Quasars are not in cluster of galaxies, but in group of galaxies

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Abstract

We have performed Suprime-Cam multi-band imaging of high redshift cluster of galaxies candidates identified by Mg II absorption lines. Our cluster candidates were selected by Mg II absorption lines which are more than 1000 km s^{-1} ***redshifted*** from the background quasar. The service observation has been done for two quasars at z~1 with *r'*, *i'*, and *z'*-bands. The seeing was good (0.6"-0.8"), and the two candidates were most promising ones, however, we could not any signs of cluster of galaxies. As the large velocity indicates the rather large mass, they may be the ancestor of 'fossil group' which has a single large galaxy with group-scale mass.

Instead, we discovered the two targeted quasars mentioned above and another quasar (z=0.74) serendipitously observed reside in the group of galaxies. There are 3-4 galaxies within 50 kpc from the quasar, and quasars and galaxies have signs of interactions.

Introduction

The popular method for discovering high redshift clusters of galaxies are (1) ``Red Sequence Cluster Survey " by wide-field opt-near IR imaging and (2) ``X-ray Survey" by such as *Chandra* and XMM-Newton satellites. The former method uses high number density of red evolved galaxies as sign of clusters of galaxies. The latter method uses hot gas as sign of deep potential of cluster of galaxies. Both methods succeed in discovering many high redshift clusters of galaxies.

We have proposed another method of searching for high-redshift clusters. Our new method uses Mg II absorption lines which are more than 1000 km s^{-1} **redshifted** from the background quasar. The objects producing those absorption lines are located in front of the quasar. Therefore the objects are moving towards the quasar. Only deep gravitational potential made by huge mass as 10^{14} solar mass can explain such high velocity..

Observations

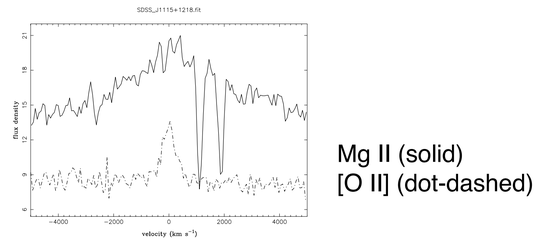
We search for high-velocity **redshifted** Mg II absorption line towards quasars as follows. (1) We selected ~ 37,000 $0.44 \leq z \leq 1.4$ quasars from Sloan Digital Sky Survey (SDSS) DR7. The redshift range is determined in order to include Mg II and [O II] lines. (2) We chose Mg II absorption lines which is more than 1000 km s^{-1} redshifted from background quasars of which redshift are defined by their [O II] emission line. Finally we discovered three quasars of which Mg II absorption line systems are more than 1000 km s^{-1} redshifted.

Two of the quasars were observed with Subaru 8.2-m telescope/SuprimeCam as the Service Program on March 31, 2011 under a photometric condition. The details of the observations are listed in the table.

seeing	1115+1218	1508+1408	integ. time
r'	0.63"	0.74"	1960s
i'	0.58"	0.64"	500s
z'	0.56"	0.78"	400s

Results - SDSS J1115+1218

This quasar is at z=1.18 (8.3 kpc/"), and radio-quiet. The absolute magnitude, M_i is -25.96.



Mg II (solid)
[O II] (dot-dashed)

Fig. 1 The redshifted Mg II absorption lines and [O II] emission line of SDSS J1115+1218.

We chose galaxies of *r'*-*i'* > 1.1 and 0.8 < *i'*-*z'* < 1.15 as the quiescent galaxies around redshift of 1. We could not find condensation of quiescent galaxies around the quasar.

Fig. 2. The *r'*, *i'*, and *z'* color composite image of the region of SDSS J1115+1218.

On the other hand, at the very vicinity of the quasar we discovered possible companion galaxies, one red object at 0.8" (6.6 kpc) south, and another one at 3.4"(28 kpc) SE.

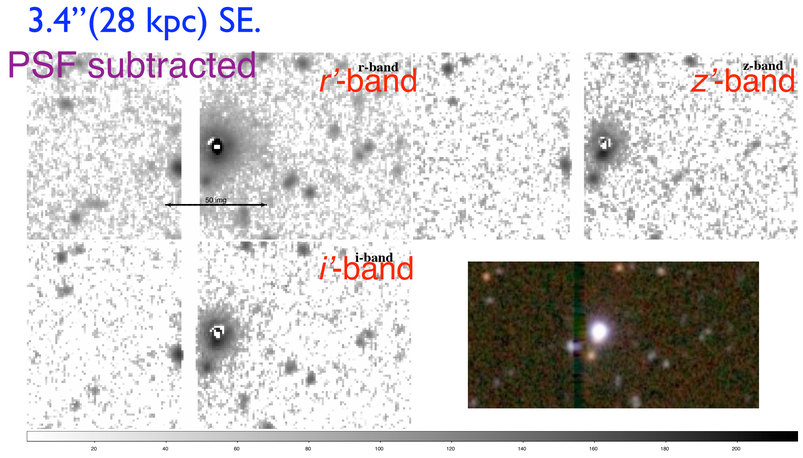
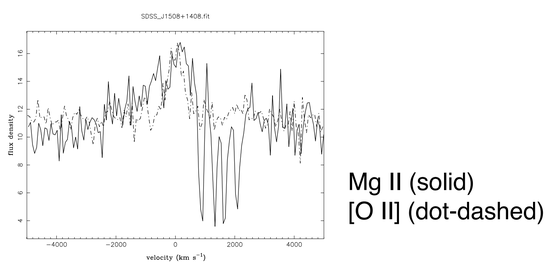


Fig. 3. The close up images of SDSS J1115+1218.

Results - SDSS J1508+1408

This quasar is at z=0.91 (7.8 kpc/") and radio-loud. M_i is -25.61.



Mg II (solid)
[O II] (dot-dashed)

Fig. 4. Same as Fig. 1, but for SDSS J1508+1408.

Fig.5 . Same as Fig. 2, but for SDSS J1508+1408.

We got the similar results of SDSS J1508+1408 as well as SDSS J1115+1218. While no passive galaxies concentrate around the quasar, several red knots exist within 50 kpc inside of a asymmetric nebulosity.

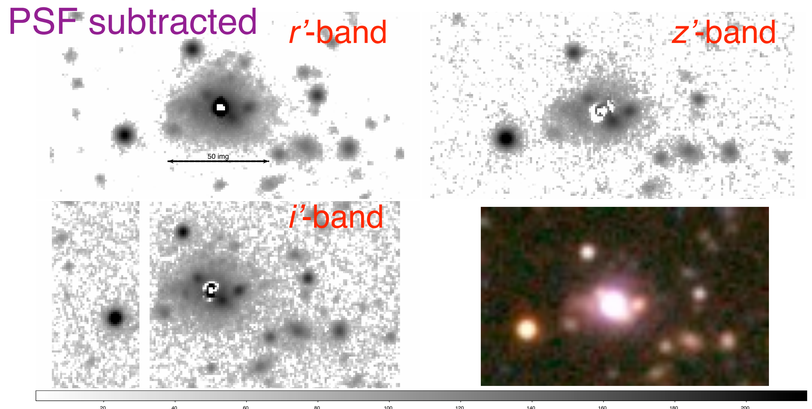


Fig. 6. The close up images of SDSS J1508+1408.

We imaged this quasar in *K'*-band with IRCS/AO188 (LGS mode) on July 30, 2011. The integration time was 4410s, final FWHM was 0.09" and Strehl ratio ~ 0.2. Most of red knots are resolved to be galaxies, and some show tidal features.

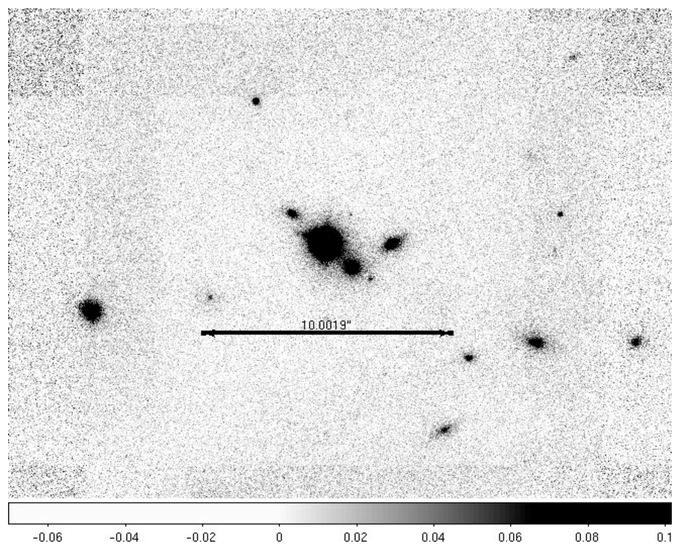


Fig. 7. The IRCS/AO188 image of SDSS J1508+1408.

These results show high velocity infalling gas does not mean cluster of galaxies. Since a large velocity requires rather large mass, we may see the precursor of 'fossil group' which is dominated by one bright galaxy in the optical light , but mass estimated by X-ray is similar to a group of galaxies.

Inconvenient Results? - SDSS J1507+1405

Another interesting result is a number of close companions. Does redshifted Mg II absorption prefers close companions? Several quasars without Mg II absorption in our FOV by chance do not have such bright companions. In the literature, a radio-loud quasar 3C 195 (z=1.195) has $z_{abs} \sim z_{em}$ (145 km s^{-1} redshifted) absorption lines and many knots and close companions (Stockton & Ridgway 2001).

On the other hand, unsupportive evidence is in our own data! One quasar, SDSS J1507+1405 at z=0.74 (7.3 kpc/"), serendipitously lies in our FOV. It has many companion galaxies, but **no** Mg II absorption lines. This quasar is radio-quiet, and M_i is -24.77.

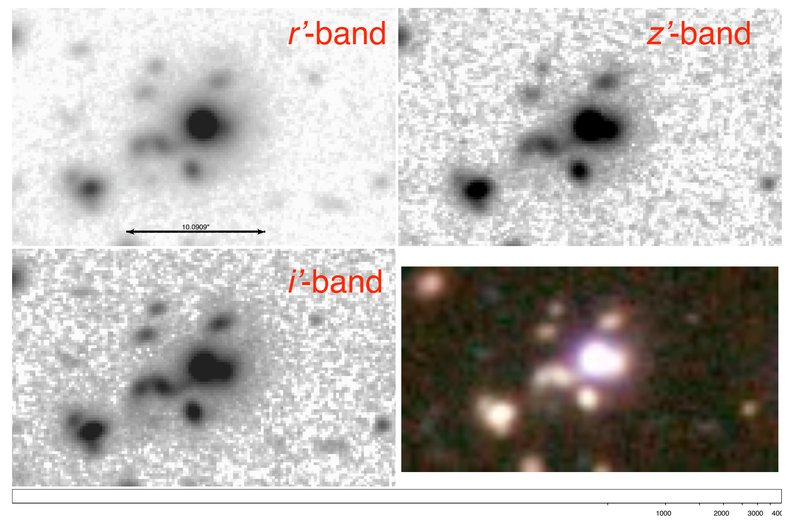


Fig. 8. The close up images of SDSS J1507+1405.