Galaxy Clusters & AGN Feedback

The Clusters Hiding in Plain Sight (CHiPS) Survey

KIPAC Tea talk

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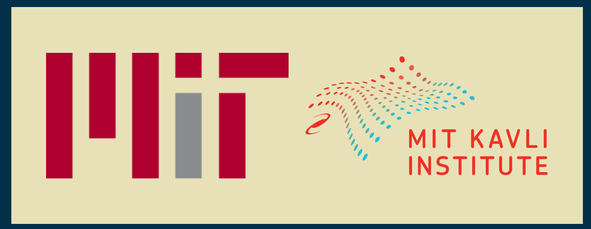
Taweewat Somboonpanyakul | Massachusetts Institute of Technology

Advisor: Michael McDonald

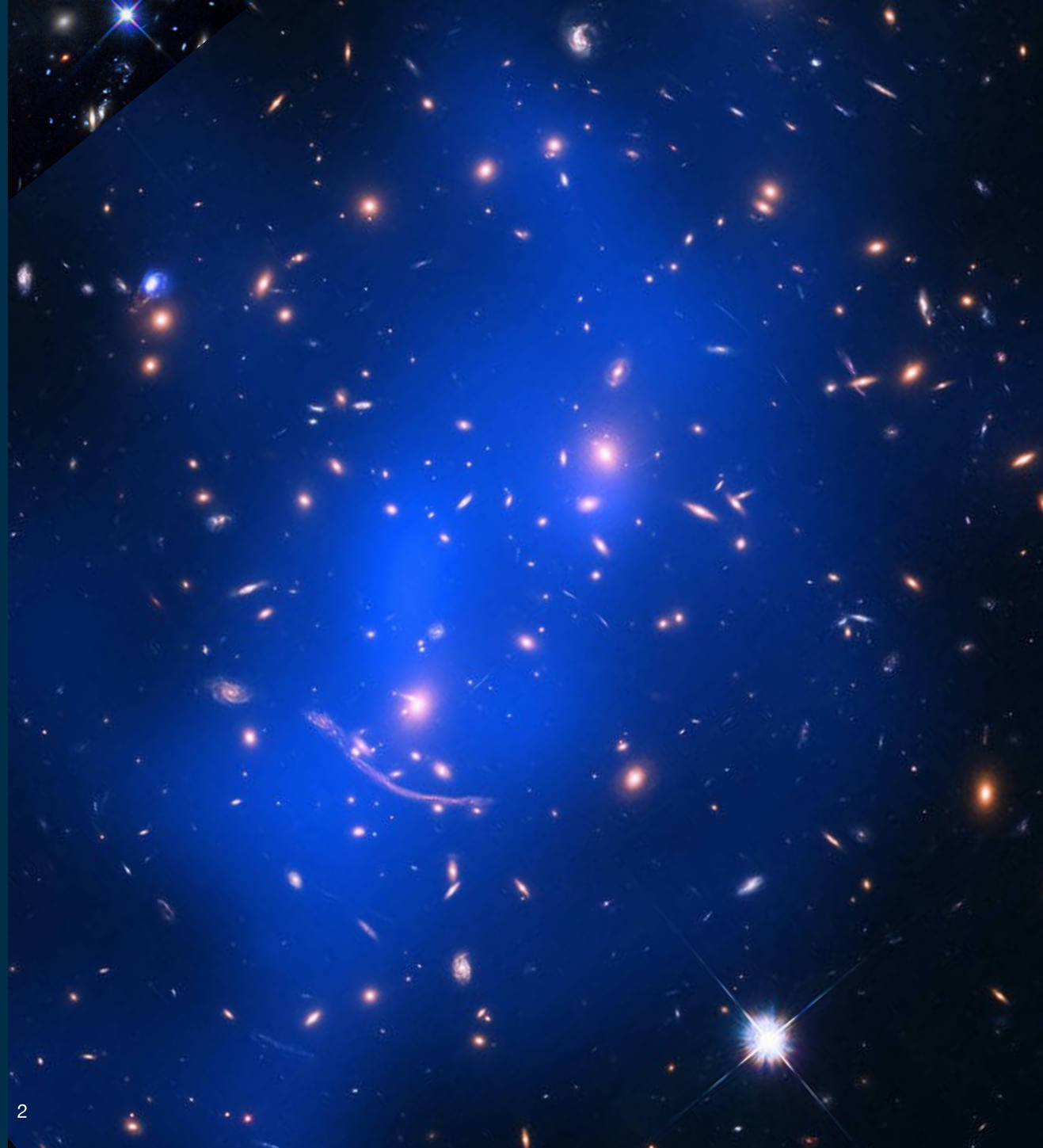
In collaboration with: A. Nobel, M. Bayliss, M. Gaspari, A. Stark, B. Stadler



Galaxy Clusters

Typical Properties

- Most massive gravitational bounded objects in the universe
- Consist of many galaxy members
- Host a central BCG and giant dark matter halo
- Contain extremely hot gas (10^7 K) inside a halo (ICM)
    - Emitting X-ray radiation



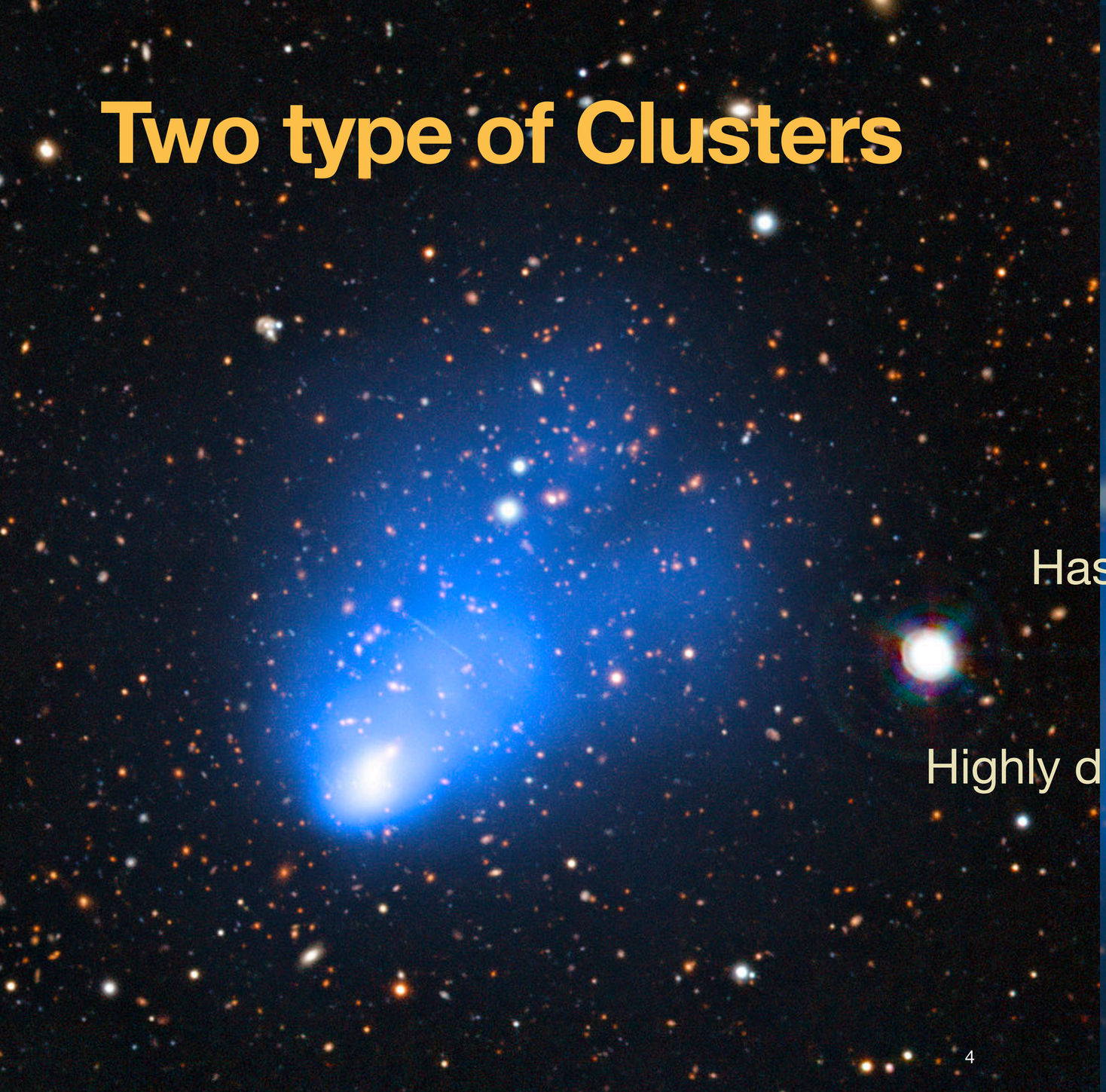
Two type of Clusters

Relaxed Clusters vs Disturbed Clusters

- E.g., **Abell 1835**
  - Mostly cool core
    (cool/denser in a core)
  - Has some cooling (~100 $M_{\odot}$ yr^{-1})
  - Host a radio-loud AGN

Credit: A. Morandi

Two type of Clusters



Disturbed Cluster

- E.g., **El Gordo**
- Mostly non-cool core
- Has almost no cooling (<10 $M_{\odot}$ yr^{-1})
- Host a radio-quiet AGN
- Highly disturbed morphology for the ICM

Two type of Clusters

Relaxed Cluster

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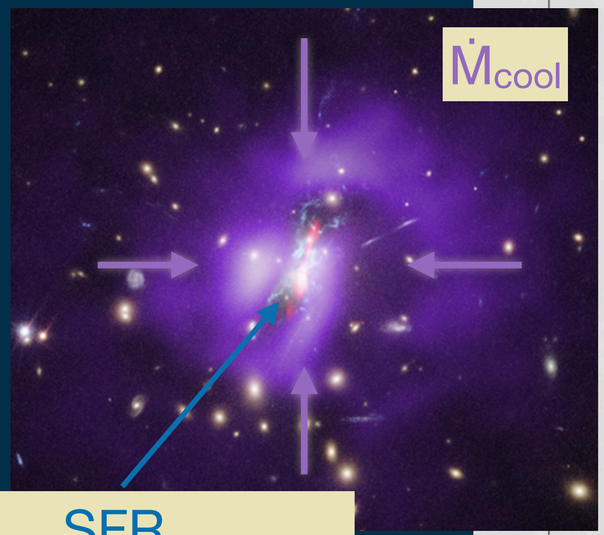
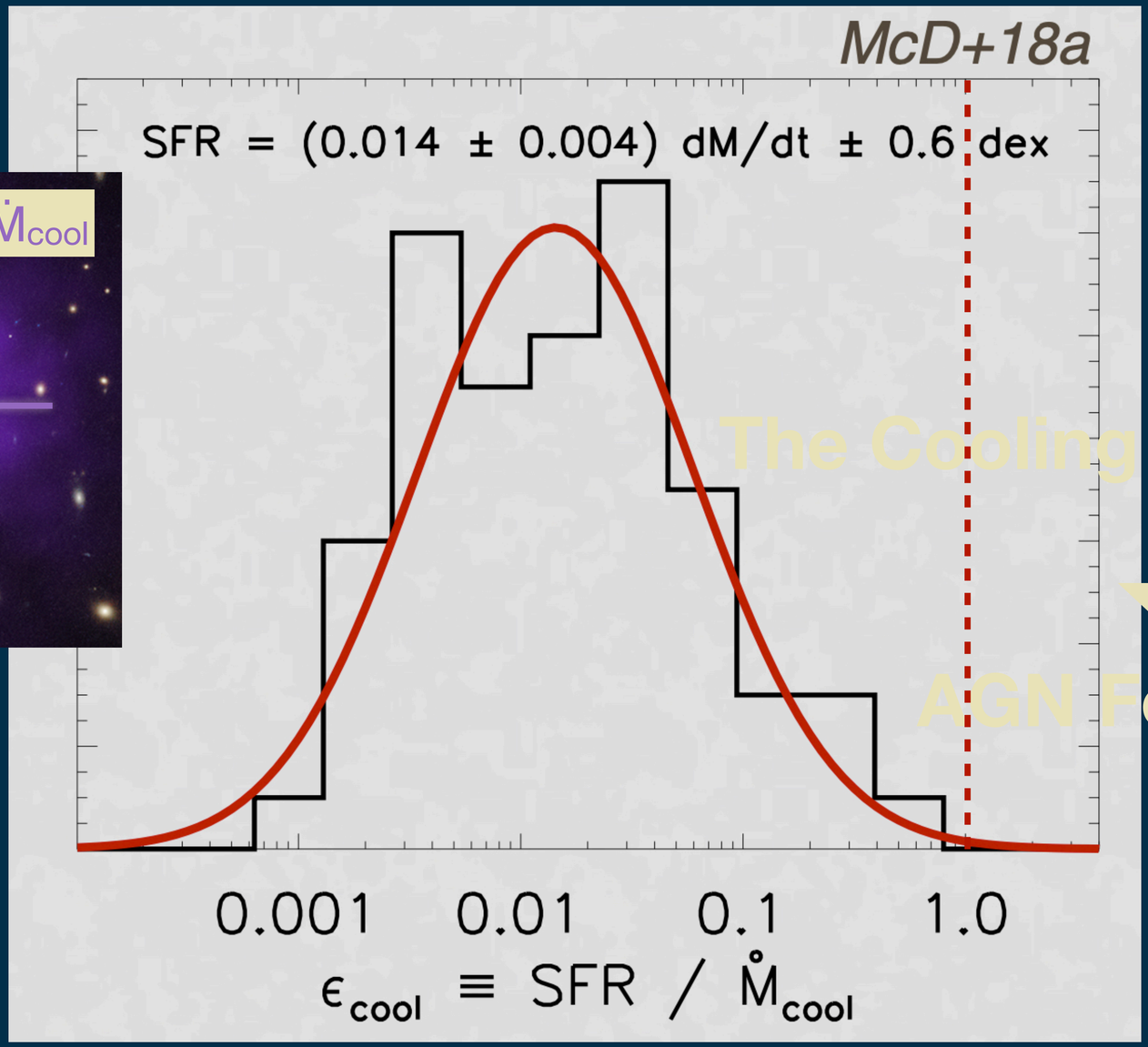
These are what massive clusters look like.

But they are not what clusters should look like.

Suppression of Star Formation



SFR
(star formation rate)



The Cooling **Flow Problem**

AGN Feedback

The Phoenix Cluster

The most famous exception to the rule

- Extremely high star formation rate (~600 $M_\odot$ yr^{-1})
- A strong cool core (core X-ray density > 0.1 cm^{-3})
- Relaxed morphology for the ICM

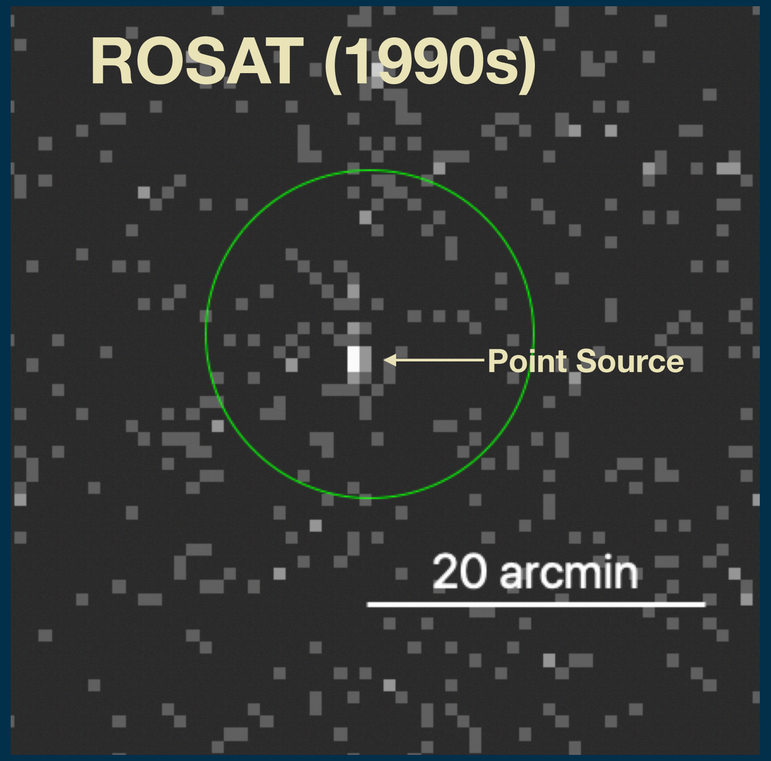
Wh How rare is the Phoenix Cluster? er?

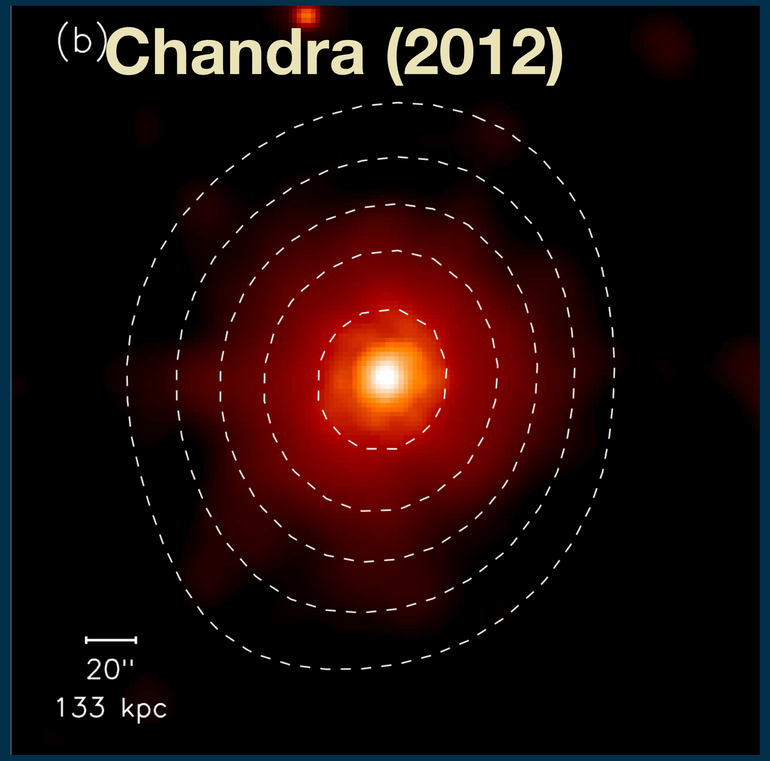
(McDonald+12,19)

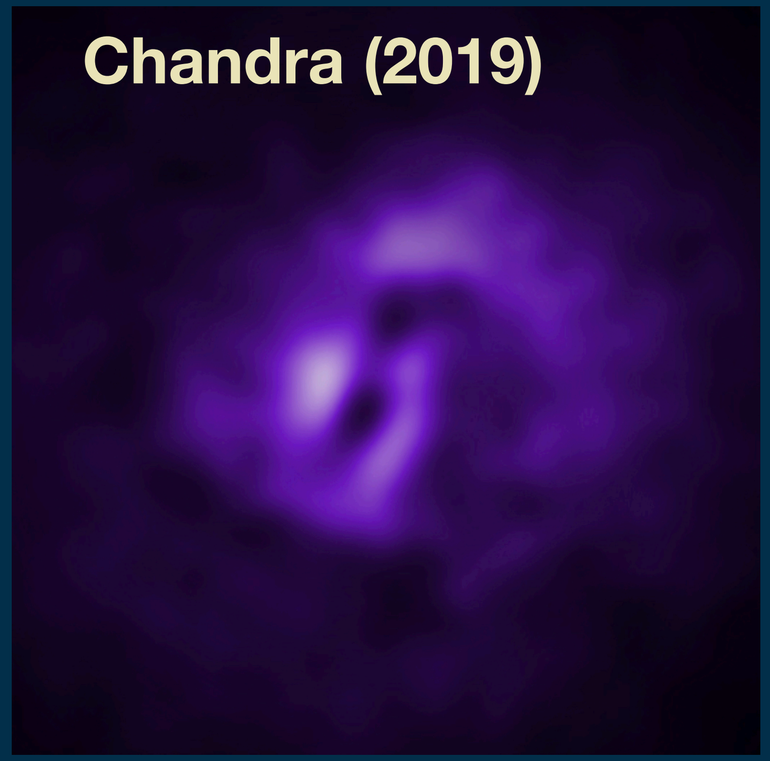
The Clusters Hiding in Plain Sight (CHiPS) Survey

Goal: To find Phoenix-like clusters from X-ray all-sky surveys

The Tale of the Phoenix Discovery



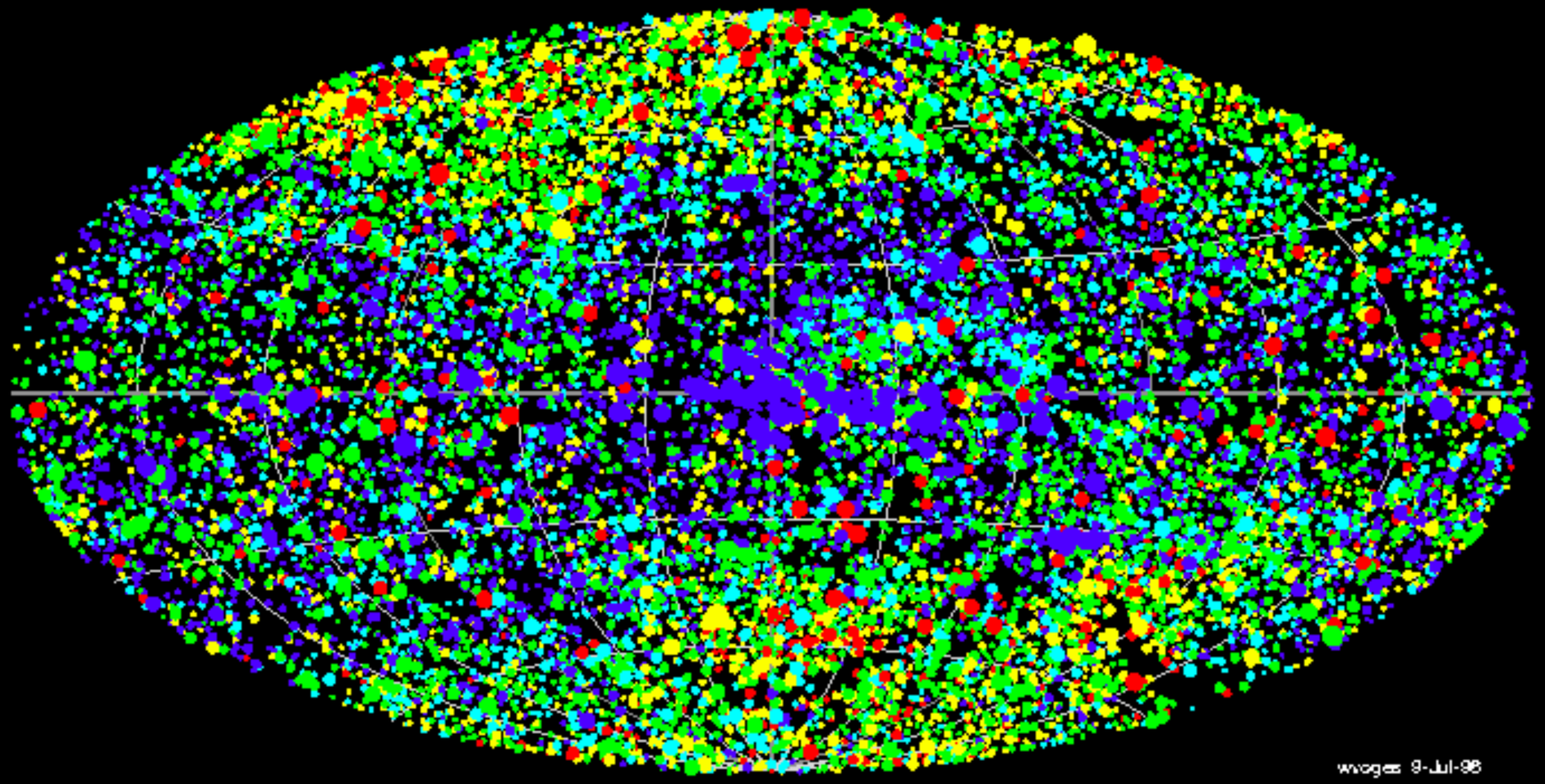




How many of these so-called X-ray point sources are in fact clusters?

ROSAT ALL-SKY SURVEY Bright Sources

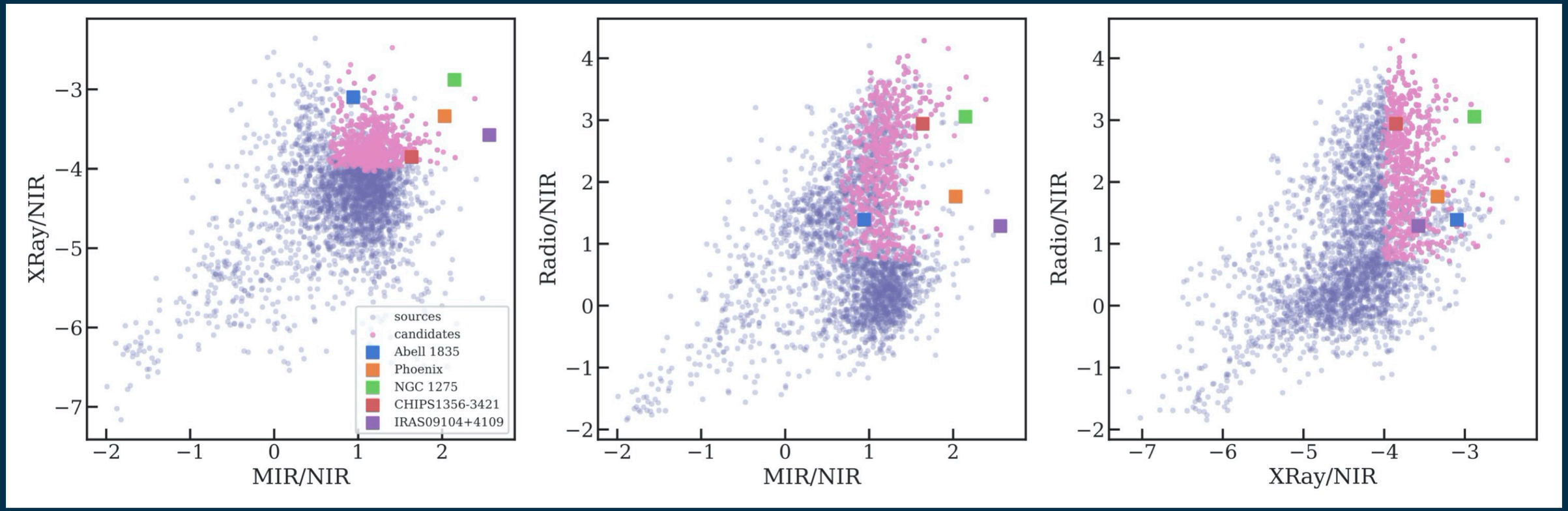
Aitoff Projection
Galactic II Coordinate System



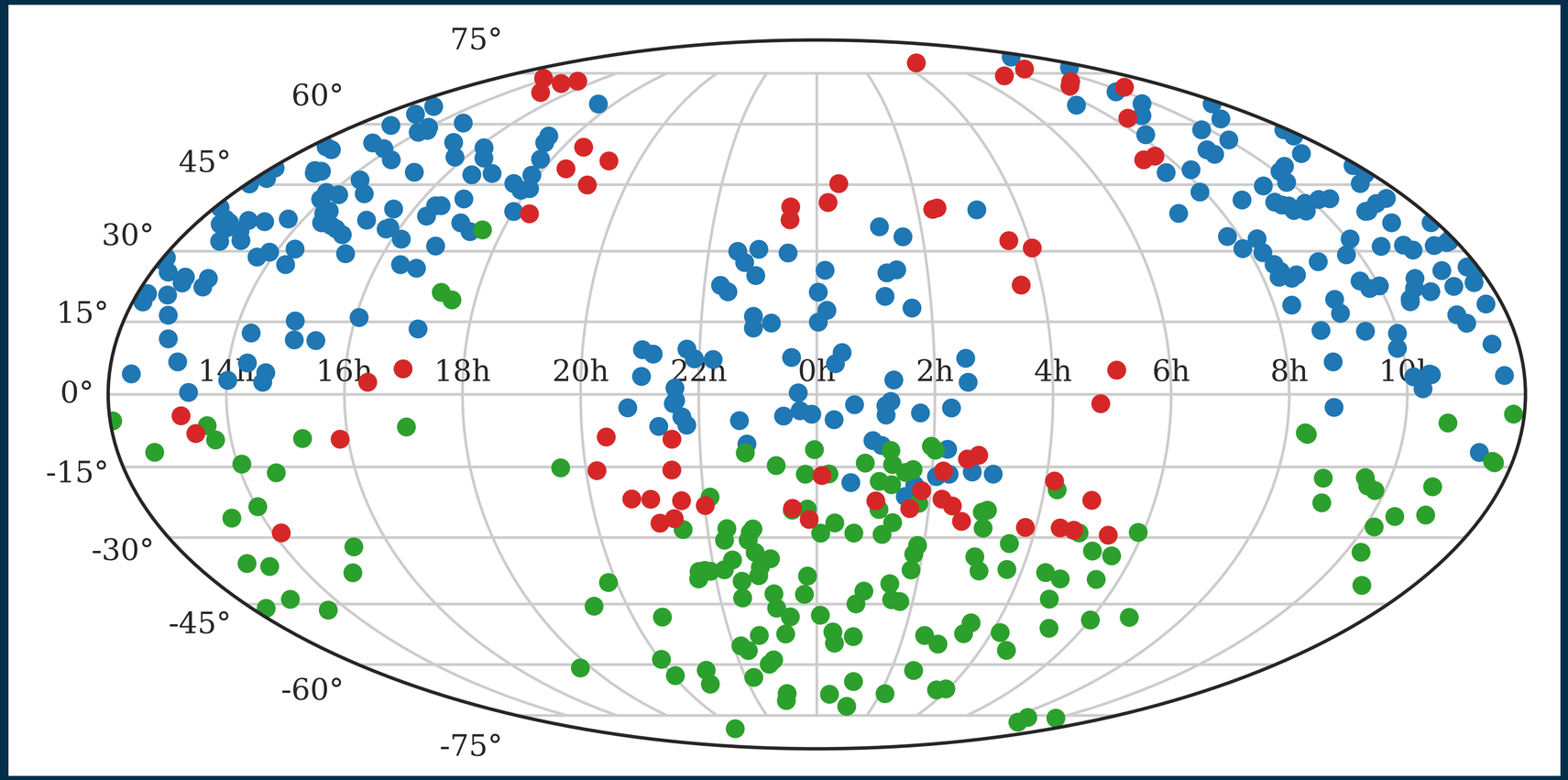
Energy range: 0.1 - 2.4 keV
Number of RASS-II sources: 18811
Hardness ratio: -1.0 | -0.4 | -0.2 | 0.2 | 0.6 | 1.0 (soft -> hard : magenta - red - yellow - green - cyan)

Matching with other all-sky surveys

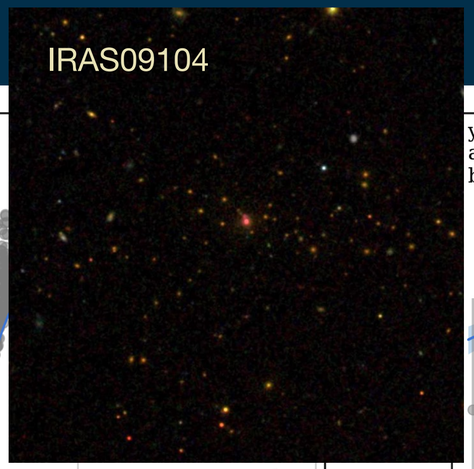
(X-ray=ROSAT, Mid-IR=WISE, Near-IR=2MASS, Radio=NVSS/SUMSS)

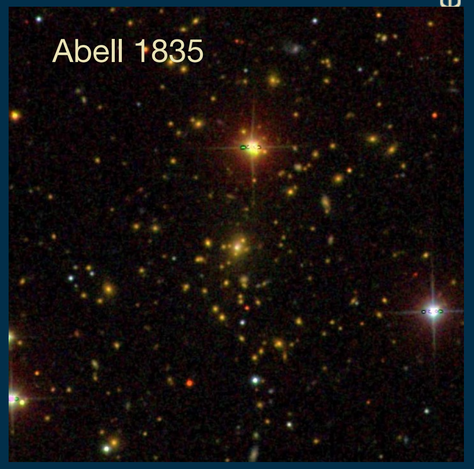


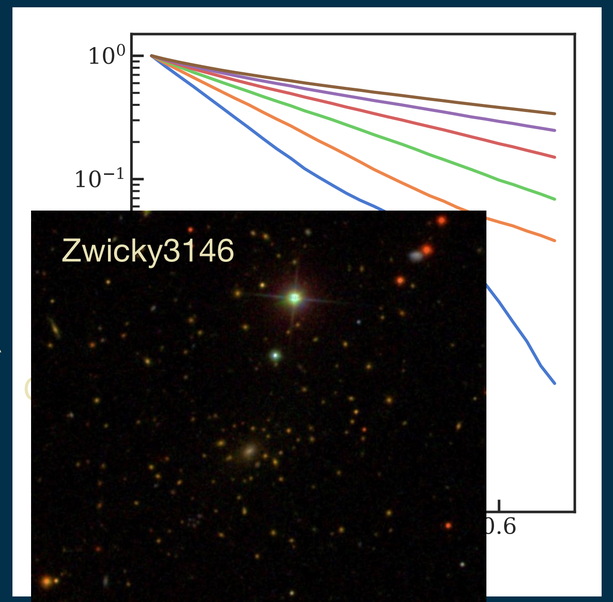
Optical Follow-up



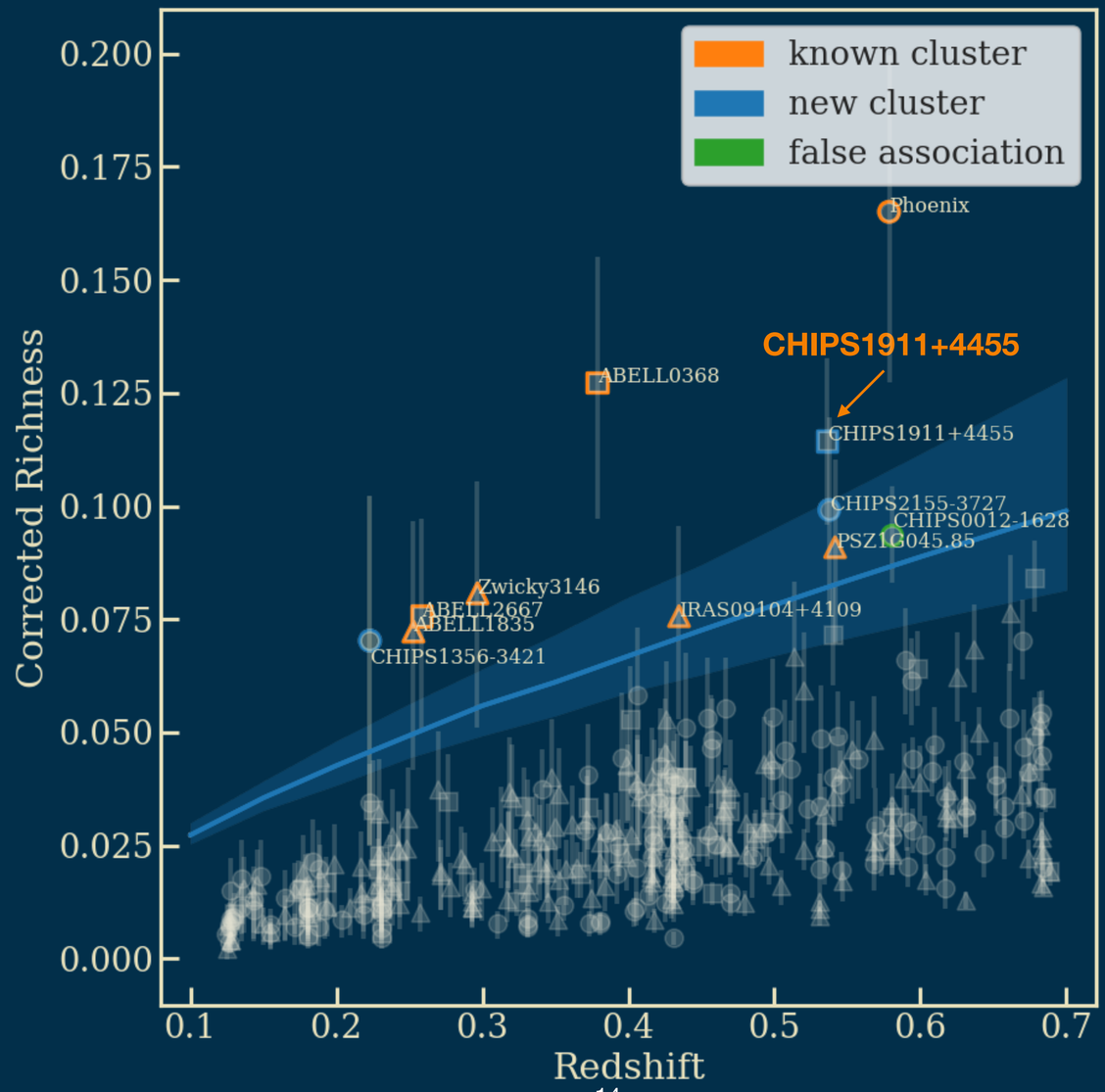
Cluster Richness vs Redshift







Cluster Richness vs Redshift



CHIPS1911+4455

Phoenix meets El Gordo

The Phoenix Cluster

The most famous exception

- Extremely high star formation rate
- A strong cool core
- Relaxed morphology for the ICM

El Gordo

The most massive cluster

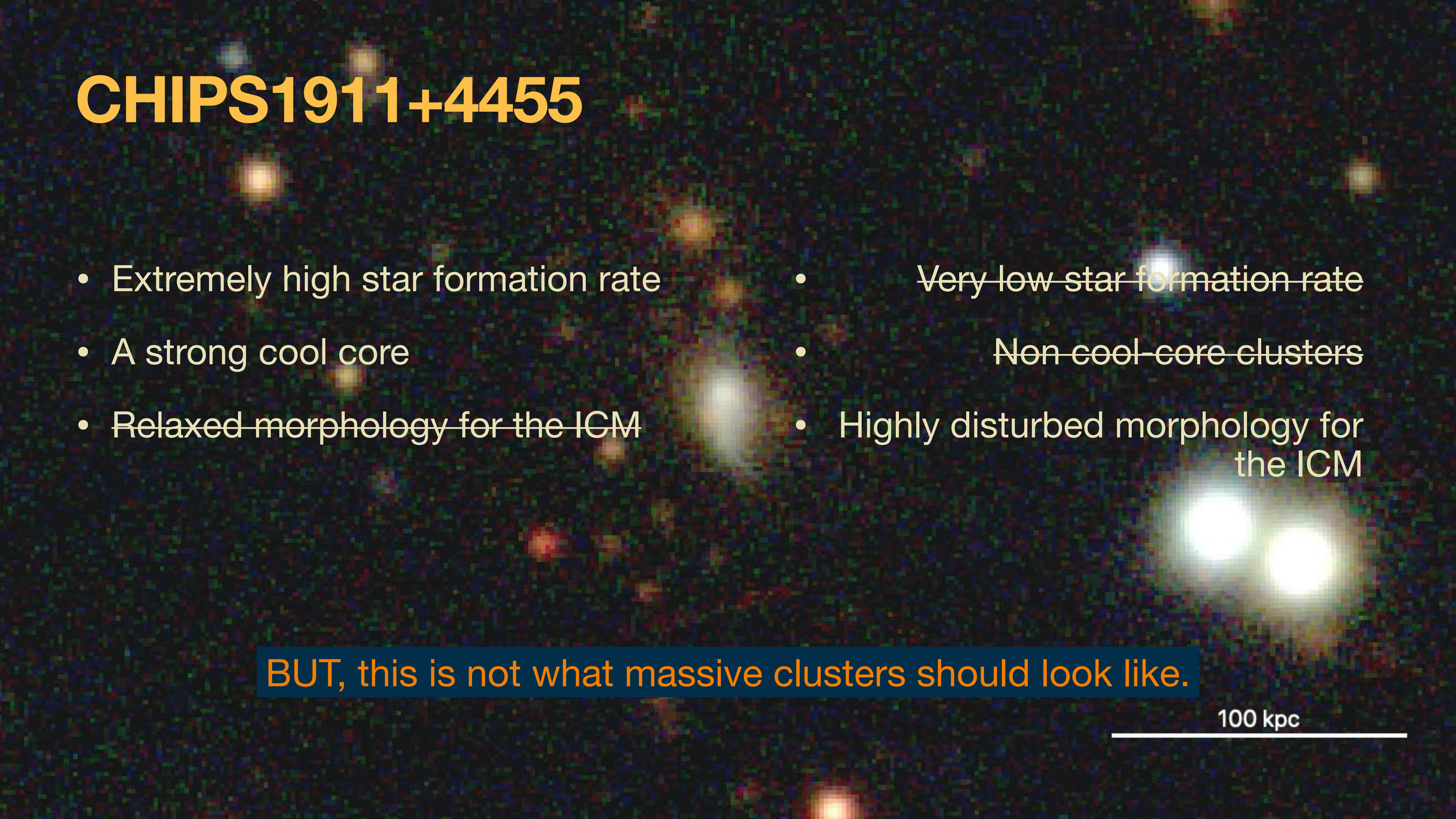
- Very low star formation rate
- Non cool-core clusters
- Highly disturbed morphology for the ICM

CHIPS1911+4455

- Extremely high star formation rate
- A strong cool core
- ~~Relaxed morphology for the ICM~~

- ~~Very low star formation rate~~
- ~~Non cool-core clusters~~
- Highly disturbed morphology for the ICM

BUT, this is not what massive clusters should look like.

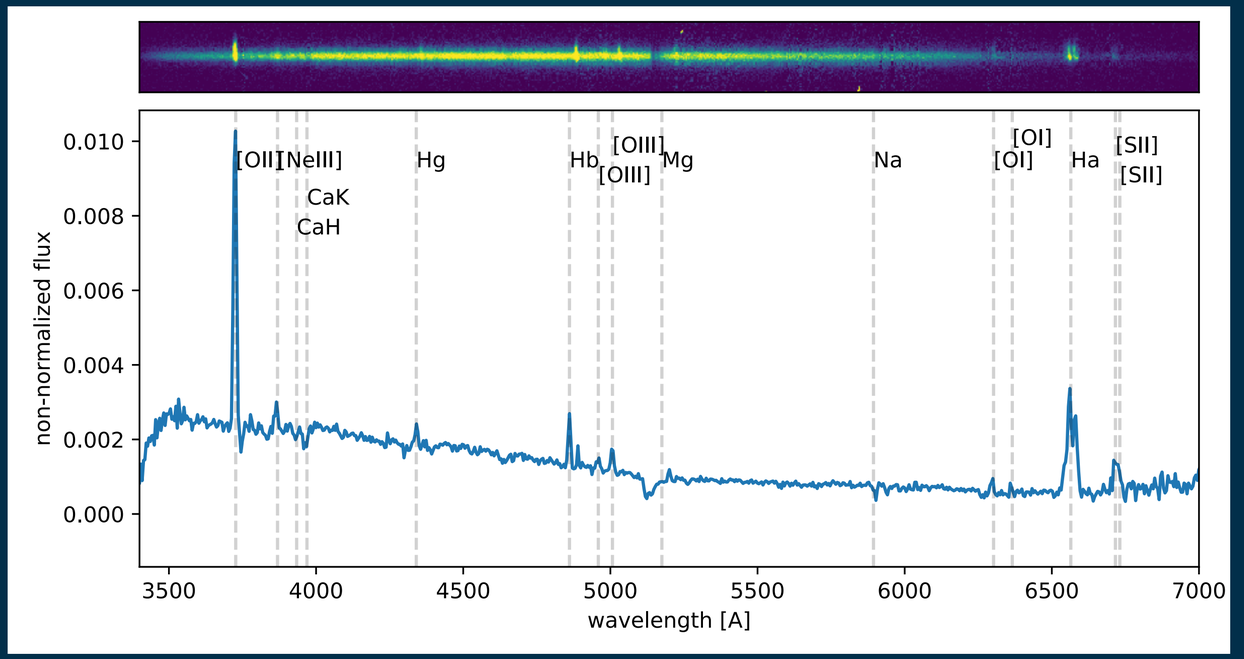


CHIPS1911+4455

Phoenix meet El Gordo (z=0.485)

Nordic Optical Telescope
for optical spectra

- **Extremely high star formation rate**
- A strong cool core
- Highly disturbed morphology for the ICM

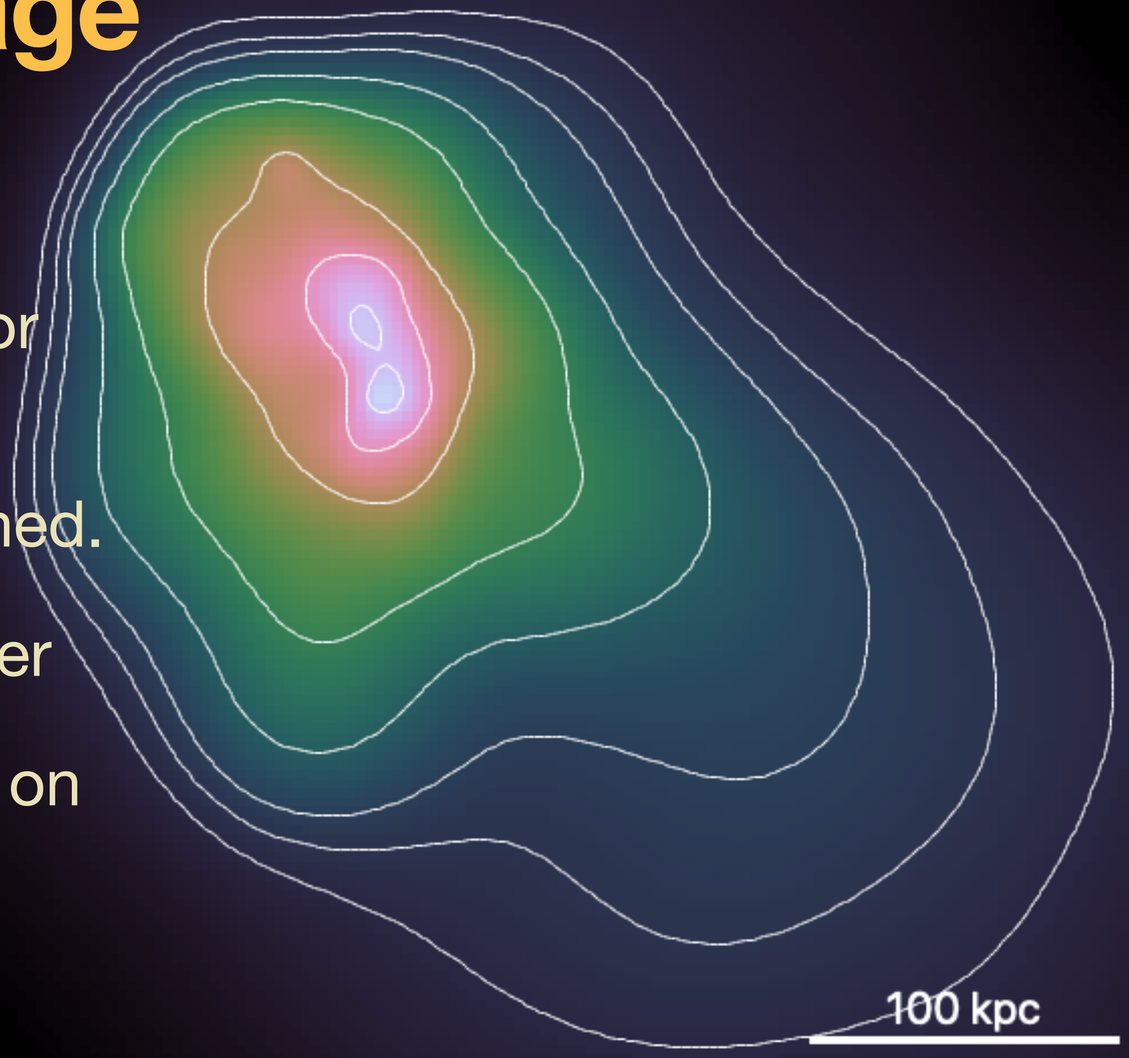


SFR [OII] = 120±15 $M_\odot$ yr^{-1}

SFR [WISE4] = 143±30 $M_\odot$ yr^{-1}

Chandra X-ray Image

- Observed in 2019 with ACIS-I for 30.5 ks
- This image is adaptively smoothed.
- It shows a cool-core in the center
- Also shows highly asymmetries on large scale.



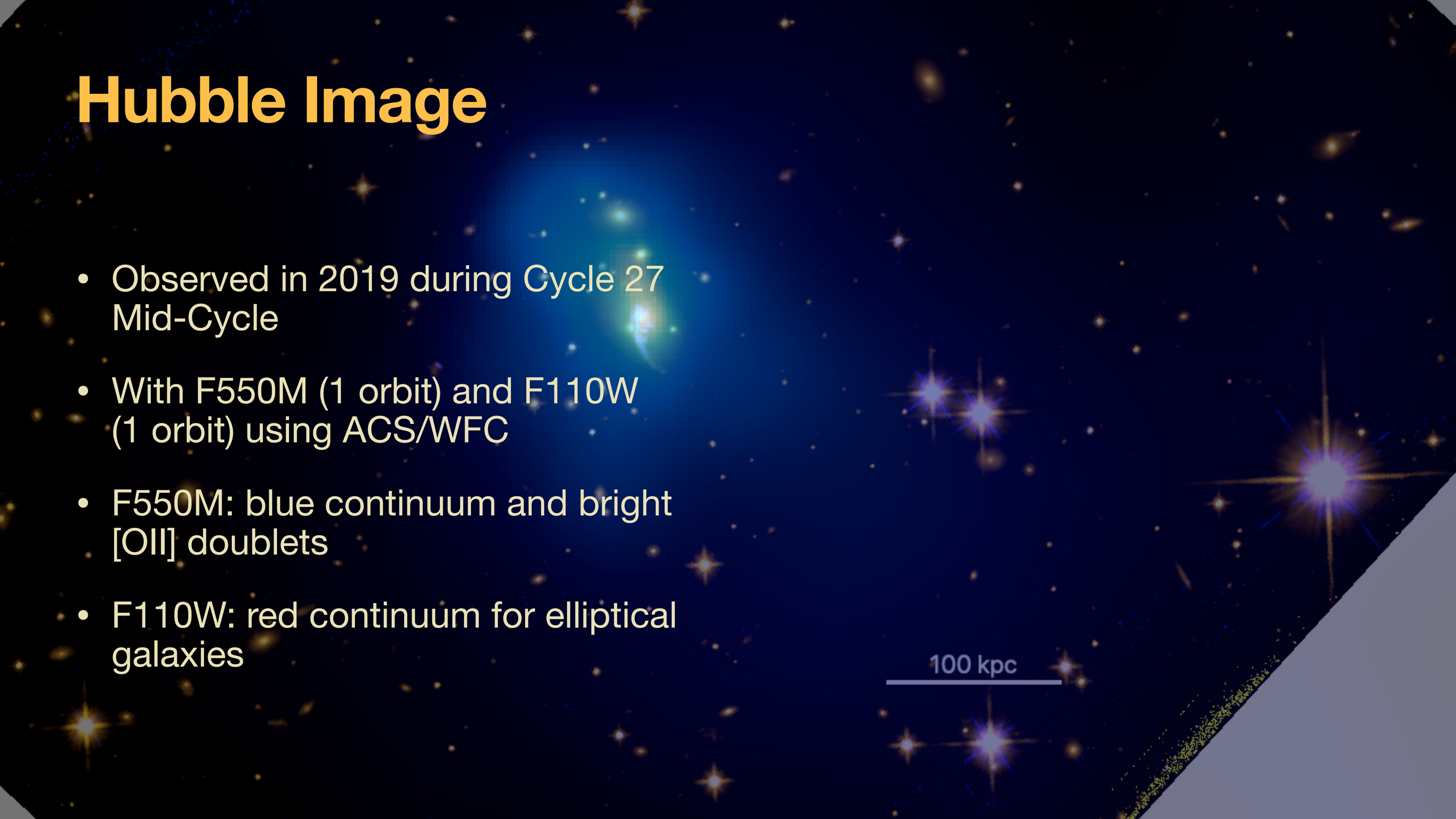
CHIPS1911+4455

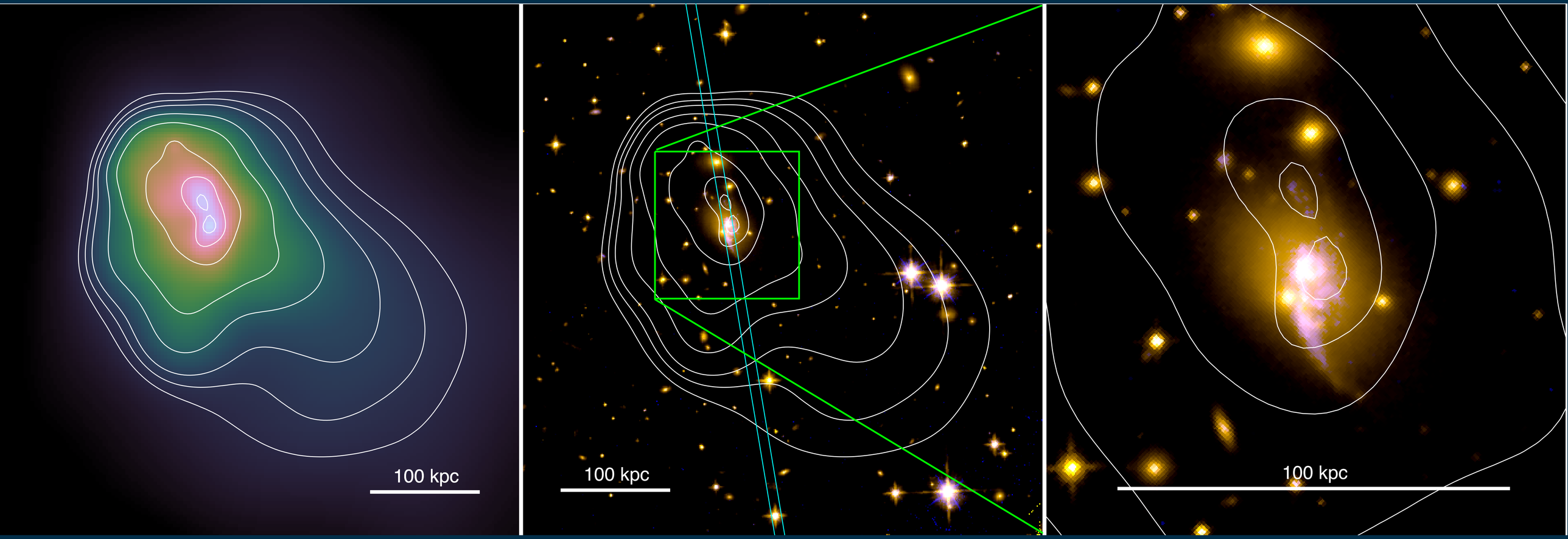
Phoenix meet El Gordo

- Extremely high star formation rate
- A strong cool core
- Highly disturbed morphology for the ICM

Hubble Image

- Observed in 2019 during Cycle 27 Mid-Cycle
- With F550M (1 orbit) and F110W (1 orbit) using ACS/WFC
- F550M: blue continuum and bright [OII] doublets
- F110W: red continuum for elliptical galaxies




100 kpc
100 kpc
100 kpc

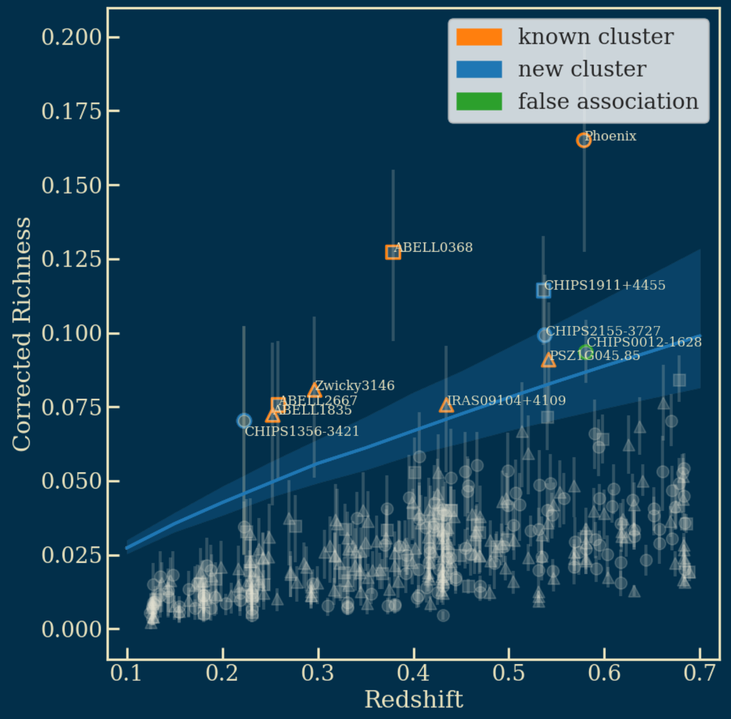
What we learned from CHiPS

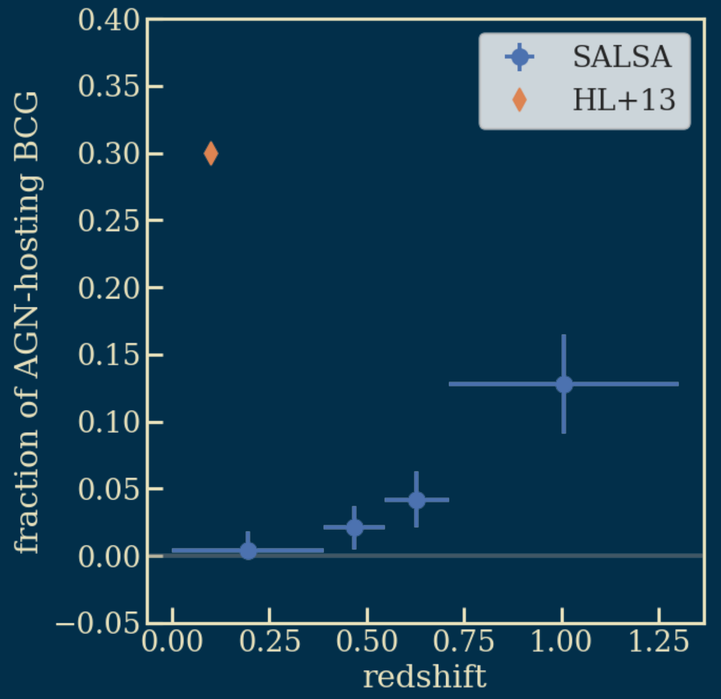
- The rarity of these extreme cases told us that CCA might be a mechanism for the feedback
- The survey found a new mode of cooling with **CHIPS1911+4455** (massive starburst in a merging cluster)

Pretty rare (2±1%)

Contributions

AGN Feedback in Galaxy Clusters





Finding more extreme clusters will help us unlock mysteries of AGN feedback.