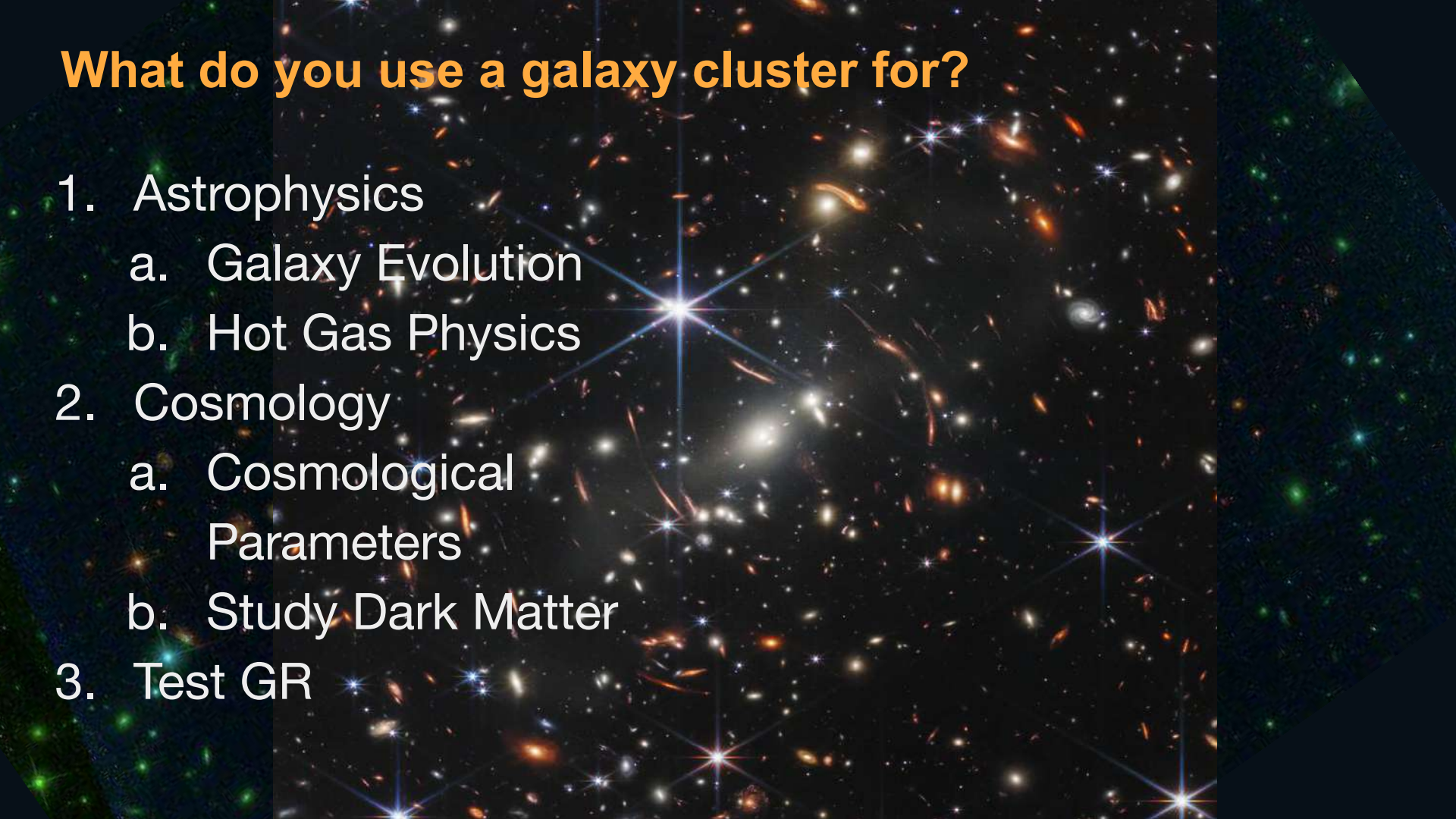
What is a galaxy cluster?

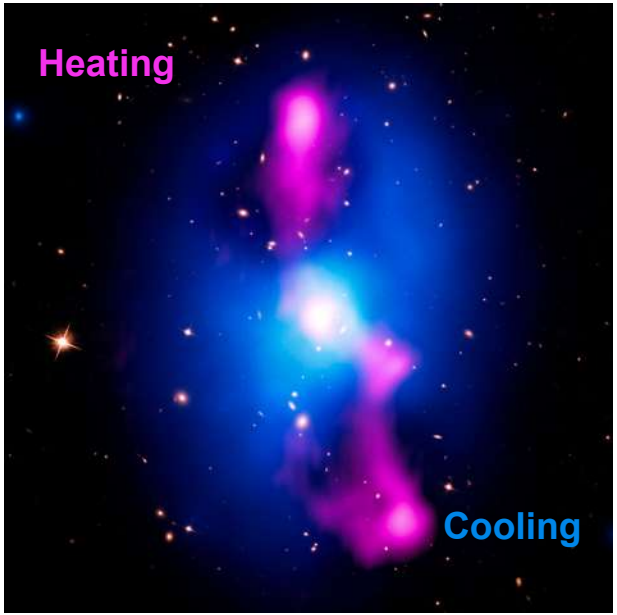
What do you use a galaxy cluster for?

1. Astrophysics
    a. Galaxy Evolution
    b. Hot Gas Physics
2. Cosmology
    a. Cosmological Parameters
    b. Study Dark Matter
3. Test GR



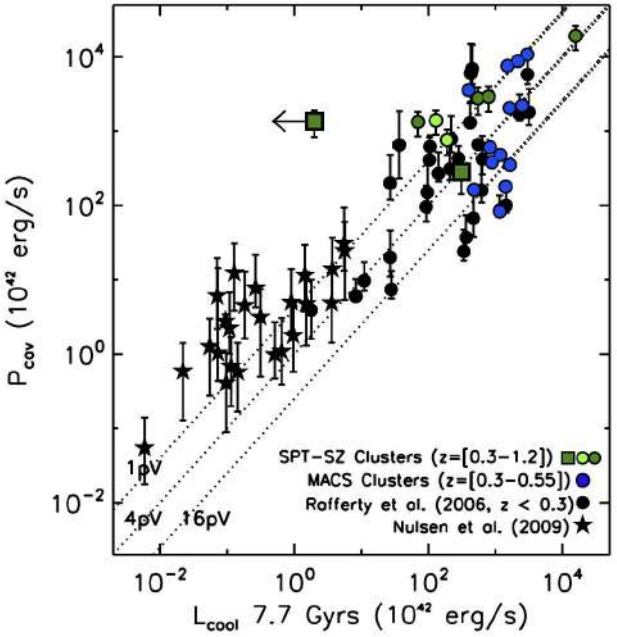
1. Feedback Physics in Clusters

AGN Heating and Cooling



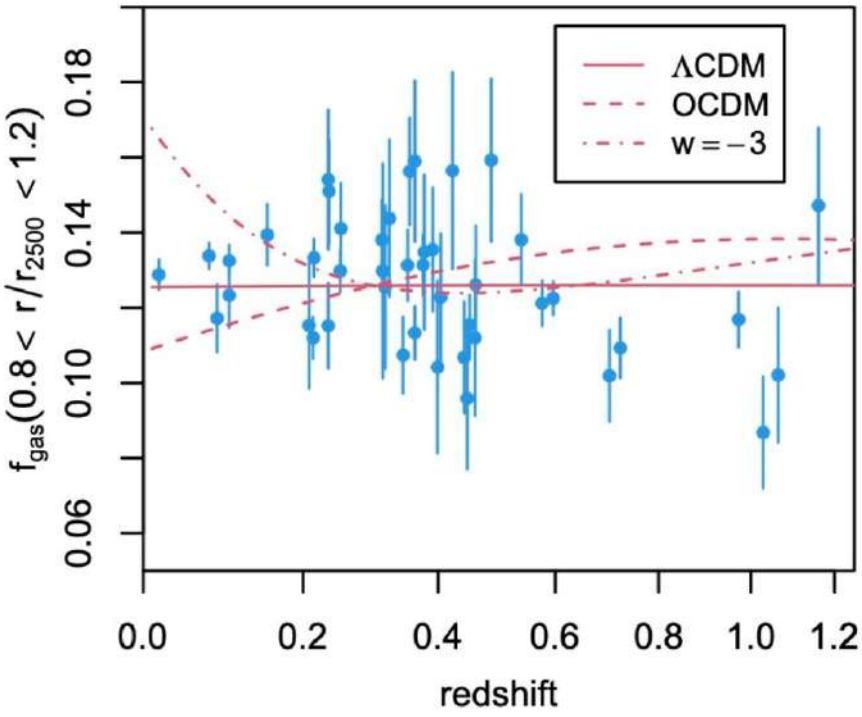
MS 0735.6+7421 (z=0.216)

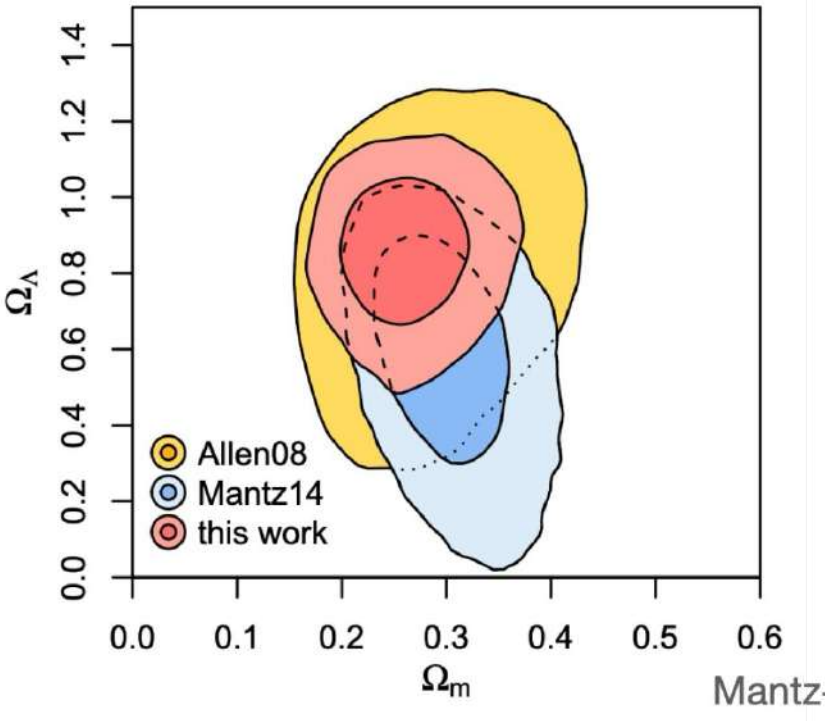
Evolution of Clusters from Feedback Study



Hlavacek-Larrondo+15

Current Constraint on Cosmology





Mantz+2022

What do you use a galaxy cluster for?

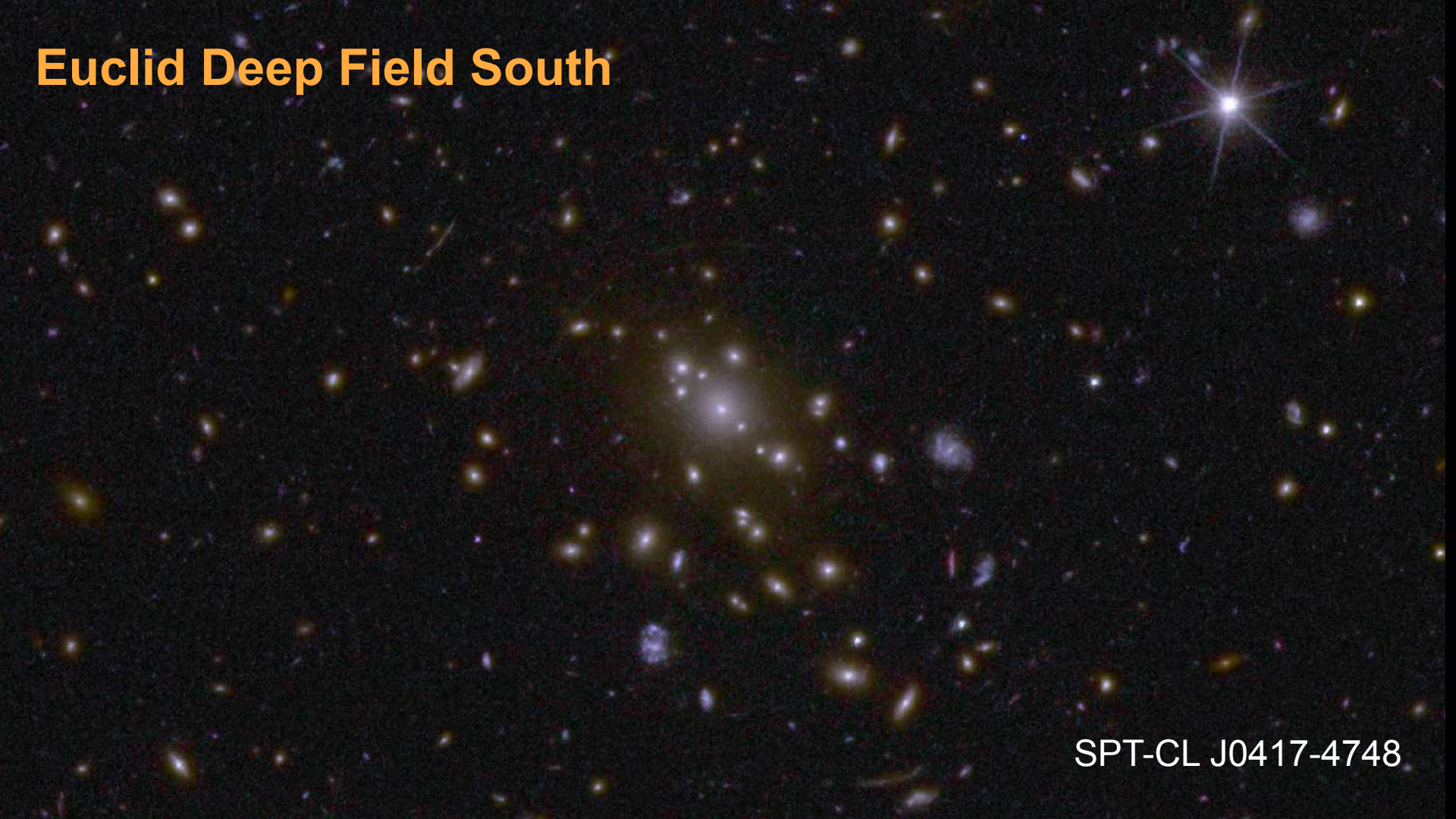
1. Astrophysics
    a. Galaxy Evolution
    b. **Hot Gas Physics**
2. Cosmology
    a. Cosmological Parameters
    b. Study Dark Matter
3. Test GR

SPT-CL J0417-4748: A Case of a Relaxed Galaxy Cluster Lacking Central Star Formation

Taweewat Somboonpanyakul
Chulalongkorn University, Bangkok, Thailand
6·12·2025

With S. Allen, A. Mantz

ภาควิชาฟิสิกส์ จุฬาลงกรณ์มหาวิทยาลัย
Department of Physics, Chulalongkorn University


Euclid Deep Field South
SPT-CL J0417-4748

Our conventional wisdom of galaxy clusters

- All member galaxies are **red-and-dead** ellipticals
- BCGs are especially massive, red, and quiescent
- Clusters host extremely hot intracluster medium (ICM)
    - Seen as extended X-ray emission

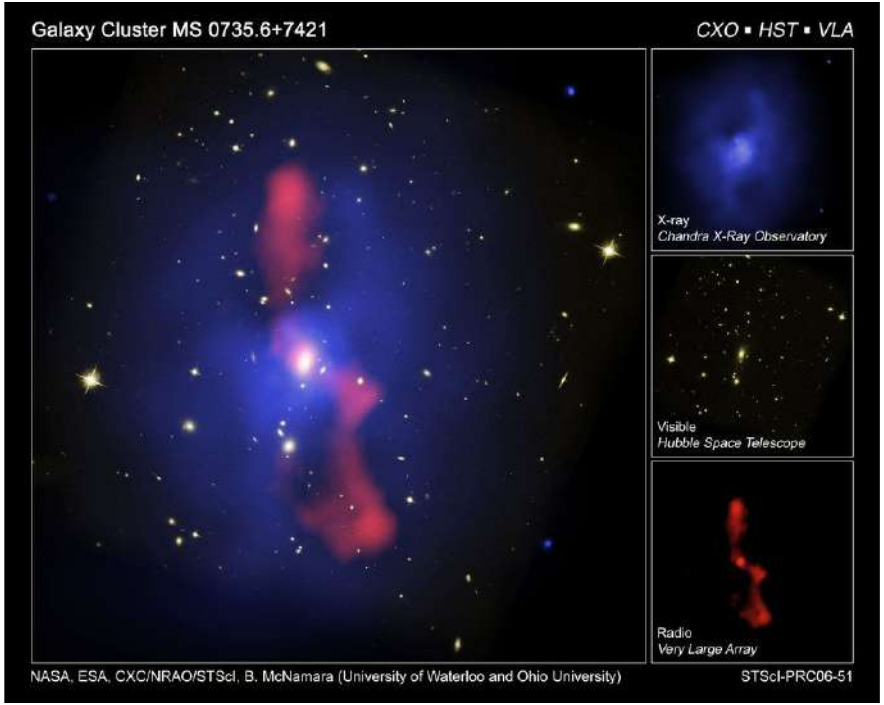
Images of Abell 1835 (z = 0.25) at X-ray, optical and mm wavelengths. All three images are centered on the X-ray peak position and have the same spatial scale, 5.2 arcmin or ~ 1.2 Mpc on a side

(Allen+11)

Our conventional wisdom of galaxy clusters

- Matches our current understanding of cluster formation

- BCG sits at the center of the gravitational potential well
  - Grows via mergers with member galaxies
  - Experiences AGN feedback
  - Gas depleted → Star formation quenched



BCGs of > 100 clusters

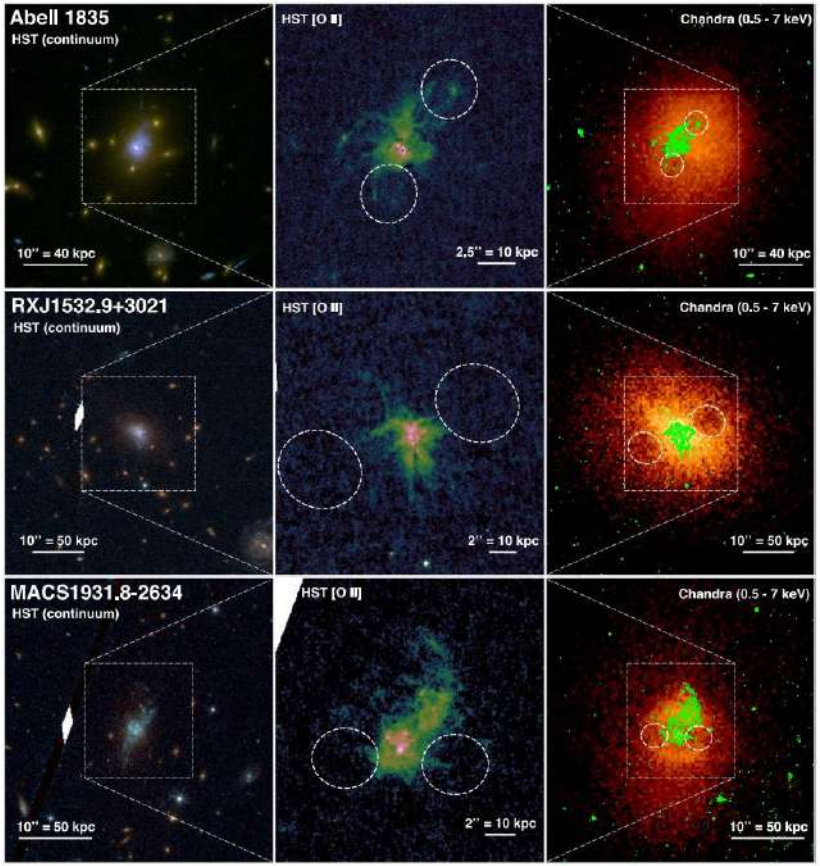
(Credit McDonald)

BUT!

BUT! Clusters with unconventional properties

Detailed observations reveal that our simple models fail to capture the diversity of galaxy clusters. Some striking examples include:

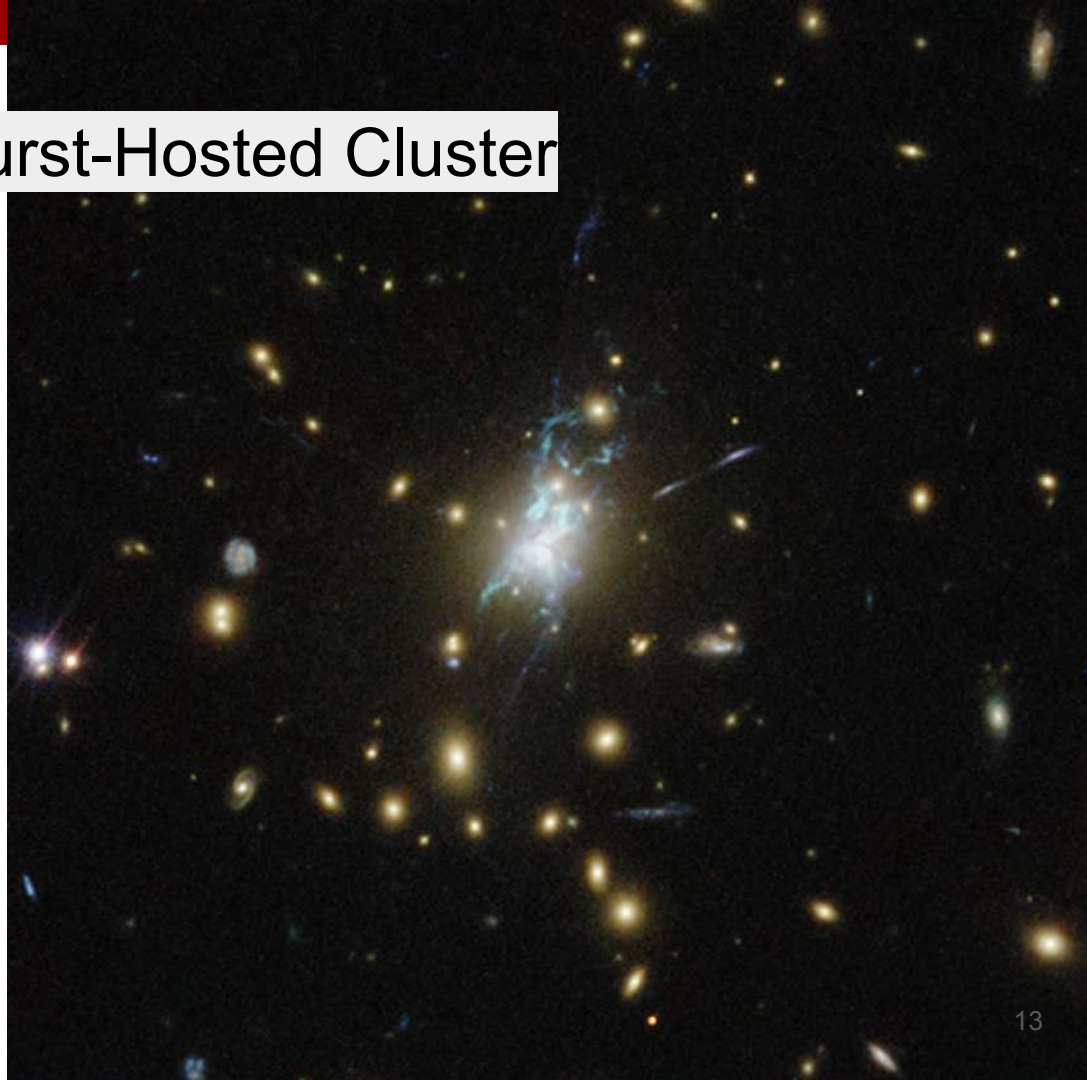
- Phoenix clusters
- H1821+643
- IRAS 09104+4109
- Abell 1835
- RX J1532.9+3021
- MACS 1931.8-2634
- RBS 797



(Calzadilla+22)

Phoenix Cluster: A Starburst-Hosted Cluster

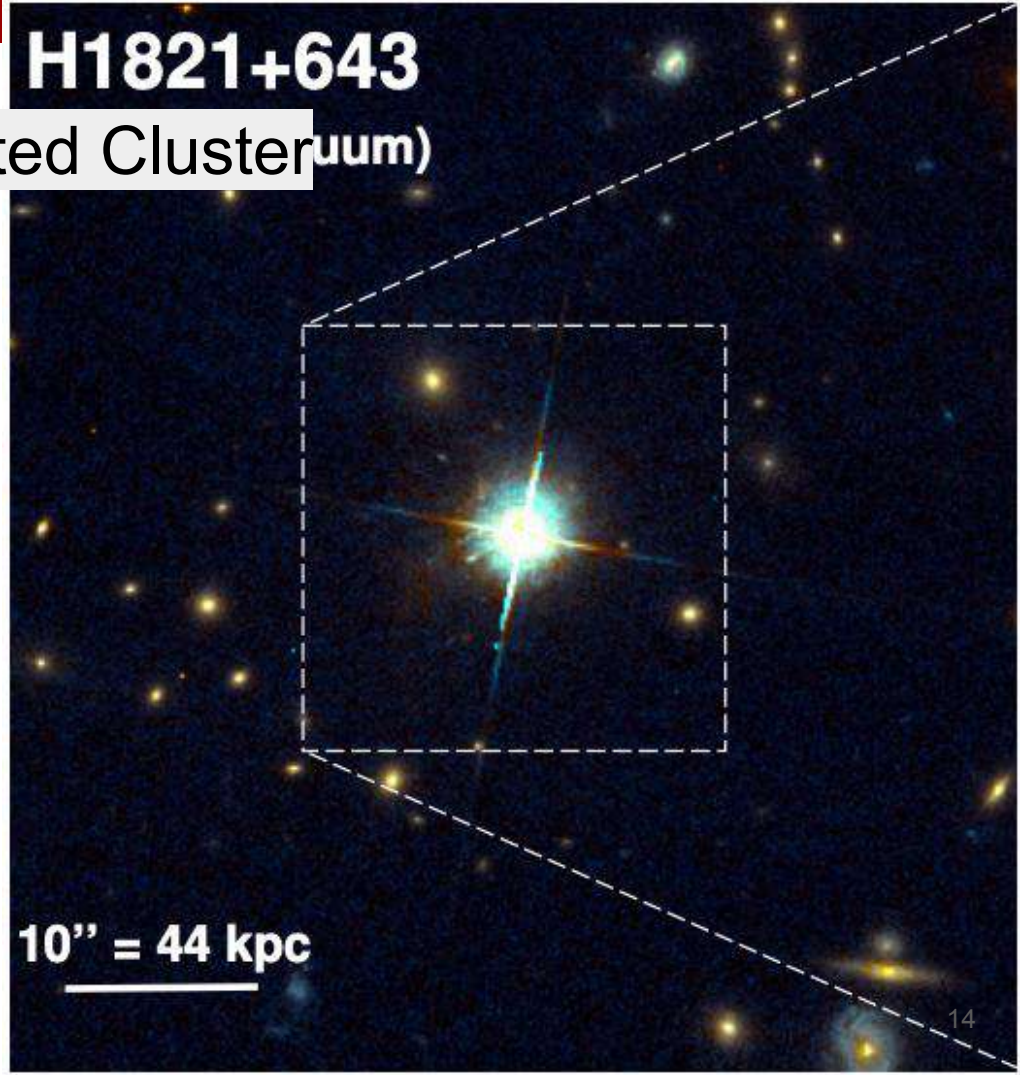
- **Star Formation Rate:** ~600 M$_\odot$/yr (extremely high)
- **Strong Cool Core:** Core X-ray density > 0.1 cm^{-3}
- **Relaxed ICM Morphology:** Smooth and symmetric



(McDonald+12, 18)

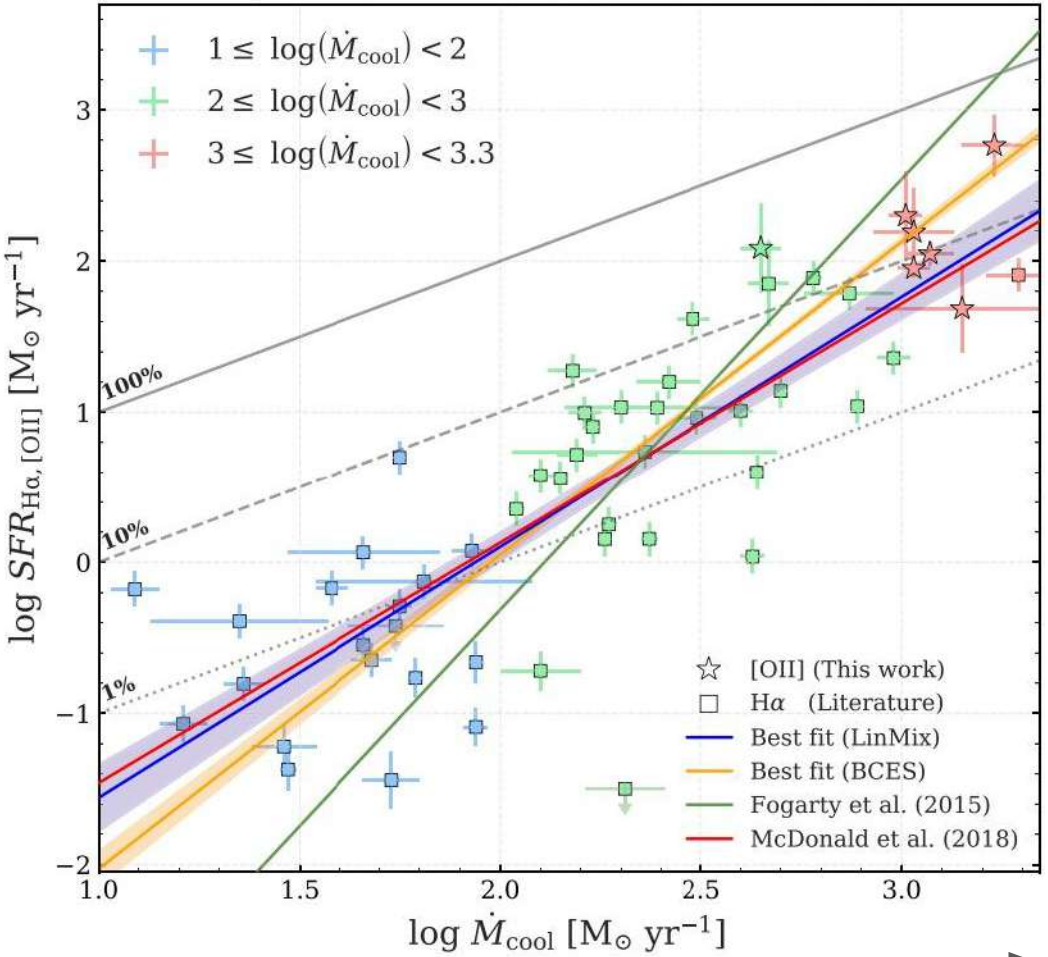
H1821+643: A Quasar-Hosted Cluster

- **BCG hosts a luminous quasar** with powerful **radio jets**
- **AGN accretion rate:** ~40 M☉/yr (Russell+2010)
- **Starburst phase:** SFR = ~120 M☉/yr (Calzadilla+2022)
- **Mass deposition rate:** Up to 3000 M☉/yr (Russell+2024)



(Calzadilla+22)

Starburst

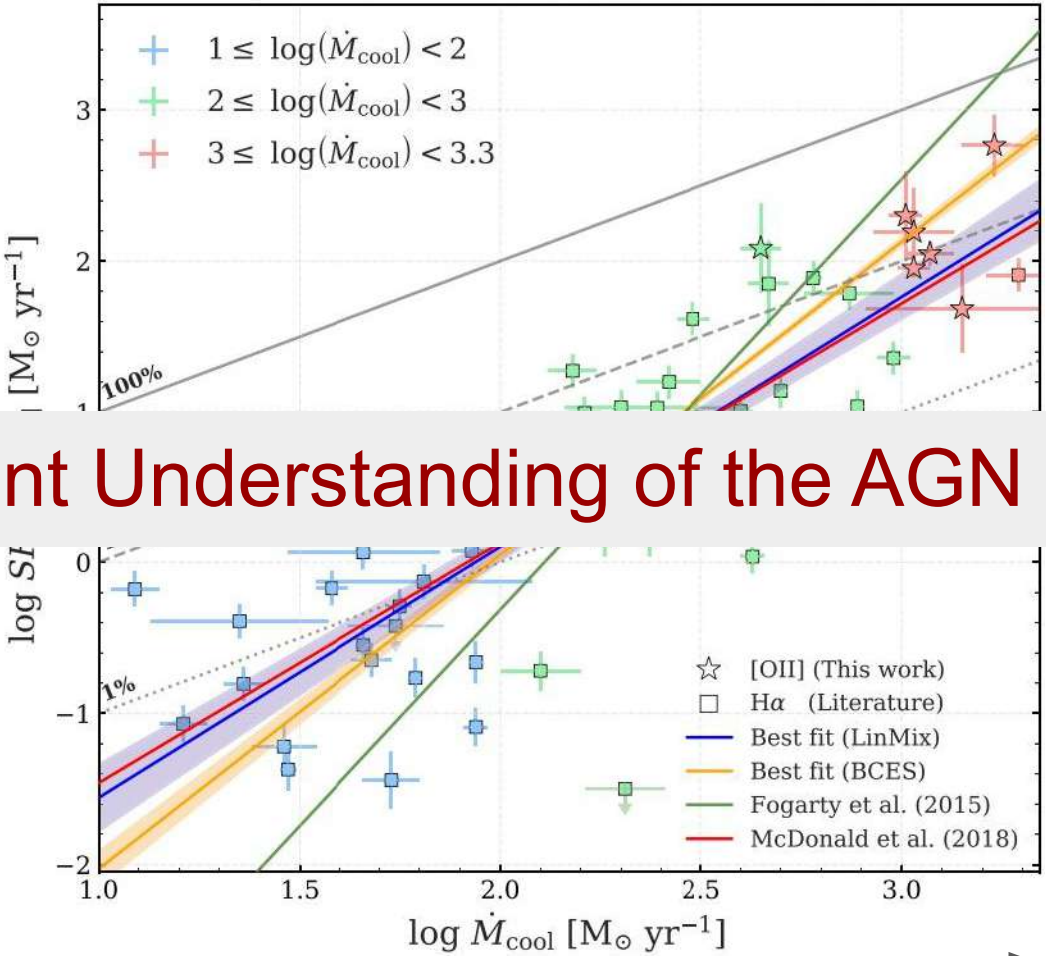


Red Elliptical

(Calzadilla+22)

Small → Massive

Our Current Understanding of the AGN Feedback



(Calzadilla+22)

Small → Massive

BUT… (the 2nd time)

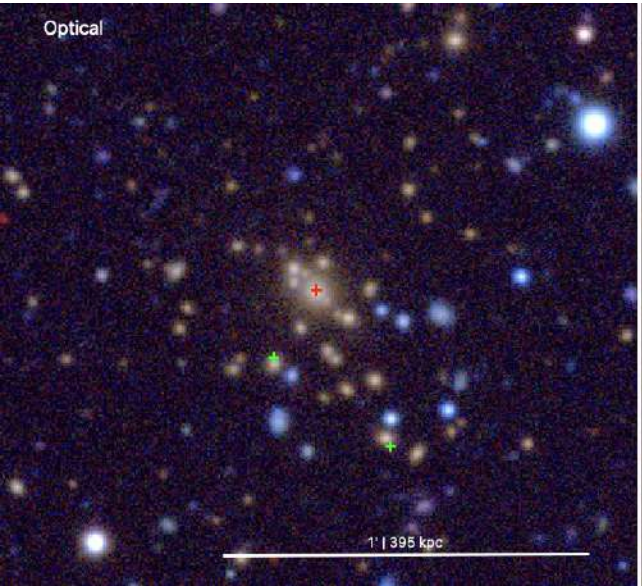
BUT… a New Puzzle: SPT-CL J0417–4748

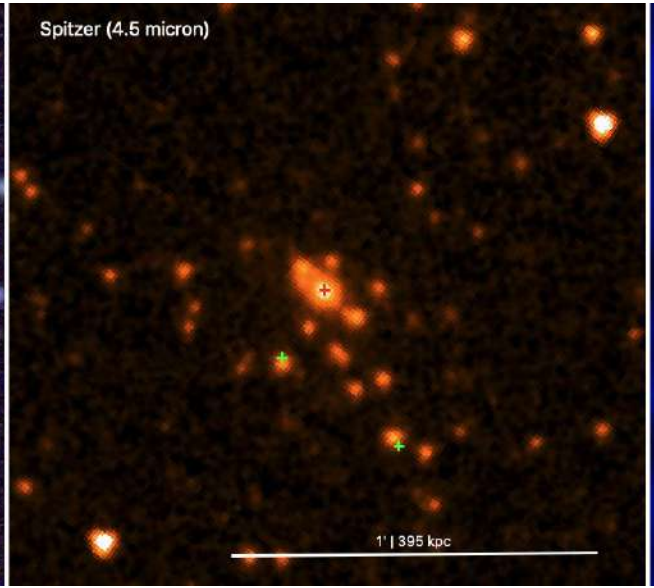
- A massive galaxy cluster at z=0.58
- Yet shows no detectable star formation
- What's going on here?

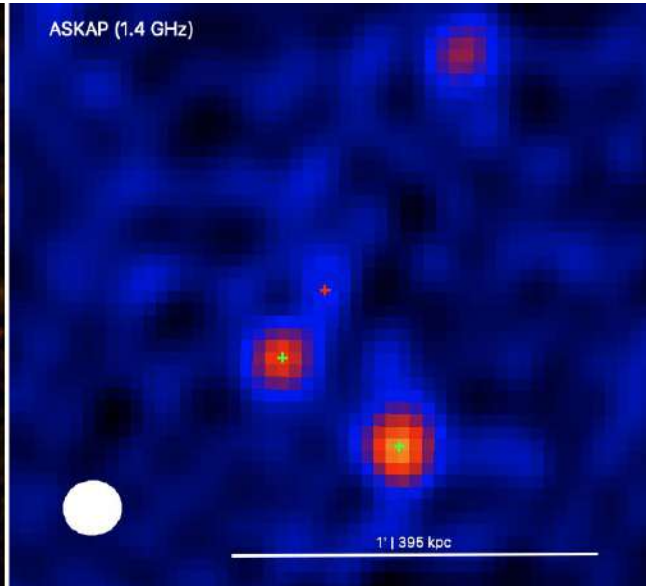
SPT-CL J0417-4748: A Deep Chandra Study of a Relaxed Galaxy Cluster Without Central Star Formation

Taweewat Somboonpanyakul et al. (in prep.)

No Signs of AGN Activity in the BCG

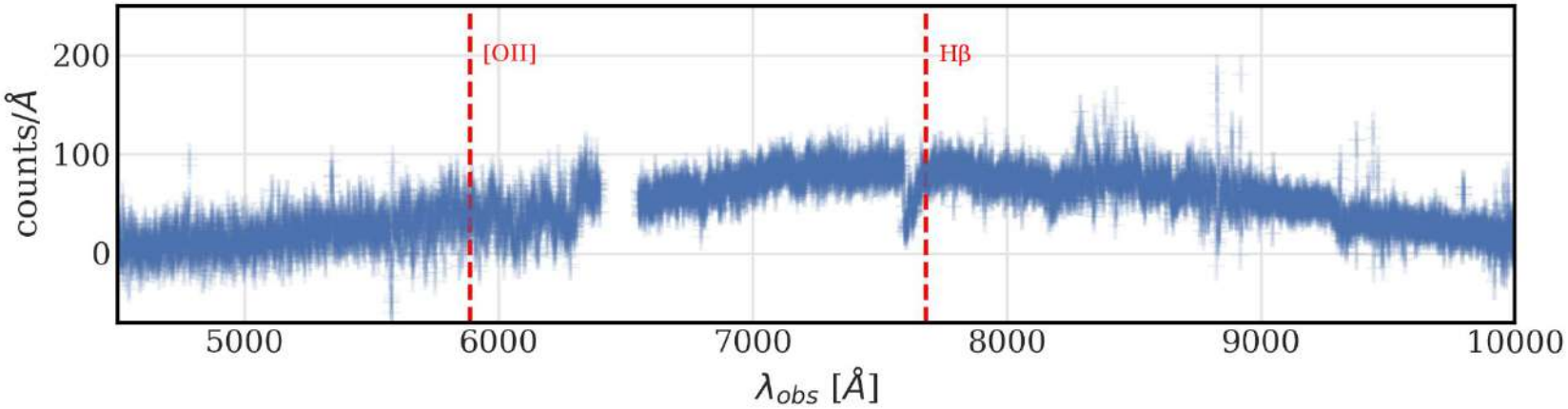






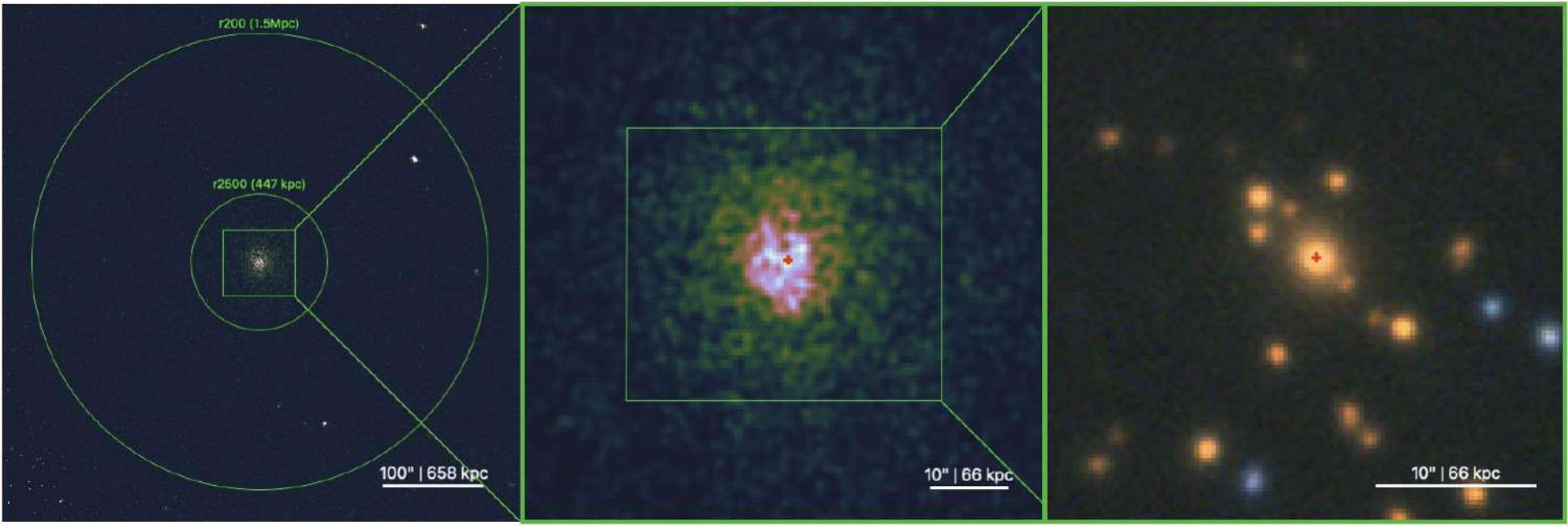
- **Radio (ASKAP):** No radio detection at BCG location → Suggests **no strong AGN activity or jets.**
- **Infrared (Spitzer):** BCG and nearby sources do not meet **IR-AGN color criteria.**

No Signs of Star Formation in the BCG



- Unbinned spectrum shows **no emission lines** → Including [O II] and Hβ
- Using [O II] non-detection → **SFR < 3.8 M⊙/yr** (McDonald+2016)
- Confirms **very low star formation** in the BCG.

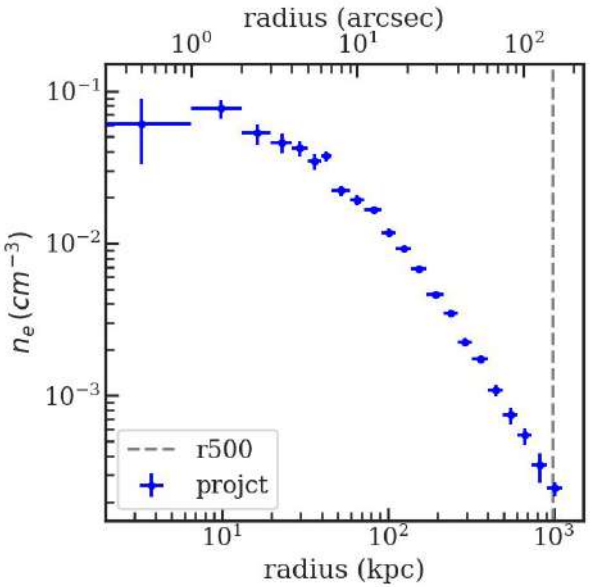
X-ray View of SPT-CL J0417–4748

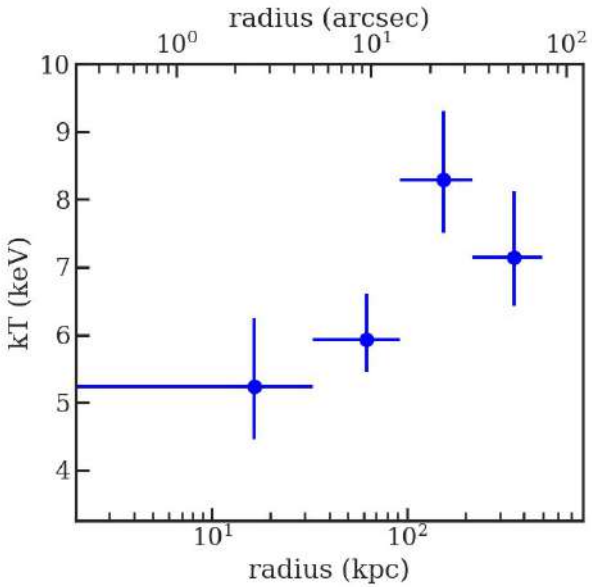


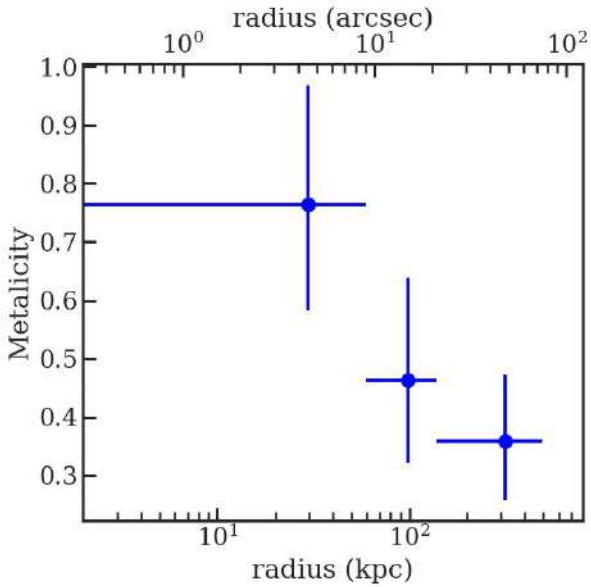
Core shows **a moderately peaked, slightly asymmetric** X-ray morphology

Exposure time: 18+85 ks, M_{500} = 5e14 Msun,

Electron Density, Temperature, and Metallicity Profiles







Electron Density: Peaked X-ray core, typical for strong cool-core clusters

Temperature: Strong cool-core with **temperature rise** from 5 - 9 keV

Metallicity: Core Enhancement → Suggests past cooling or star formation enriched the center

Entropy and Cooling Time: Probing ICM thermal history

Entropy: (heat content of the gas) $K(r) = kT(r) \times n_e(r)^{-2/3}$

→ Flat core:

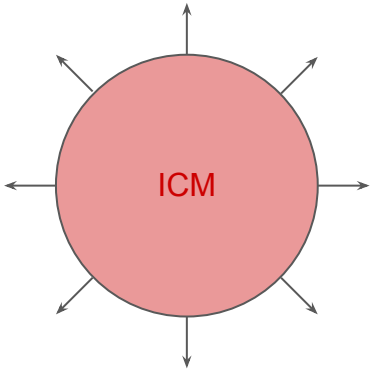
→ Outer profile follows typical relaxed cool-core behavior

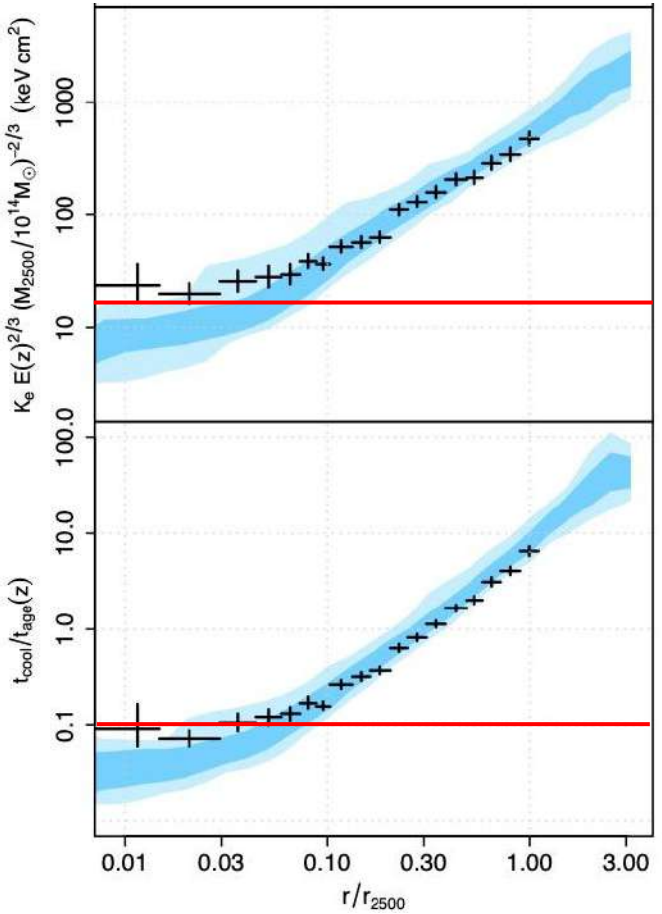
→ **Note**: Center offset by 0.76″ may affect inner-bin accuracy

Cooling Time:

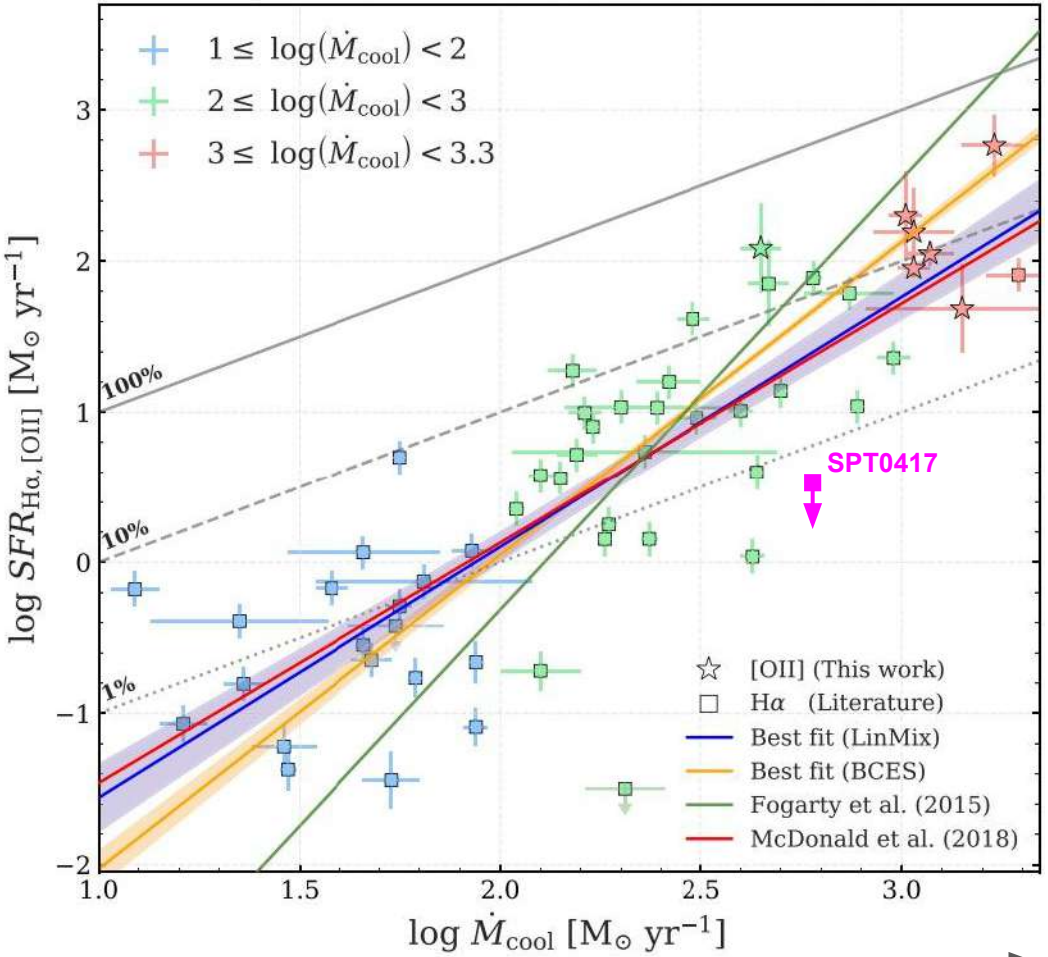
→ tcool ~ 640 Myr at r<6 kpc

→ Falls below **1 Gyr threshold** → indicates *strong cool-core!*





Starburst



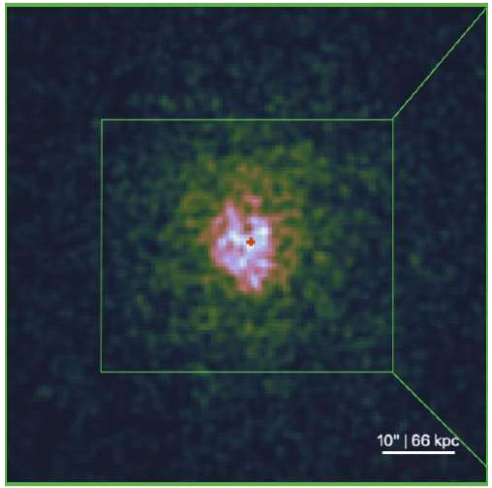
Red Elliptical

(Calzadilla+22)

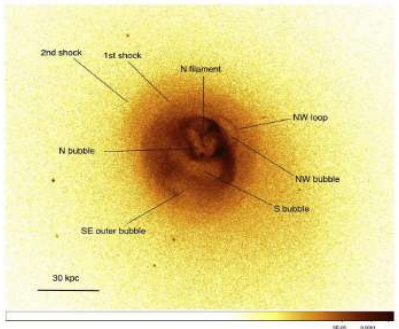
Small → Massive

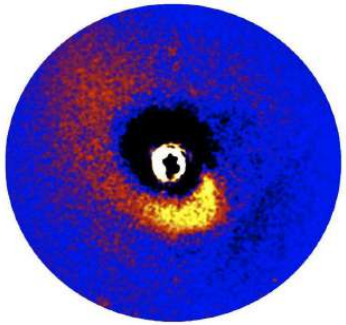
Possible Scenarios for This Cluster

Sloshing Feature

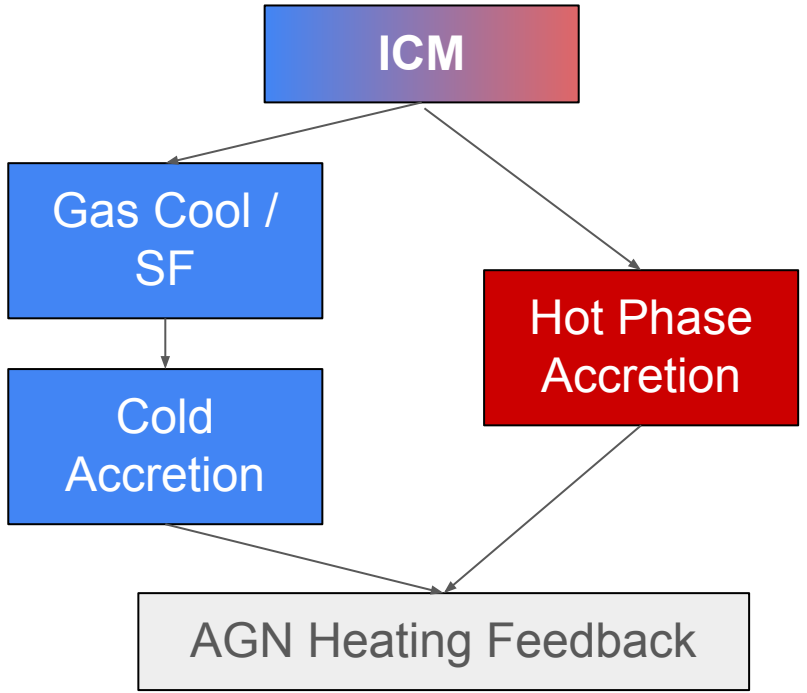


Abell 2029 (SFR = 0.6 Msun/yr)



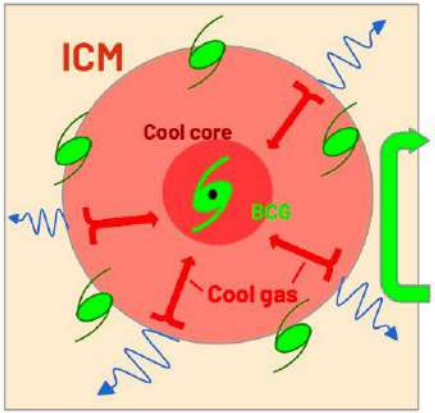


Accretion from the Hot Phase

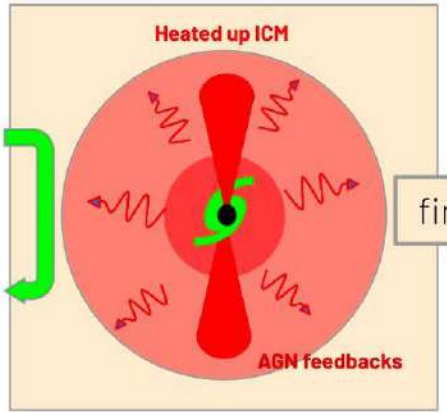


The Evolution of Radio AGN Activity in Brightest Cluster Galaxies

O-S2-22: 11.00-11.15am

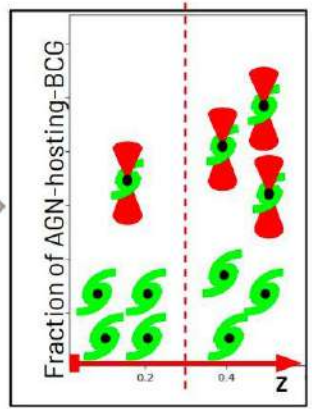


Simplify diagram for BCG with no "cooling flow"



Simplify diagram for AGN feedback

find



Evolution map of radio (loud) AGN-hosting-BCG

Puttichai Lorchutnopphakhun (CU)

Advisor

Dr. Taweewat Somboonpanyakul (CU)

Background

- Radio-loud-AGN is a potential answer to cooling flow problem in BCG.

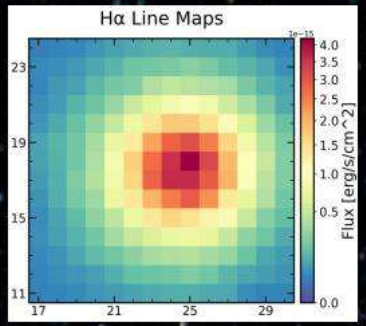
Challenge

- Difficulties in obtaining radio-loud AGNs in BCGs at high redshift due to inherent limitations of radio astronomy.

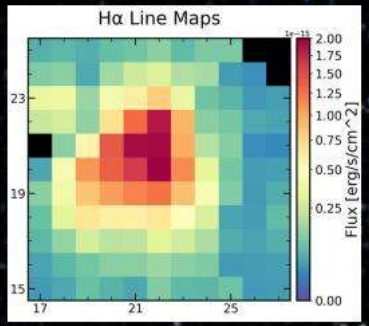
Objective

- Find the radio-loud AGNs' influence on the evolution of cooling flow in BGCs.

Integral Field Unit Observations of Low-Redshift Compact HII Galaxies



LEDA 2816114
(z = 0.136495)



SDSS J161245.52+081701.0
(z = 0.149143)

Characteristics high SFR, strong emission lines, low metallicity

Importance low-z analogs of high-z SFGs in the early Universe

O-S2-16: 9.15-9.30am

Theerachot Rattanasiridamri (CU)

Advisors

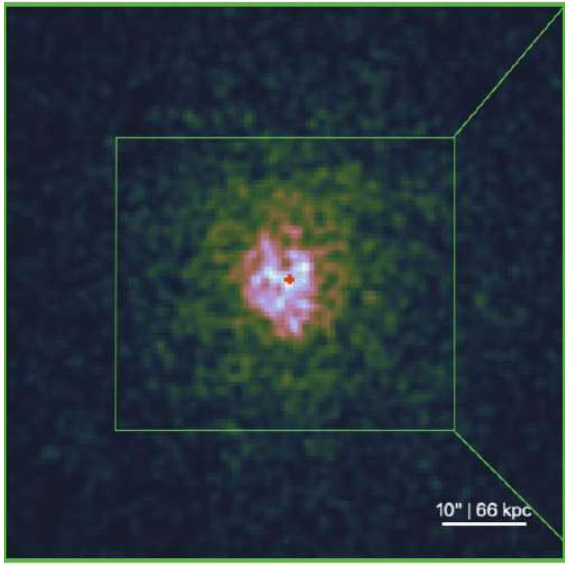
Dr. Krittapas Chanchaiworawit (NARIT)

Dr. Taweewat Somboonpanyakul (CU)

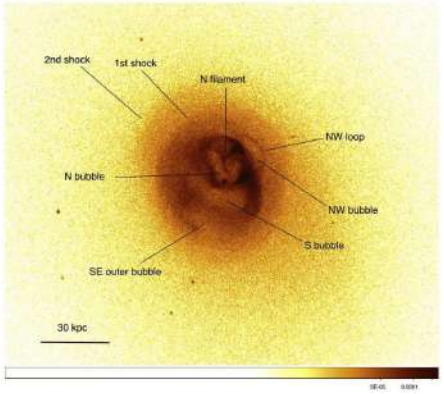
Objectives

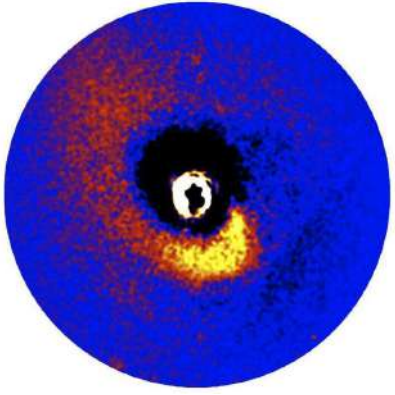
- To study emission lines, kinematics, dust extinction, and SFR with the GTC/MEGARA IFU instrument.
- To study the star formation and galaxy evolution in the early Universe.

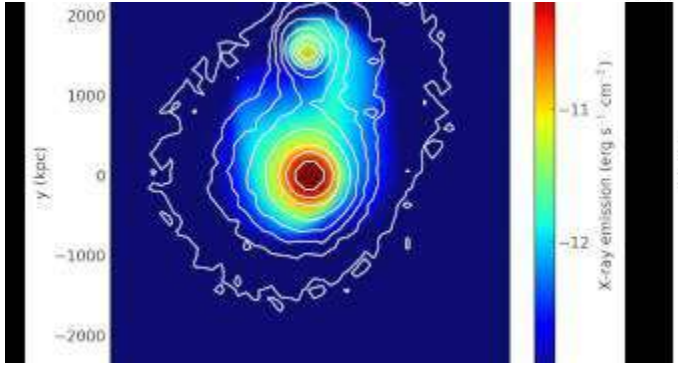
A Possible Scenario for This Cluster (?)

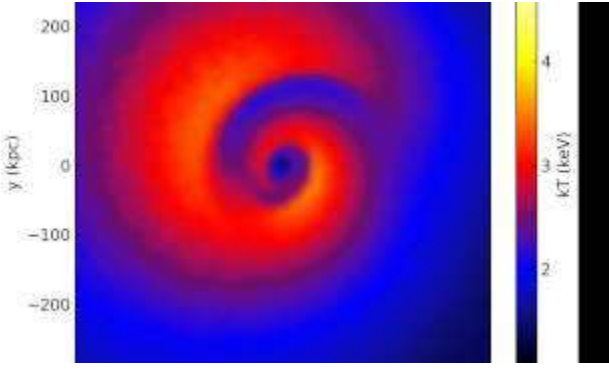


Abell 2029 - Sloshing Feature (SFR = 0.6 Msun/yr)









Galaxy Cluster Evolution: A Story Still Unfolding

- Questions in galaxy cluster studies: **How do cooling and AGN feedback shape cluster evolution over cosmic time?**
- Over the past decade, we've realized:
  → The cooling-feedback cycle is **far more complex** than we once thought.
- Conventional view:
  → **Galaxy clusters** don't form stars
  → **Massive clusters** often do
  → Yet, **some massive clusters** show **no** star formation
- This talk highlights one such case:
  → **SPT-CL J0417-4748** — a massive, relaxed cluster **without** star formation
- This exception reminds us:
  The story is far from over — and that's what makes science exciting!