[4B] Discovery of an Extreme Ionized-gas Outflow in an *AKARI*-selected Ultra-luminous Infrared Galaxy at $z = 0.5$

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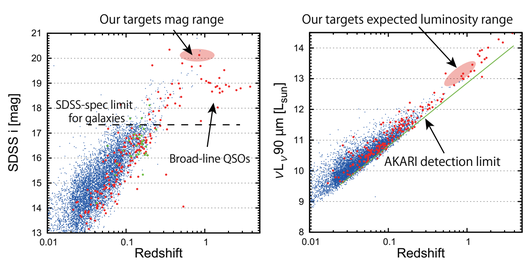
1. Introduction

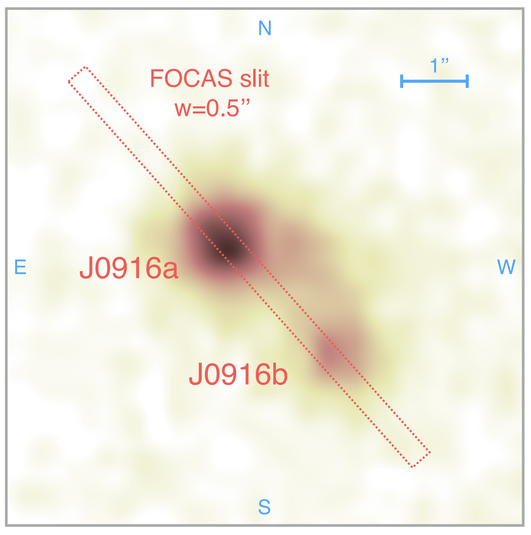
Ultra-luminous infrared galaxies (ULIRGs, with infrared luminosity, $L_{\rm IR} > 10^{12}$ L$_\odot$) are a population of the most intensely star-forming galaxies in the local universe. They are thought to represent rapidly growing phase of massive galaxies. The vigorous starburst and / or AGN in ULIRGs can induce strong outflowing winds, which would blow out the gas and dust and terminat the activity of the galaxies.

2. Sample Selection

In order to construct a sample of ULIRGs at $0.5 < z < 1$, we are conducting an optical follow-up program for bright 90-μm FIR sources with a faint optical ($i < 20$ mag) counterpart selected in the *AKARI* FIS Bright Source catalog (Ver.2).



J0916a, identified at $z = 0.49$ in the spectroscopic follow-up observation, indicates signatures of an extremely strong outflow in its emission line profiles.



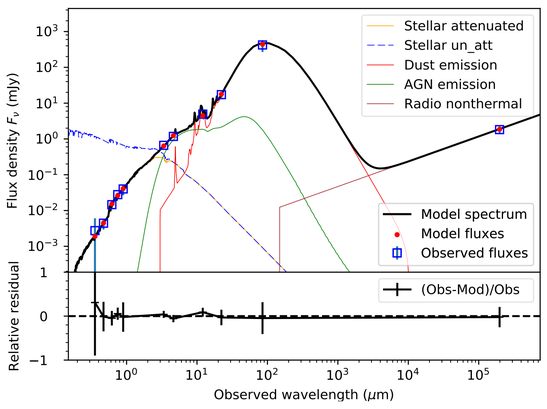
6. Conclusion

J0916a shows extremely broad and extended profiles in both [OIII] and [OII] emission lines, which indicate one of the most powerful outflow among galaxies at $z < 1.6$. However, the AGN activity in J0916a is relatively weak. The powerful outflow probably reflect a historical effect of the central engine.

7. Reference

• Chen et al. 2018, submitted to PASJ AKARI special issue

3. SED analyses and galactic properties

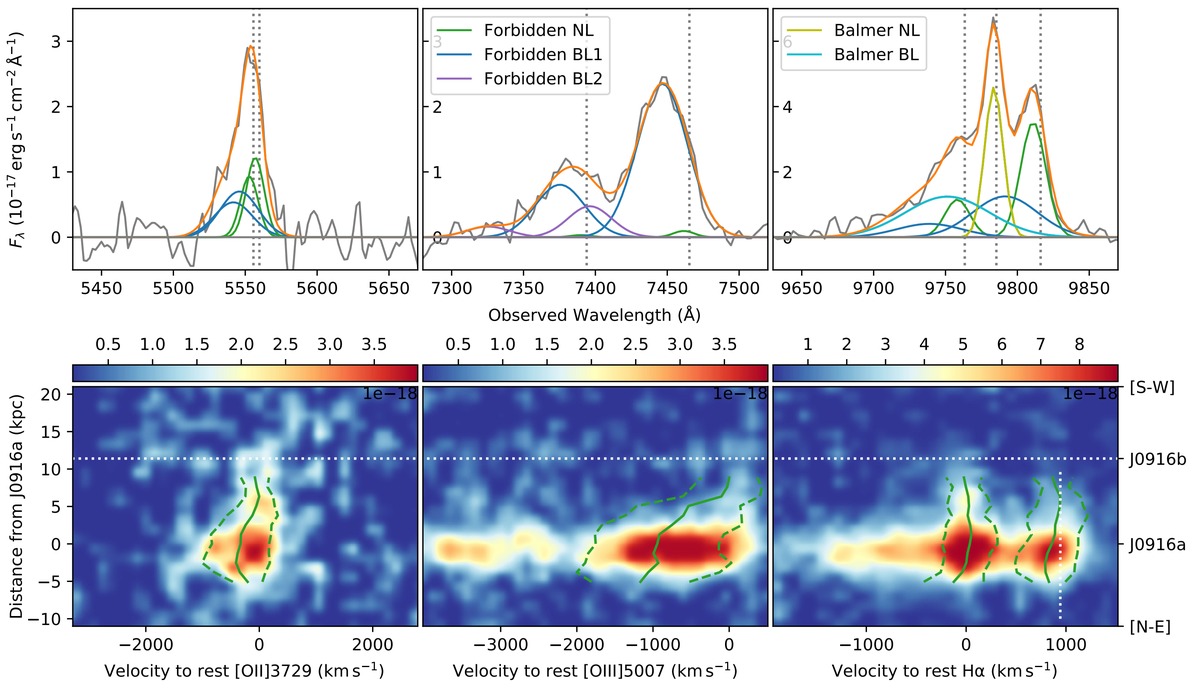


Combining the photometric data from SDSS, *WISE*, *AKARI* and VLA FIRST Survey, we performe SED fitting with `CIGALE`.

• J0916a shows intense star formation but relatively weak AGN contribution in the IR luminosity.

SFR	990 ± 44 M$_\odot$ yr^{-1}
$M_\star$	$9.5 \pm 1.7 \times 10^{10}$ M$_\odot$
$L^{\rm star}_{\rm unattenuated}$	$6.9 \pm 0.3 \times 10^{12}$ L$_\odot$
$E(B-V)_{\rm SED}$	1.5 ± 0.1
$E(B-V)_{\rm Balmer}$	1.0 ± 0.3
$L^{\rm dust}_{\rm IR}$	$5.8 \pm 0.3 \times 10^{12}$ L$_\odot$
$L^{\rm tot}_{\rm IR}$	$6.1 \pm 0.3 \times 10^{12}$ L$_\odot$
$L^{\rm AGN}_{\rm bol}$	$4.7 \pm 0.4 \times 10^{11}$ L$_\odot$
$f^{\rm AGN}_{\rm IR}$	6.27 ± 0.66 %
$f^{\rm AGN}_{\rm bol}$	6.34 ± 0.65 %

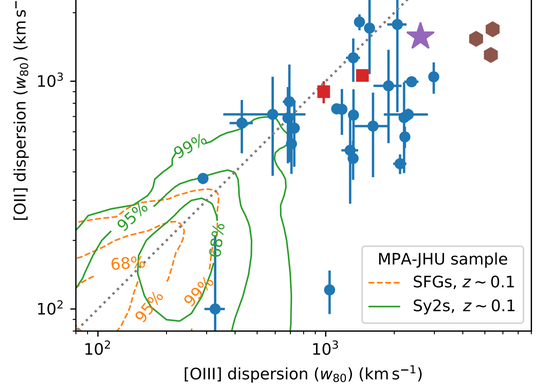
4. Extreme outflow indicated by broad [OII] and [OIII] lines



The spectral fitting is performed for the integrated spectrum (upper) and 2D long-slit spectroscopy image per line (bottom), after extraction of stellar continuum.

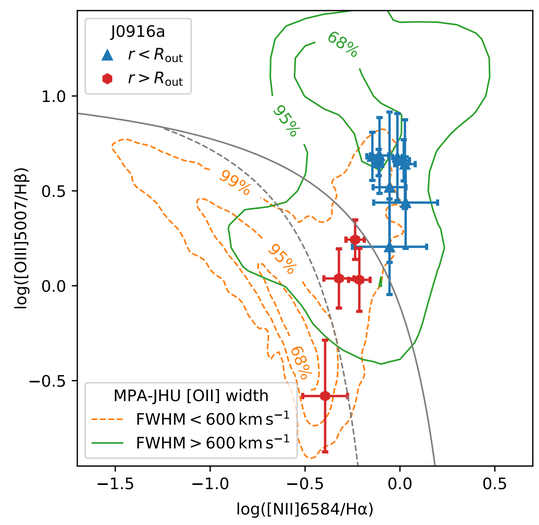
• Both of high- and low-ionization potential emission lines, e.g., [OIII] and [OII] doublets, show large velocity dispersions and shifts in relative to the stellar absorption lines.

(km s^{-1})	[OII]	[OIII]
shift (v_{50})	-384 ± 20	-894 ± 38
width (w_{80})	1570 ± 85	2607 ± 172



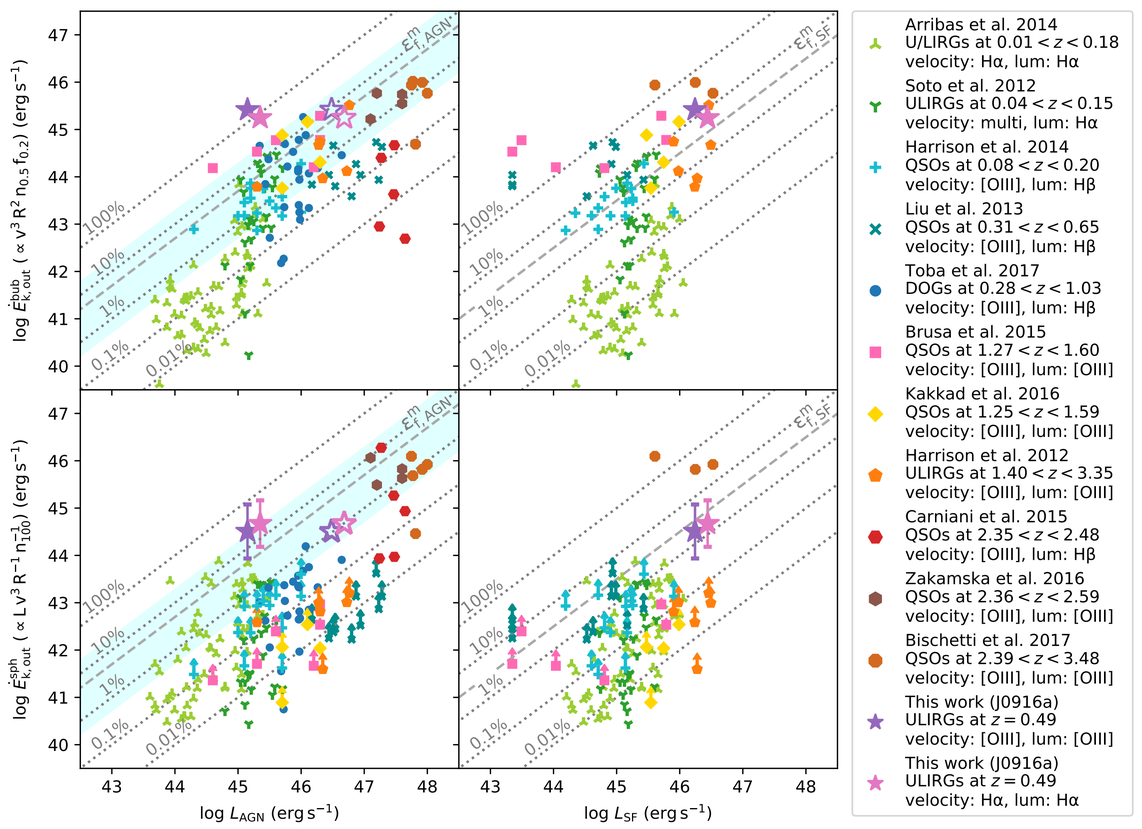
• The broad profiles of [OII] doublet and [OIII] line correspond to one of the fastest outflow among ULIRGs / DOGs at $0.3 < z < 1.0$, and are even comparable to the luminous quasars at $z \sim 2$.

• The long-slit spectroscopy image shows that the outflow extends up to 6 kpc. AGN dominates the ionization in the outflow region.



5. Large energy ejection rate with weak AGN activity

The energy ejection rate of J0916a is estimated with two models:
(1) assuimng the ionized outflowing gas in a spherically symmetric sector, $\dot{E}^{\rm sph}_{\rm k,out}$;
(2) assuimng an energy-conserving shocked bubble expanding into a uniform medium, $\dot{E}^{\rm bub}_{\rm k,out}$.
For reference, we also calculate $\dot{E}^{\rm sph}_{\rm k,out}$ and $\dot{E}^{\rm bub}_{\rm k,out}$ for U/LIRGs and QSOs from local universe to intermediate and high redshifts, assuming $n_{\rm e} = 100$ cm^{-3} and $T_{\rm e} = 10^4$ K in model (1), and ambient density $n_0 = 0.5$ cm^{-3} in model (2). The $\dot{E}_{\rm k,out}$ versus AGN bolometric luminosities and SF IR luminosities are summarized in right figure.



• J0916a shows one of the largest $\dot{E}_{\rm k,out}$ among the galaxies at $z < 1.6$. However, the $L_{\rm AGN}$ (from MIR luminosity) of J0916a corresponds to only 1 %–10 % of $L_{\rm AGN}$ of the galaxies with similar $\dot{E}_{\rm k,out}$. The low $L_{\rm AGN}$ implies the possibility that AGN lies in a fading status; while the observed extreme [OIII] and [OII] outflows probably reflect a historical effect of the central engine during its preceding active phase, due to the time-lag between AGN activity in a nuclear region (dusty torus) and outflow in an ionization cone.
• The intense star formation activity also possibly contributes to the fast outflow in J0916a.