

# Future High-Resolution Spectroscopy & Cluster Astrophysics Mark Bautz MIT Kavli Institute for Astrophysics and Space Research

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Naomi Ota (Nara Women's U.), Kosuke Sato (Tokyo Science U.), Madoka Kawaharada & Hiroki Akamatsu (Tokyo Metropolitan U.) & Tetsu Kitayama (Tohu U.)



# Overview

- New spectroscopic tools in the near and far future: Astro-H and Athena
- Questions they may address
- Example applications







# New Tools Near Term: Astro-H

- Key instrument: Soft X-ray Spectrometer
  - \* First Cryogenic X-ray Microcalorimeter
  - \* 5 eV spectral resolution, 0.5-10 keV
  - \*  $A_{eff} = 220 \text{ cm}^2, \theta_{HPD} = 1.1',$
  - \* 36 pixels, FOV 3'x3'
- Also:
  - \* Hard X-ray Telescope (per GM talk)
  - \* Wide-field CCD imager
  - \* Soft Gamma Detector
- On schedule for 2014 launch
- JAXA-led + NASA, ESA, Stanford...



14 September 2011



#### Mitsuda, Kelley+, 2010

#### Astro-H Soft X-ray Spectrometer, SXS







<sup>14</sup> September 2011

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# Far-term New Tools: Athena

- Candidate for next ESA large mission
- Just a study now, but:
  - \*  $A_{eff} = 10^4 \text{ cm}^2 @1.25 \text{ keV}, \theta_{HPD} = 10''$
  - \* Advanced (TES) microcalorimeter:
    - 3 eV FWHM, 32x32 pixels, 2.4' x 2.4' FOV
    - "X-ray IFU Spectrometer"
  - \* Also includes silicon widefield imager (24' x 24')
- Launch projected 2022
- Selection decision expected early 2012

# Noti Some Questions Raised by Chandra & XMM

- Do we understand mergers & cold-fronts?
- Do we understand the role of "turbulence":
  - \* In accelerating particles?
  - \* In supporting the cluster plasma against gravity?
- What are thermal conditions in the ICM?
- How did the intracluster metals get there?

# **in** Abell 3667



- Classic merger
- Archetype of cold front
- Brightest radio relic
- Shocks

# Abell 3667 Geometry



- Line of sight 1400 km s<sup>-1</sup>,  $M\sim1$ 
  - Flow around low-S core (eventually) develops K-H instabilities
  - Magnetic draping suppresses conduction across 'front'



Heinz+ 2003: Entropy (color) and velocity 14 September 2011 Stockholm

### Mi Merger Kinematics with Astro-H in Abell 3667



#### With Astro-H:

- 3' × 3' FOV;
- ~1.2' resolution ~70 kpc
  (z=0.05)
- Use multiple pointings to probe plasma flows and instabilities around front and shocks



# Abell 3667 Spectroscopy

Stockholm



Other questions:

- Ionization equilibrium?: H/He Fe line ratio to 15%
- Suprathermal electrons in shocks: satellite lines (?)
- Non-thermal X-rays

### Non-thermal support from ICM bulk motions & turbulence Lau, Kravtsov & Nagai '09



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### Nyi Probing Feedback with Athena (Heinz et al. 2010)





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### Athena & Perseus





### Athena & Perseus



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# Summary (1/2)

### Astro-H, within 3 years, will begin to:

- \* Nail down merger kinematics to < 100 km s<sup>-1</sup>
- \* Map ICM kinematics for clusters @ z ~<0.05, testing predictions of long-lived motions
- \* (Perhaps) constrain velocity power spectra of the ICM (Zhuraleva & Churazov)
- \* Test association of radio relics with ICM motion
- \* Probe the thermal equilibration of the ICM
- \* Measure abundance patterns w/ new precision



# Summary (2/2)

#### Athena, within ~10 years, could begin to:

- \* Constrain feedback power via bubble kinematics
- \* Probe instabilities in mergers & cold fronts
- \* Provide details of line profiles in bright clusters
- \* (Probably) measure ion temperatures directly
- \* Map non-thermal support in a cosmologically significant set of clusters, bringing new accuracy to mass estimates
- \* Obtain temperatures and redshifts for clusters to very high z (~ 2?)



# Thank you

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