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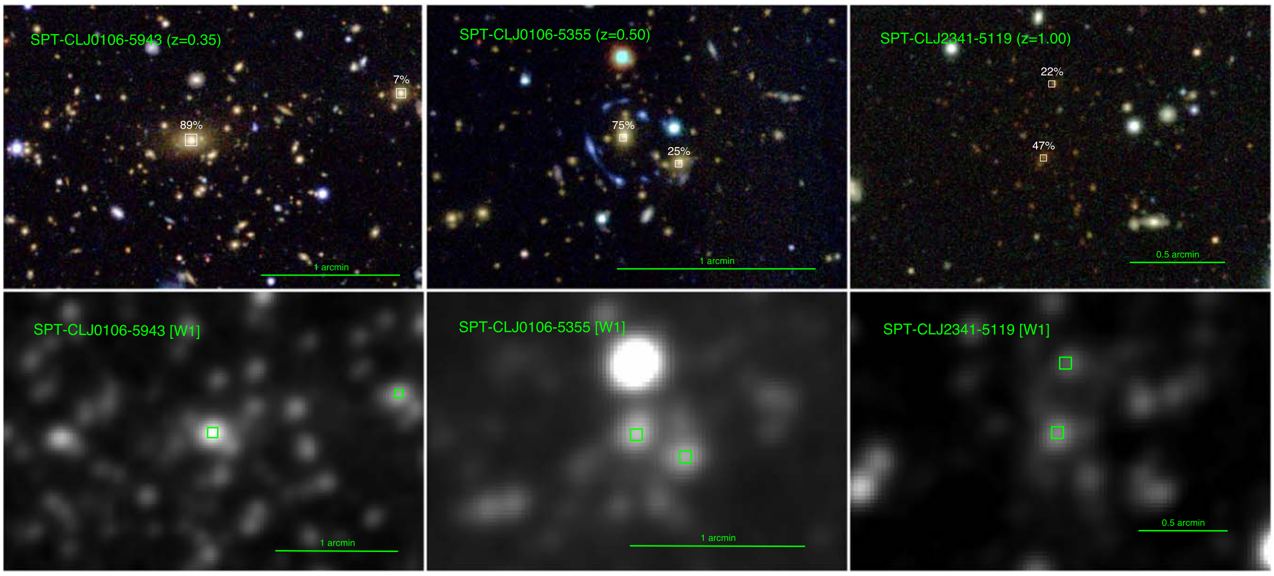

Figure 1. The top three panels show DES *gri* optical images of three SPT galaxy clusters, including SPT-CLJ0106-5943, SPT-CLJ0106-5355, and SPT-CLJ2341-5119. The white boxes show the location of the two highest-probability BCG candidates for each cluster, while the white numbers show the probability (in percentage) for each object to be a true BCG. The three examples are ranging from $z = 0.35$ to $z = 1.00$, demonstrating the ability of this method to find BCG candidates up to high redshift. The bottom three panels show the corresponding WISE images from the W1 channel for the three SPT clusters. The green boxes show the same location of the two highest-probability BCG candidates, suggesting that the BCG candidates are detectable in mid-IR.

WISE color for each BCG, which has the advantage that more than four times as many exposures are included as were used for the AllWISE catalog while using the same AllWISE software. This makes a comparison with previous works more straightforward.

For every identified BCG (with a probability >5%) from Section 2.2, we search for mid-IR counterparts in the CatWISE catalog within a radius of 3″ from the identified BCG because the typical FWHMs for $W1$ and $W2$ are 6.″08 and 6.″84, respectively. Both $W1$ and $W2$ are converted from Vega into AB magnitudes using the correction from the Explanatory Supplement to the WISE Products.[57] The bottom three panels of Figure 1 show $W1$ images of the three SPT clusters, showing that their BCG candidates can be detected with WISE data.

2.3.2. CatWISE Color Correction

We perform a comparison test between the AllWISE and CatWISE catalogs. The test is carried out by comparing the $(W1 - W2)_{\rm AB}$ color of bright objects ($16.5 < W1_{\rm AB} < 18$) between the two catalogs within 10 arcmin of one field. A histogram of the color differences is plotted in Figure 2, showing the offset between the color from AllWISE and CatWISE to be around 0.042. Further investigation reveals that this is due to the gradual diminishing of the $W2$ throughput with time, leading to a bluer $(W1 - W2)_{\rm AB}$ color compared to AllWISE. We apply this correction of 0.042 mag to CatWISE $W1$–$W2$ colors.

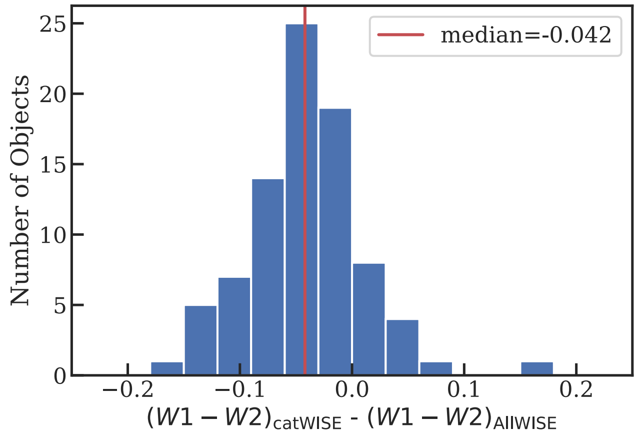

Figure 2. This figure shows a comparison of $W1$–$W2$ between AllWISE and CatWISE. The red line is the median of the difference at 0.042 mag.

3. Method

3.1. AGN Selection

With the WISE satellite, Stern et al. (2012) developed a well-known formula for quickly identifying AGN candidates with a simple color criterion, $(W1 - W2)_{\rm Vega} \geqslant 0.8$ or $(W1 - W2)_{\rm AB} \geqslant 0.16$. One benefit of mid-IR selected samples is that both unobscured (type 1) and obscured (type 2) AGN can be identified (Lacy et al. 2004; Stern et al. 2005, 2012). However, because the colors of galaxies drastically change over a large redshift range, this simple criterion is not accurate enough to characterize a large population of AGNs. To increase the number of AGNs we can identify, we develop a new color criterion that depends on the redshifts of galaxies.

3.1.1. EzGal Galaxy Color Model

To determine whether each BCG harbors an AGN, we calculate the expected color for typical elliptical galaxies using EzGal.[58] EzGal calculates the magnitude evolution as a function of redshift from evolving the spectral energy distribution (SED) models of a stellar population with time

[57] wise2.ipac.caltech.edu/docs/release/allsky/expsup/sec4_4h.html

[58] www.baryons.org/ezgal/