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Optical properties of infrared-bright dust-obscured galaxies viewed with Subaru Hyper Suprime-Cam

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Abstract. Optical properties of infrared-bright (IR-bright) dust-obscured galaxies (DOGs) are reported. DOGs are faint in optical but very bright in mid-IR, which are powered by active star formation (SF) or active galactic nucleus (AGN), or both. The DOGs is a candidate population that are evolving from a gas-rich merger to a quasar. By combining three catalogs of optical (Subaru Hyper Suprime-Cam), near-IR (VIKING), and mid-IR (ALLWISE), we have discovered 571 IR-bright DOGs. Using their spectral energy distributions, we classified the selected DOGs into the SF-dominated DOGs and the AGN-dominated DOGs. We found that the SF-dominated DOGs show a redder optical color than the AGN-dominated DOGs. Interestingly, some DOGs shows extremely blue color in optical (blue-excess DOGs: bluDOGs). A possible origin for this blue excess is either the leaked AGN light or stellar UV light from nuclear starbursts. The BluDOGs may be in the transition phase from obscured AGNs to unobscured AGNs.

Keywords. galaxies: active, galaxies: starburst, infrared: galaxies, methods: statistical

1. Introduction

Dust-obscured galaxies (DOGs), whose color between optical and mid-IR is very red ($(i-[22])_{\rm AB} \geqslant 7.0$; Toba *et al.* 2015), are believed to be a candidate population that are evolving from gas-rich mergers to quasars. The origin of their red color is faint optical emission reduced by dust and bright mid-IR emission powered by active star formation (SF) or active galactic nucleus (AGN), or both (Dey *et al.* 2008). DOGs are classified into SF-dominated DOGs and AGN-dominated DOGs by using the spectral energy distribution (SED). The SED of SF-dominated DOGs shows a bumpy feature at rest-wavelength 1.6 μm (hereafter bump DOGs), while the SED of AGN-dominated DOGs shows a power-law SED between optical and mid-IR (hereafter PL DOGs). However, optical properties of IR-bright DOGs are still unclear, since their number density is very

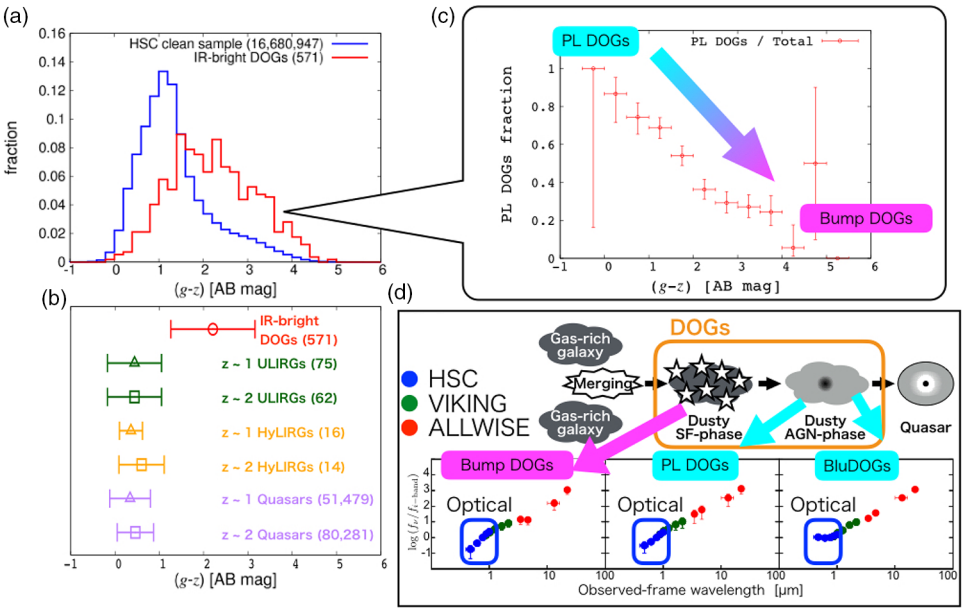

Figure 1. [A]: The $(g-z)_{\rm AB}$ color distribution of IR-bright DOGs (red) and the entire HSC sample (blue). [B]: The $(g-z)_{\rm AB}$ color means and standard deviations of IR-bright DOGs (red), ULIRGs (green), HyLIRGs (yellow), and quasars (purple). [C]: The PL fraction as a function of the $(g-z)_{\rm AB}$ color. [D]: The gas-rich major merger scenario (upper illustration; e.g., Dey *et al.* 2008), and the averaged SED of bump DOGs (lower left panel), PL DOGs (lower center panel), and BluDOGs (lower right panel).

low ($\log \phi = -6.59 \pm 0.11$ [Mpc^{-3}]: Toba *et al.* 2015), and their optical fluxes are very faint ($\sim$23 mag or fainter: Toba *et al.* 2015). In this work (presented in Noboriguchi *et al.* 2019), we investigate optical properties of IR-bright DOGs using the Hyper Suprime-Cam (HSC) wide-field data obtained through the Subaru Strategic Program survey (Aihara *et al.* 2018).

2. Sample selection, results, and discussion

By combining three catalogs of optical (HSC), near-IR (VIKING), and mid-IR (ALLWISE), we discovered 571 IR-bright DOGs. The $(g-z)_{\rm AB}$ color of IR-bright DOGs is redder and broader than that of the entire HSC sample (as a typical object sample), dusty galaxies (e.g., ULIRG and HyLIRG) and quasars (Figure 1 [A] and [B]). By comparing the $(g-z)_{\rm AB}$ distribution of bump DOGs with PL DOGs, we found that the bump DOGs occupy the redder part while the PL DOGs occupy the bluer part in the optical color distribution of DOGs (Figure 1 [C]). Some of our DOGs show extremely blue color as also reported for dusty galaxies by Assef *et al.* (2016), and we call them blue-excess DOGs (BluDOGs). The possibilities for the origin of the blue excess are 1) leaked AGN light and 2) radiation of massive stars in the starburst region. By focusing on their optical SED, BluDOGs are suggested to be in the evolving phase between obscured phase (i.e., DOGs) and unobscured phase (i.e., quasar) as shown Figure 1 [D].

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