Galaxy Clusters Hiding in Plain Sight (The CHiPS Survey)

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Introduction

The recent discovery of the "*Phoenix cluster*" [4] which, at z = 0.6, is the most X-ray luminous cluster known and harbors a massive starburst at its center, begs the question: Why was it not discovered until recently? In fact, this cluster was previously detected by several all-sky surveys at a variety of wavelengths, but was consistently classified as a quasar (QSO) because of the extremely bright central galaxy and a (relative) lack of extended X-ray emission due to its distance. This leads us to wonder how many nearby galaxy clusters with central QSOs or starbursts are currently mislabelled in existing all-sky surveys.

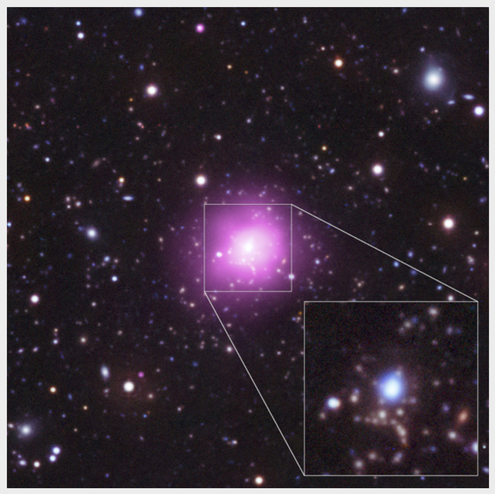

Figure 1. Optical/UV/X-ray composite view of the Phoenix Cluster, with a zoom-in on the central region to optical/UV image. Image released August 15, 2012.
Credit: X-ray: NASA/CXC/MIT/M.McDonald; UV: NASA/JPL-Caltech/M.McDonald; Optical: AURA/NOAO/CTIO/MIT/M.McDonald

Method

A unique property of the Phoenix cluster which helps us identify similar objects is that it is bright at multiple wavelengths, including X-ray (intracluster medium and central AGN), near-IR (giant central elliptical galaxy), mid-IR (warm dust from starburst and AGN) and radio (radio-loud central AGN).

Therefore, we can identify potential Phoenix-like clusters by cross-correlating all-sky surveys from ROSAT [6] (X-ray), 2MASS [5] (near-IR), WISE [7] (mid-IR) and both SUMSS [3] and NVSS [1] (radio). By requiring candidates to be detected in all four surveys, we can quickly find (among other sources) a sample of candidate galaxy clusters that can be followed up either by using archival images from SDSS for Northern-hemisphere objects or with the Magellan telescope for Southern-hemisphere objects. Figure 2 summarizes the process of selecting candidate clusters for follow-up.

With our pilot study, we have discovered two new galaxy clusters at low redshift with this technique. Figure 4 shows our first newly-discovered cluster.

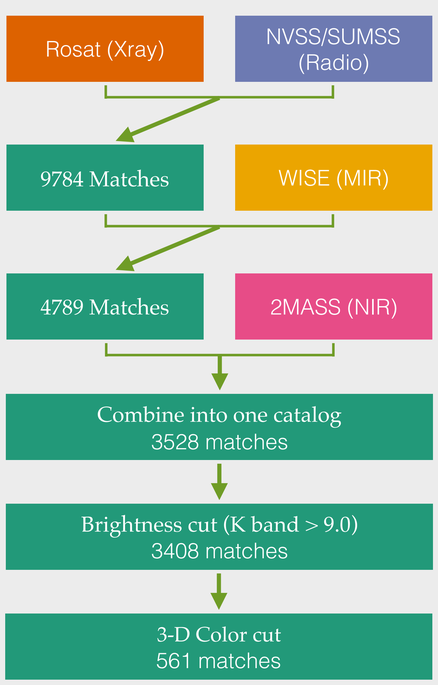

Figure 2. This figure illustrates how we cross-correlate various publicly-available all-sky surveys to arrive at a sample of sources that are bright at all wavelengths from the X-ray through radio. By making conservative brightness and color cuts, we arrive at a sample of 561 sources with similar properties to the central galaxy in the Phoenix cluster.

Results

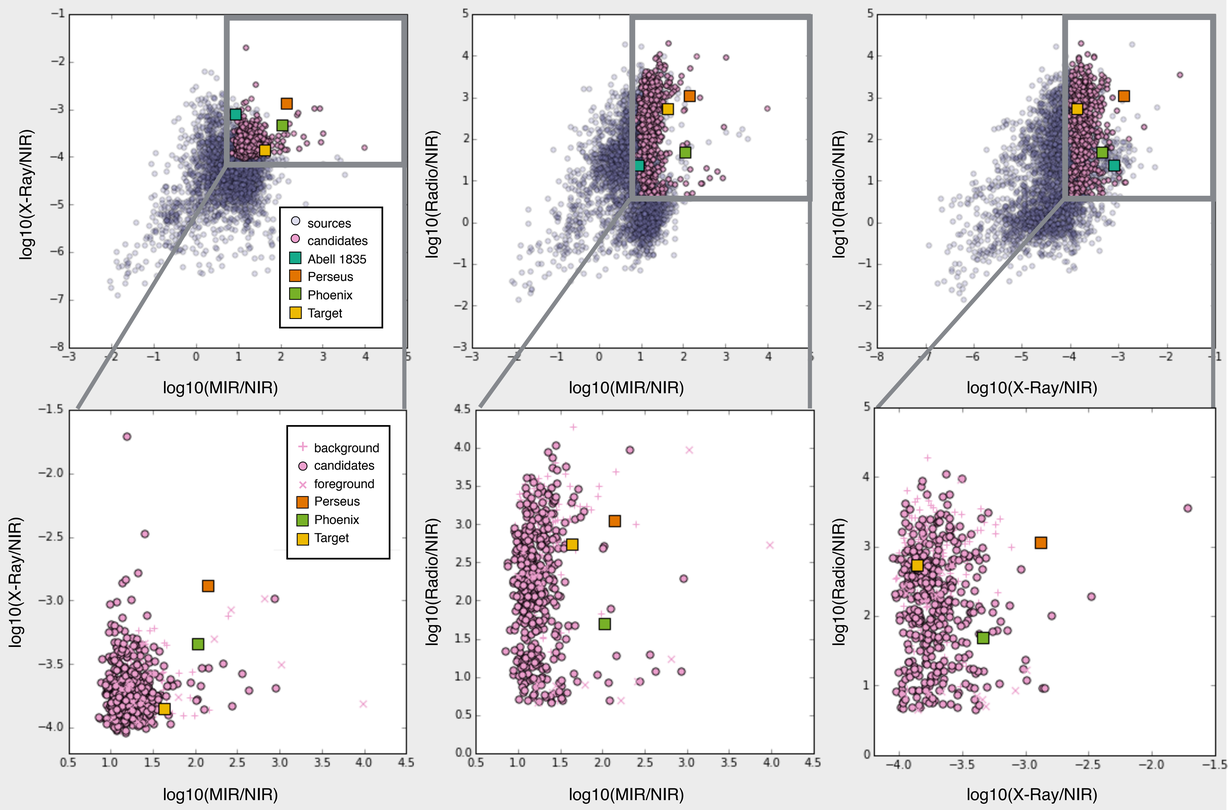

Figure 3. The top three panels show color-color diagrams for objects that are detected in all catalogs (3408 objects). The axes are the logarithm of the ratio of the X-Ray, mid-infrared (MIR) or radio flux to the near-infrared (NIR) flux. The bottom three panels show potential galaxy cluster candidates (561 objects) based on our chosen color-color cuts. We remove background (z > 0.7) and foreground (z < 0.1) sources from our sample based on redshift information from NED. The Phoenix and Perseus clusters are shown with orange and green boxes, respectively, while our first confirmed cluster (see below) is shown in yellow.

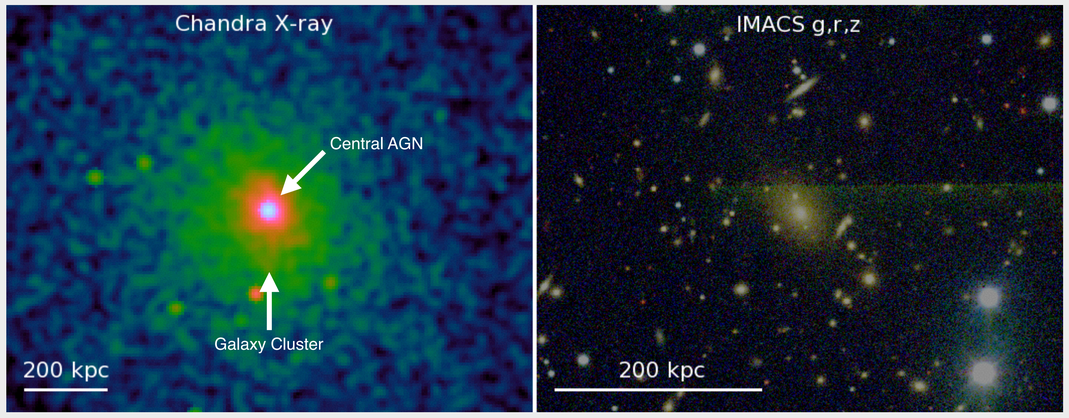

Figure 4 (left) shows a Chandra X-ray image of our first newly-discovered galaxy cluster at redshift ~0.2 which was flagged as a point source in RASS. This image clearly shows both the central AGN and the extended cluster halo. Figure 4 (right) shows the same cluster in the optical from the Magellan telescope.
Credit: X-ray: NASA/MIT/M.McDonald; Optical: CIS/MIT/M.McDonald.

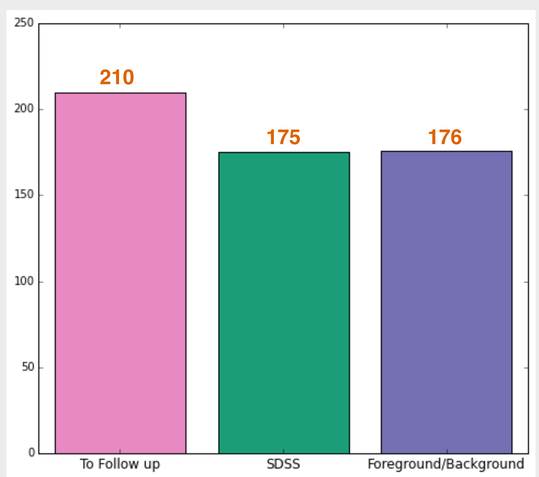

Figure 5. This figure demonstrates the status of our follow-up campaign. Those candidates that lie outside of the SDSS footprint and with redshifts 0.1 < z < 0.7 will be followed up with the PISCO camera on the Magellan Clay Telescope.

What's Next?

We are in the midst of following up these 385 galaxy cluster candidates. Most of our candidates in the Northern hemisphere (175) have data available from the Sloan Digital Sky Survey (SDSS). For the candidates in the Southern hemisphere, we have begun follow up observation using the Magellan telescope.

On completion of the optical follow-up, we will use both the SDSS/Magellan images to determine which candidates lie at the center of rich clusters using the Red Sequence Method [2].

Confirmed galaxy clusters harboring extreme central galaxies will be followed up using the Chandra X-ray Observatory. The full catalog of clusters hosting extreme (QSOs or starbrusts) central galaxies will be published based on the optical follow-up (Somboonpanyakul in prep).

Broader Impacts

The discovery of new, nearby galaxy clusters missed by previous all-sky surveys will allow insight into the completeness of these survey, leading to improved constraints for both astrophysical and cosmological studies.

In addition, this will be an ideal sample to study the effects of QSOs on the intracluster medium, providing a testing ground for various feeding and feedback scenarios.

Literature cited

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Further Information

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