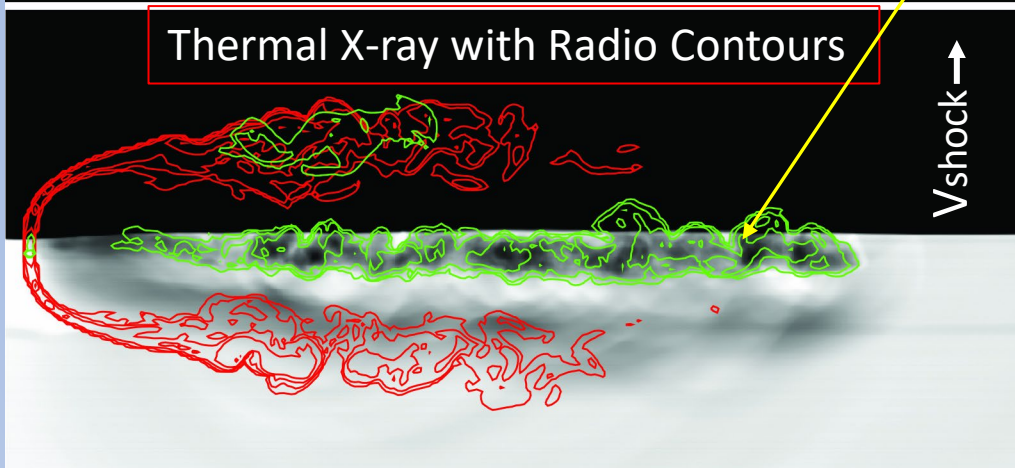
Shock aligned with jets



Shock normal to jets

In initial experiments ICM mostly B-field off.  
But, also MHD Turbulence, Isolated ICM Magnetic Filament

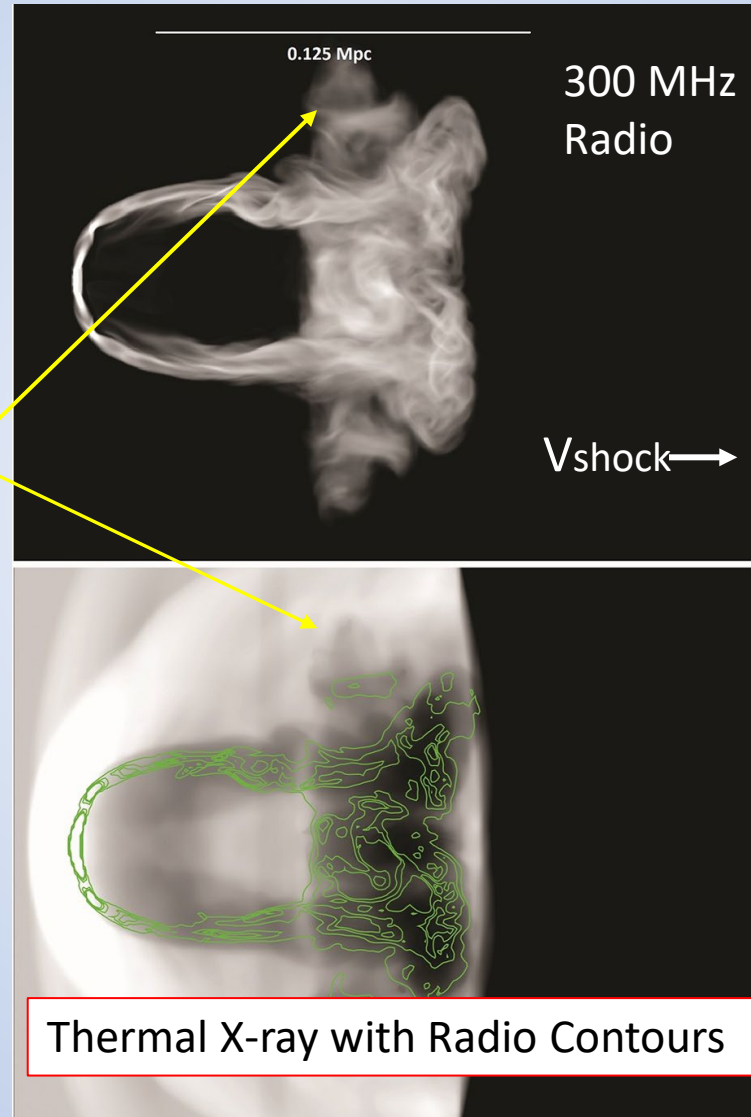
# Representative Synthetic Emission Snapshot Images of Shocked RGs:



O'Neill + '19, '20  
Nolting + '20

# Representative Synthetic Emission Snapshot Images of Shocked RGs:

Vortex Loop (From RG Lobes)



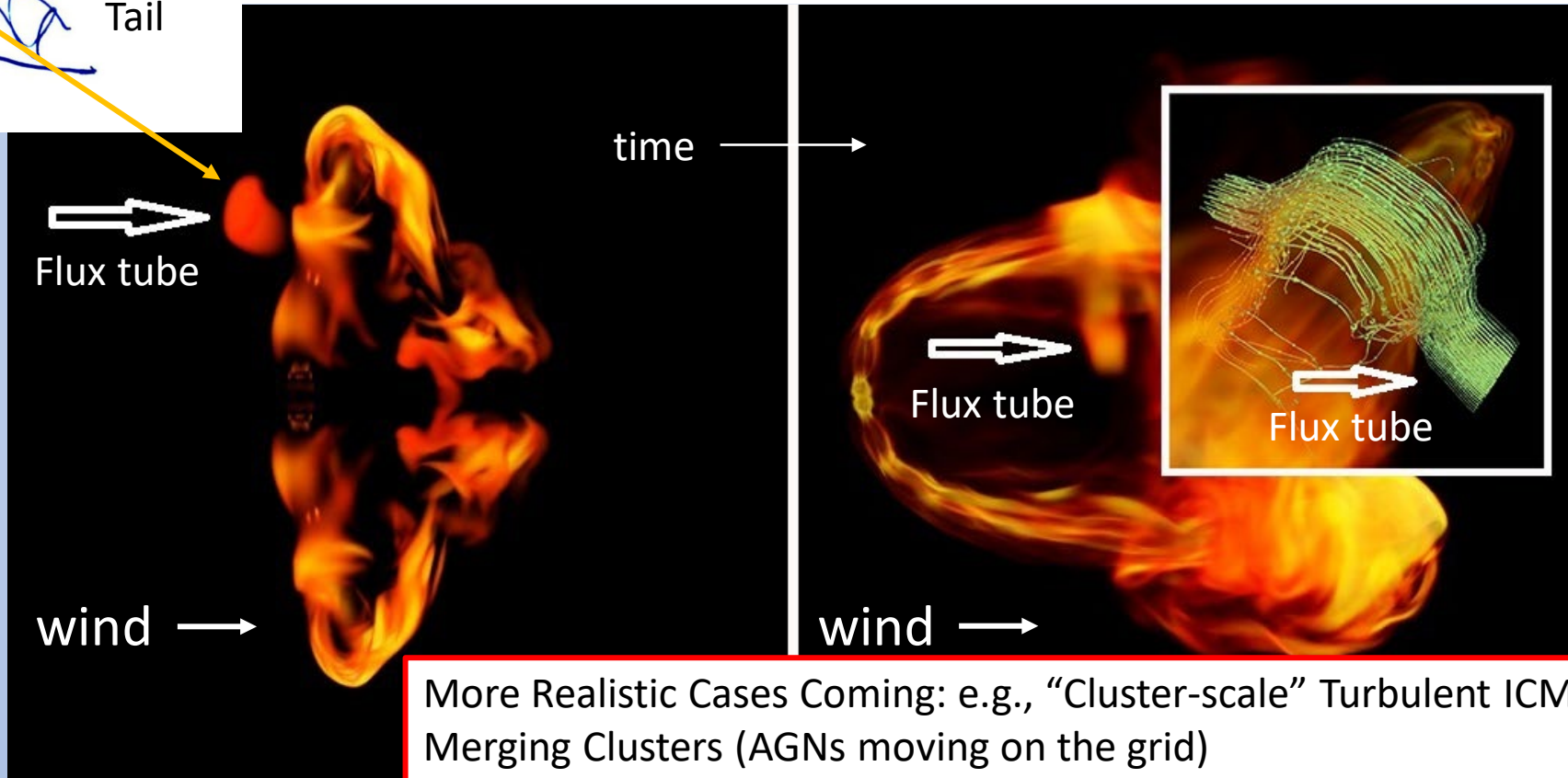
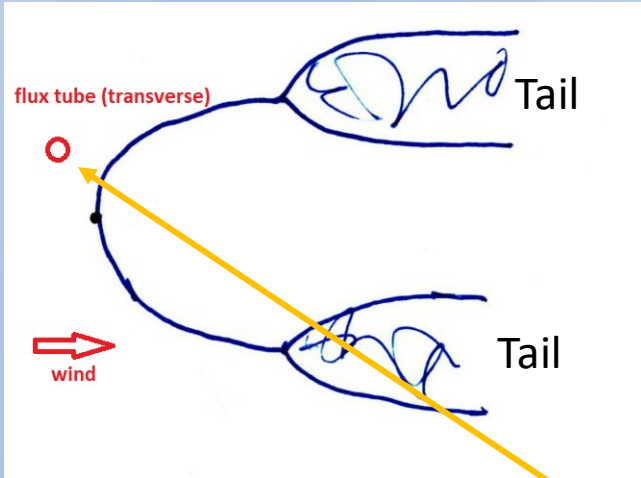
M4 Shock Normal to Jets

Nolting + '20

## (Extensions In Progress) Other ICM Structures: E.g., ICM Magnetic Filament Draped Over NAT

Questions Include, Do the ICM Filament and NAT Fields Connect?  
(Not Much in Our Multiple Experiments, So Far)

Also in progress, e.g., jets crossing idealized “sloshing fronts”



More Realistic Cases Coming: e.g., “Cluster-scale” Turbulent ICM,  
Merging Clusters (AGNs moving on the grid)

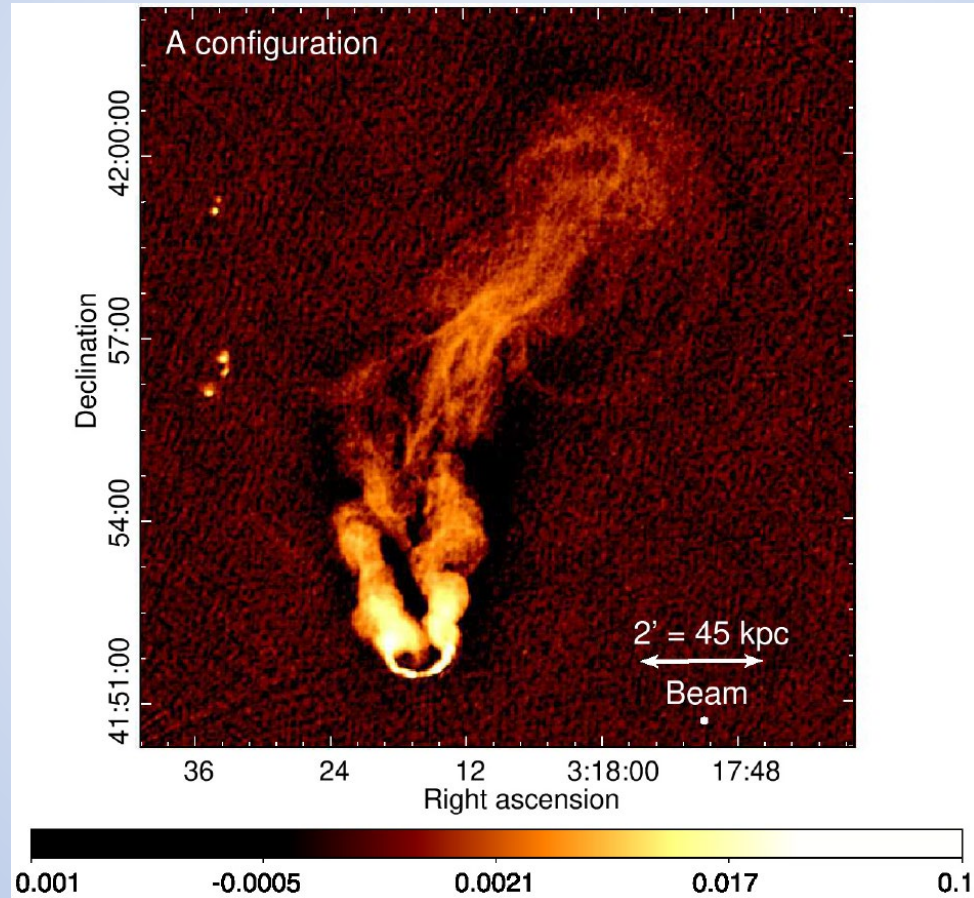
## Summary:

- Radio Galaxy Jet/ICM Interactions Can Be Revealing Tools:
- Identify & Characterize ICM dynamical structures
- Verify associated physics of jets, ICMs & interactions
- Map out cluster dynamical histories
- Clarify ICM “microscale” physical properties (e.g., viscosity)



**Thanks!**

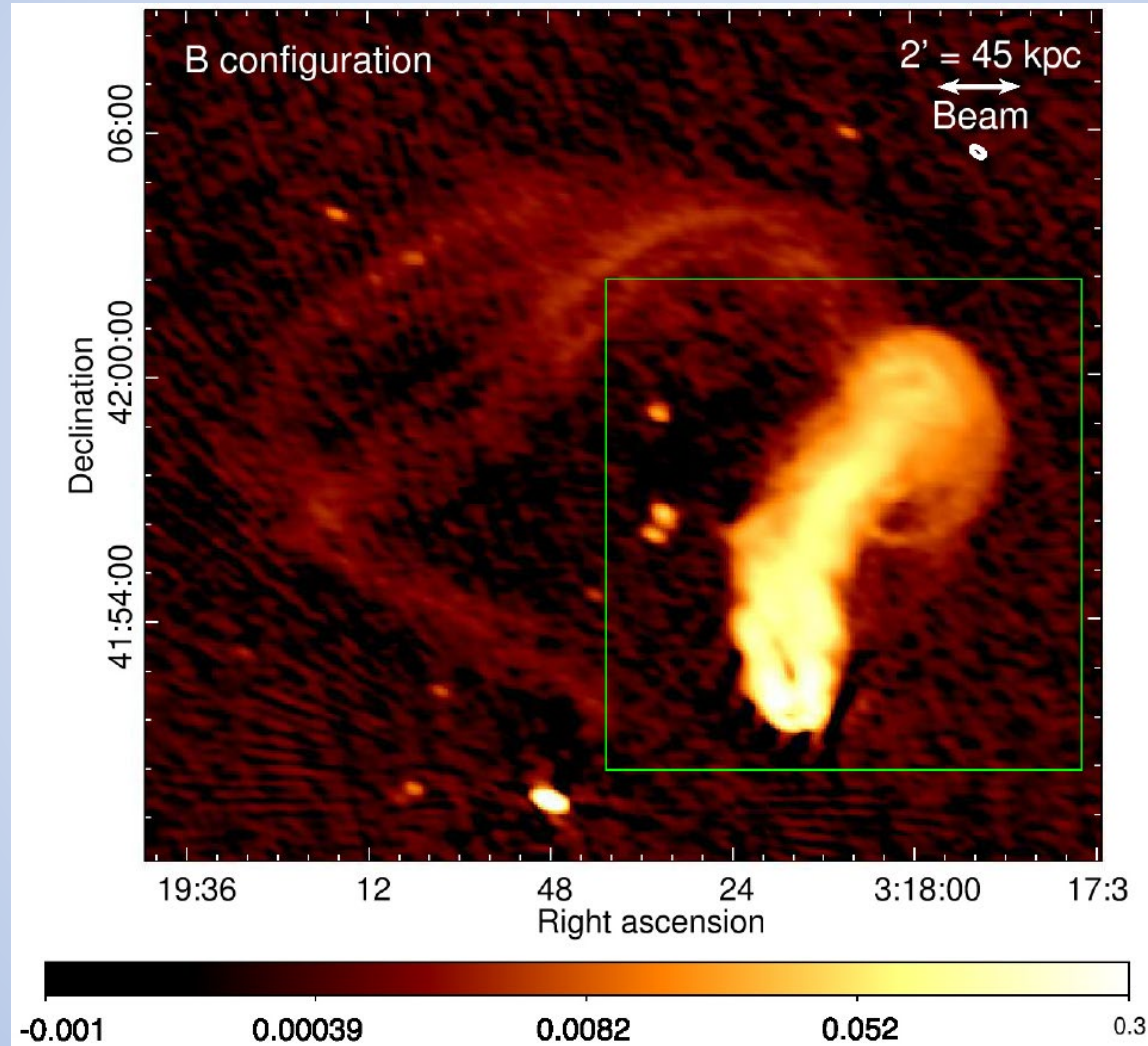
RG Deformations via ICM Interactions  
Not New; e.g., “tails” such as NGC 1265  
in Perseus => relative RG/ICM motion



VLA 230-470 MHz

Gendron-Marsolais + '20

# Often More Clearly Going On!



More Extended View of NGC 1265:  
Evidence for Shock Passage?  
(Pfrommer & Jones 2011)

Gendron-Marsolais + '20