OBSERVATIONAL EXTRAGALACTIC ASTRONOMY & COSMOLOGY

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University of Helsinki – PAP-PAPU Summer Meeting

CAREER PATH

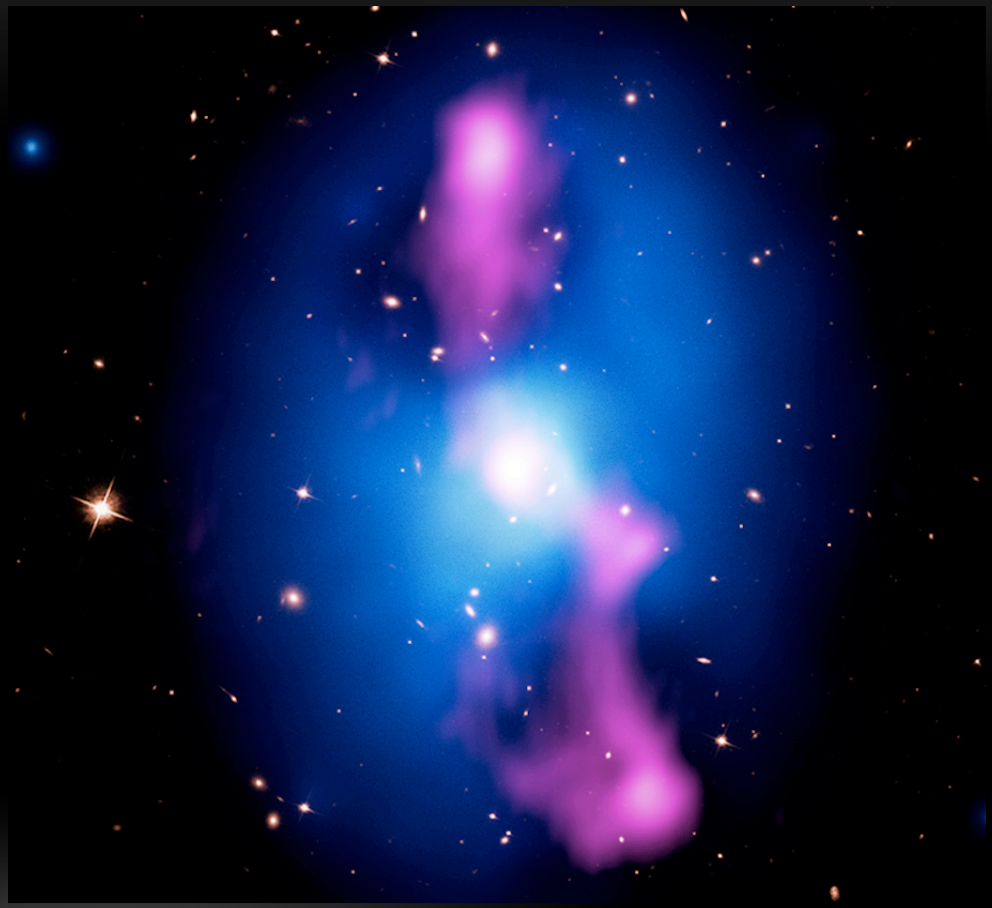
- Michigan State University (US)
  - 2005 Graduated B.S. in Astronomy & Astrophysics
- Ohio University -> University of Waterloo (CA)
  - Studied physics of galaxy clusters
  - 2012 Graduated Ph.D. in Physics
- Left Astronomy 2012 - 2014
- University of Helsinki (FI)
  - First Post-doc position

BIG QUESTIONS IN COSMOLOGY

- What is dark energy?
  - Only recently we have come to understand that the universe is actually accelerating
  - Either dark energy, ~70 percent of the energy content of the universe, is acting as a gravitationally repulsive force
  - Or, the theory of general relativity on large scales needs to be modified
- How has the Universe evolved over time?
  - The rate at which structure grows tells us about the equation of state of dark energy

Galaxy Clusters

- Largest gravitationally bound objects in the Universe
- Composition
  - ~90% dark matter (What we don't see)
  - ~9% hot gas (X-ray emitting)
  - ~1% galaxies (What we see)
- The mass distribution and redshift distribution of galaxy clusters depends on the geometry and the growth rate of the Universe
- Compliment to constrain cosmological models

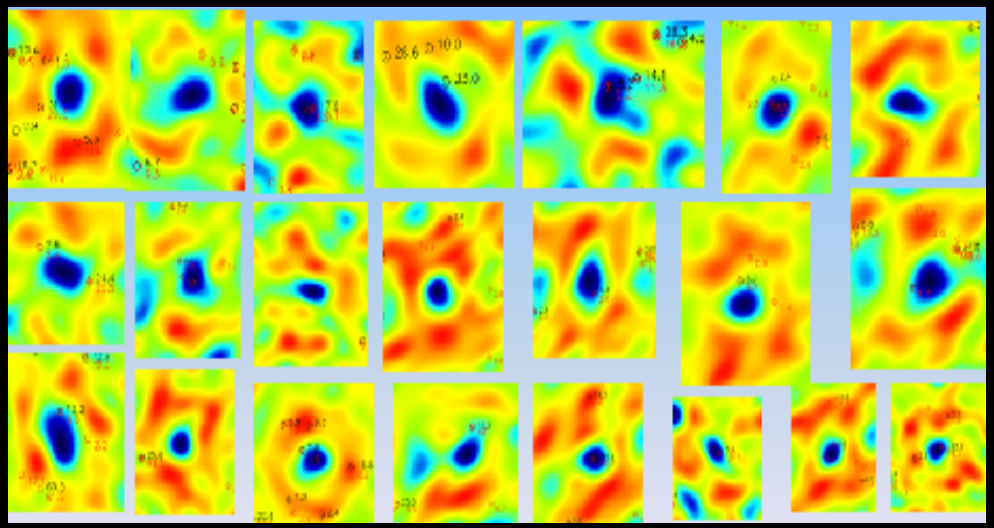


Searching for Clusters

- Optical
  - Detect visual groupings of galaxies in projection
  - Identify members by red-sequence or with spectroscopy
  - Surveys: Sloan, Euclid (2020)
- X-ray
  - Detect extended X-ray emission
  - Surveys: RASS, eROSITA (2017)

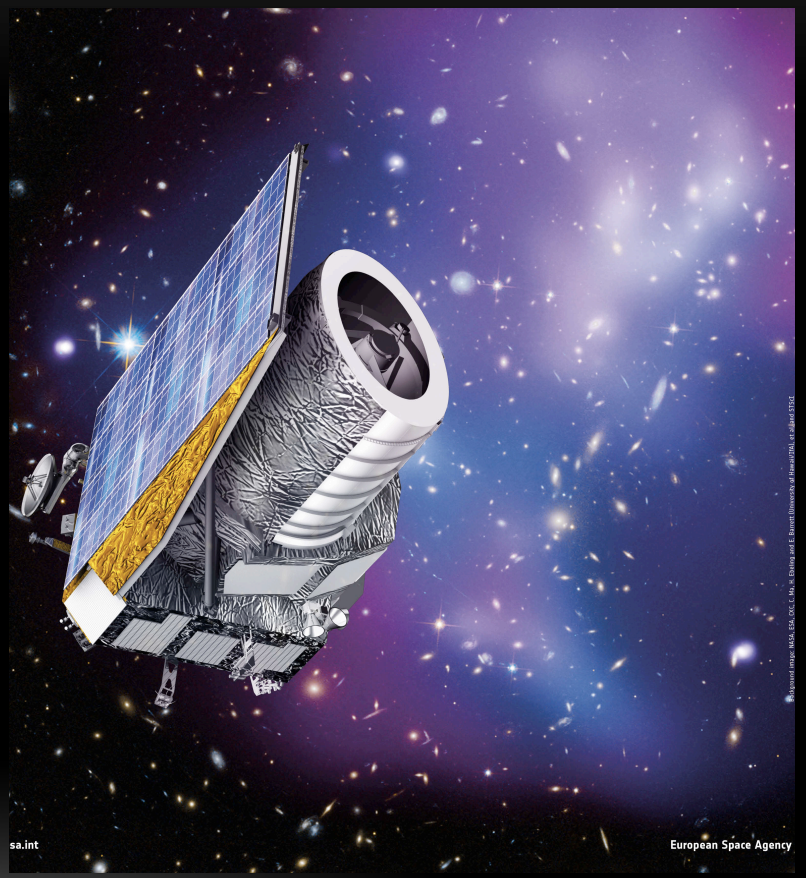
Searching for Clusters

- Thermal SZ
  - Inverse Compton scattering of CMB photons as they pass through Hot ICM
  - Surveys: SPT-SZ, Planck



EUCLID

- Infrared imaging + spectroscopy and visual imaging 15000 square degrees of the sky starting in 2020.
- Main science goal: understanding the accelerating expansion of the universe
  - Weak lensing ~ 1 billion sources
  - Spectroscopic redshifts ~ 30 million sources
- Finland's role:
  - Science data centre
    - 10 billion sources observed
    - ~30 Petabytes of data
  - Data quality common tools
  - Simulated Euclid data
    - Testing processing algorithms and communication between SDCs



THE ROLE OF SMALL TELESCOPES

- Spectroscopic surveys and mass scaling relations are needed for the primary science
- Surveys we are involved with, SPIDERS and 4MOST (2020), are/will follow up large scale imaging surveys to obtain spectra for millions of galaxies
- With thousands of discovered galaxy clusters, there is no way to directly measure their mass
- Targeted follow up with the Nordic Optical Telescope can obtain 20+ redshifts per cluster quickly, providing much need dynamical information
- With velocity dispersion, can calibrate a scaling relation with observable from SZ or X-ray data
- Can help interpret WL mass measurements by identifying double peaks in galaxy velocity histogram