Hydrodynamic Models of AGN Feedback in Cooling Core Clusters 209th Meeting of the AAS

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### Outline

# Cooling Clusters and AGN

- Background
  - Cooling Flows
  - Galaxy Formation
  - AGN
- ▶ 3D Hydro Models
- Precessing Jets
- Conduction and Perseus

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#### Background

- The Intracluster Medium (ICM) in rich relaxed clusters is cooling.
- Seen primarily in X-ray (Chandra, XMM-Newton, etc.)
- Central cooling times shorter than the age of the cluster.
- Strong observational limits on the amount of cool gas.
- ▶ Nothing below  $\sim \frac{1}{3}T_{virial}$  (from XMM-Newton observations).

#### ▶ This is the classic Cooling Flow Problem.

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## Background – Galaxy Formation

- Why are the most massive galaxies not still forming?
- Gravity alone would want them to mirror the dark matter halos of the cluster.
- Same thing as the Cooling Flow Problem.
- A formation process we can study in the local universe.

# High End Cutoff



K-Band galaxy luminosity function from Benson et al. 2003 209th Meeting of the AAS - 01/08/2007 - John C. Vernaleo - Page 6

### Solutions?

- Mergers
- ► AGN
- Cosmic Rays
- Cluster Gas Physics

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- Powerful, with right energy to balance cooling (but see Bîrzan et al. 04 for possible problems with this idea).
- Often in cluster centers, just where heating is needed.
- Feedback should allow this to work on clusters of different scales.

#### Evidence for Interaction



#### Perseus A, Fabian et al. 2005

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## Public Hydro Code



- Modified and updated version of FORTRAN 77 NCSA release.
- ZEUS-MP v1.5.11
- http://www.astro.umd.edu/~vernaleo/zeusmp.html

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## Single Jet Burst – Density

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#### Feedback Scenarios

See Vernaleo & Reynolds 06

- Single Jet
- Immediate Feedback
- Delayed Feedback
- Cluster Rotation
- Cutoff Feedback

Image: 1

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# Delayed Feedback – Mass accretion on inner boundary



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# Channels and Deposition



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## ▶ Basically get the same result for all cases.

- Jets fail to heat cluster center.
- Channels seem to be the cause.
- ► Hard to couple (powerful) jets to ICM gas.

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Variable jet axis or background motions?
Heinz et al. 06 did work similar to this with background motions.

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#### Precessing Jet – Entropy

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# Precessing Jet – Mass accretion on inner boundary



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## What about ICM Physics?

Variety of scales make it unlikely to work alone.

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- Viscosity
- Thermal Conduction
- Magnetic Fields

## Other models

Currently working on:

Conduction at some fraction of Spitzer value.

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- Bring heat from outer regions in.
- Dissipate wave energy.
- Models scaled to match Perseus.