Discovery of blue-excess dust-obscured galaxies by using Subaru Hyper Suprime-Cam

Akatoki Noboriguchi,

Tohru Nagao, Masaru Kajisawa, Yoshiki Matsuoka,
Yuichi Terashima, Takuji Yamashita, Mana Niida,
Shuhei Koyama, Nobuhara Kodai (Ehime U.),
Masafusa Onoue (MPIA),
Yoshihiro Ueda, Yoshiki Toba (Kyoto U.),
Yutaka Komiyama (NAOJ), Yu-Yen Chang (ASIAA),
Toshihiro Kawaguchi (Onomichi-city U.)

Noboriguchi et al. accepted to ApJ
2019ApJ...876..132N

Summary

- We searched for infrared-bright (IR-bright) dust-obscured galaxies (DOGs) with a blue excess in optical bands in 105 deg^2.
- We found **8 blue-excess DOGs (BluDOGs)**.
- **The possible origins of their blue-excess** are a **leaked AGN light** and/or **stellar UV light** from starbursts.

Dust-Obscured Galaxies

very red

- **definition**

  R - [24] ≥ 14.0 [vega mag] Dey+08
  i - [22] ≥ 7.0 [AB mag] Toba+15

rare

- **number density**

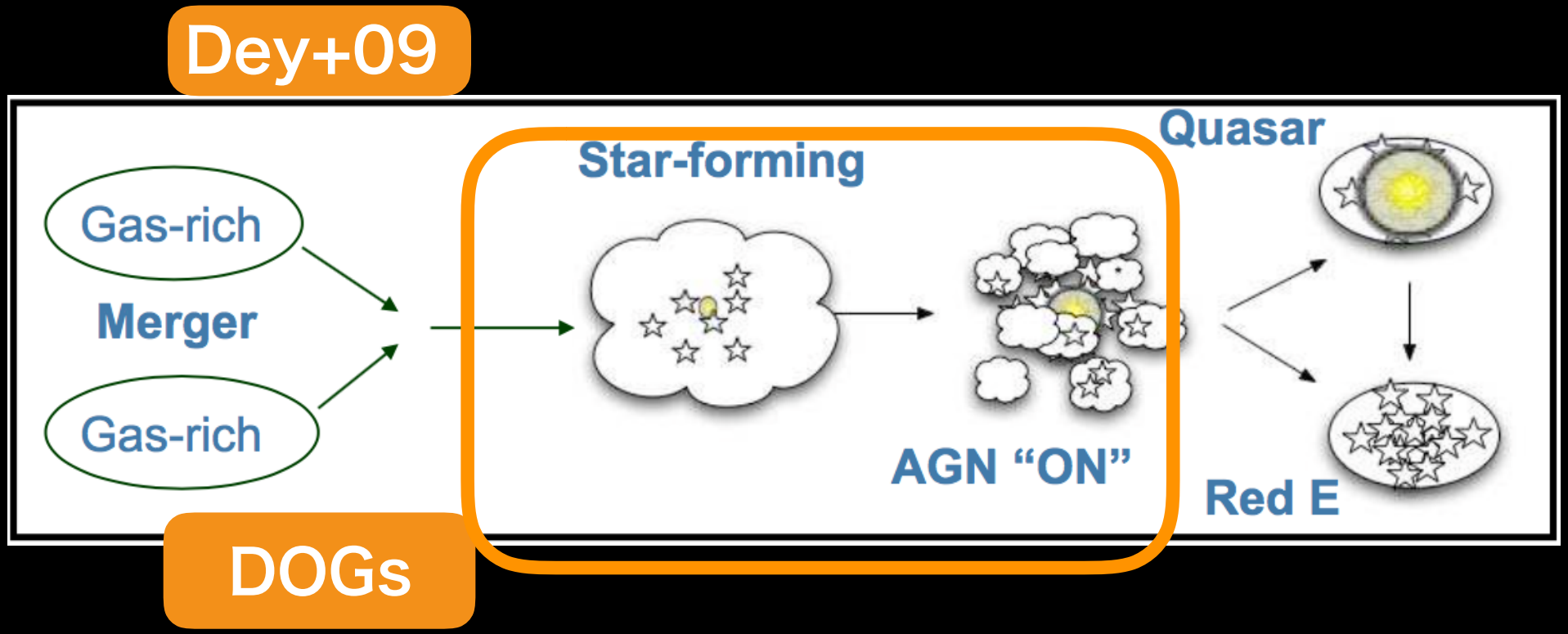
  $\log\varphi = -6.59 \pm 0.11$ [Mpc^{-3}] Toba+15

far

- **redshift**

  z = 1 - 2 Dey+08, Toba+15

The major merger scenario



Dey+09 suggested
the DOGs are in the transition phase.

Hot DOGs

Hot DOGs are selected by only using the WISE bands.
(Eisenhardt+12; Wu+12)

Dust temperatures

DOGs
$T_{dust} < 60$ K
Melbourne+12

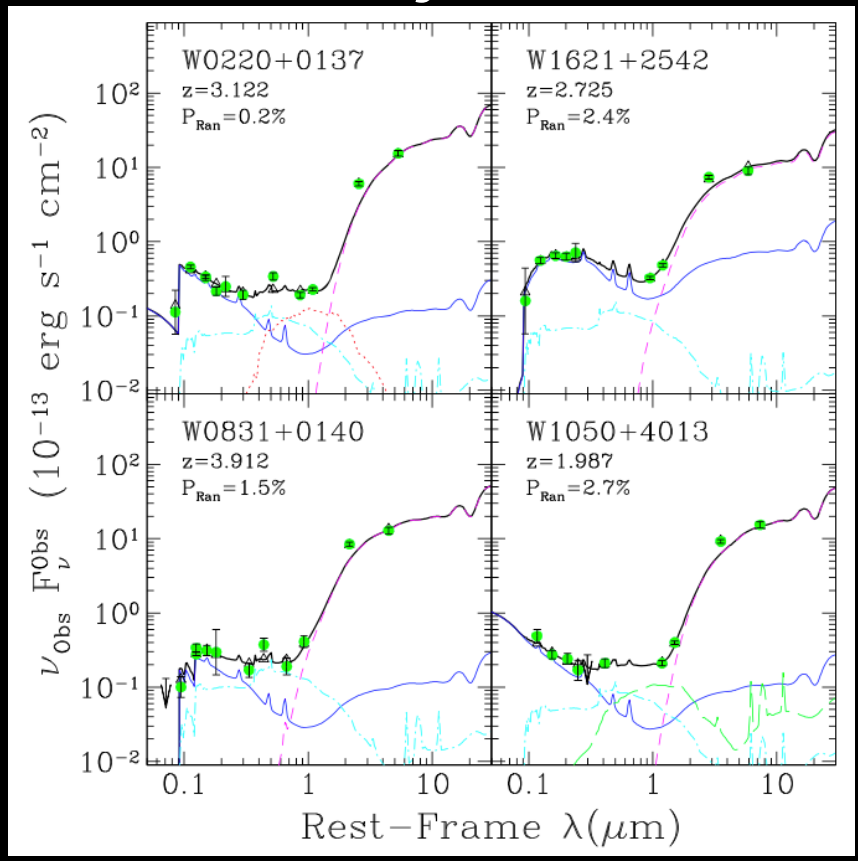
Hot DOGs
$T_{dust} > 60$ K
Eisenhardt+12; Wu+12

DOGs' feature +
High dust temperatures

blue-excess Hot DOGs

Blue-excess Hot DOGs are discovered by Assef+16.

- Blue excess in optical bands
- $N_H \sim 6 \times 10^{23}$ [cm^{-2}] from X-ray observation



They suggest that the blue excess of Hot DOGs is thought to be a **leaking scattered AGN emission into our line of sight**.

The optical blue-excess of Hot DOGs may be an evidence of the evolution from DOGs to quasars.

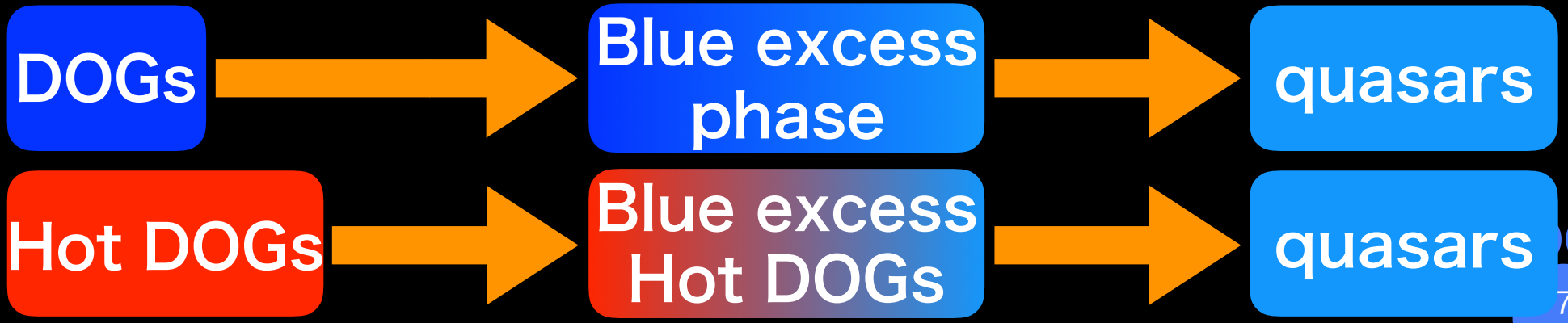
The relation among HotDOGs, DOGs, and quasars

However…

Do DOGs evolve into quasars via Hot DOGs?
If DOGs can directly evolve into quasars,
DOGs should experience the blue excess phase.

Path A

Path B



Purpose of this work

Question

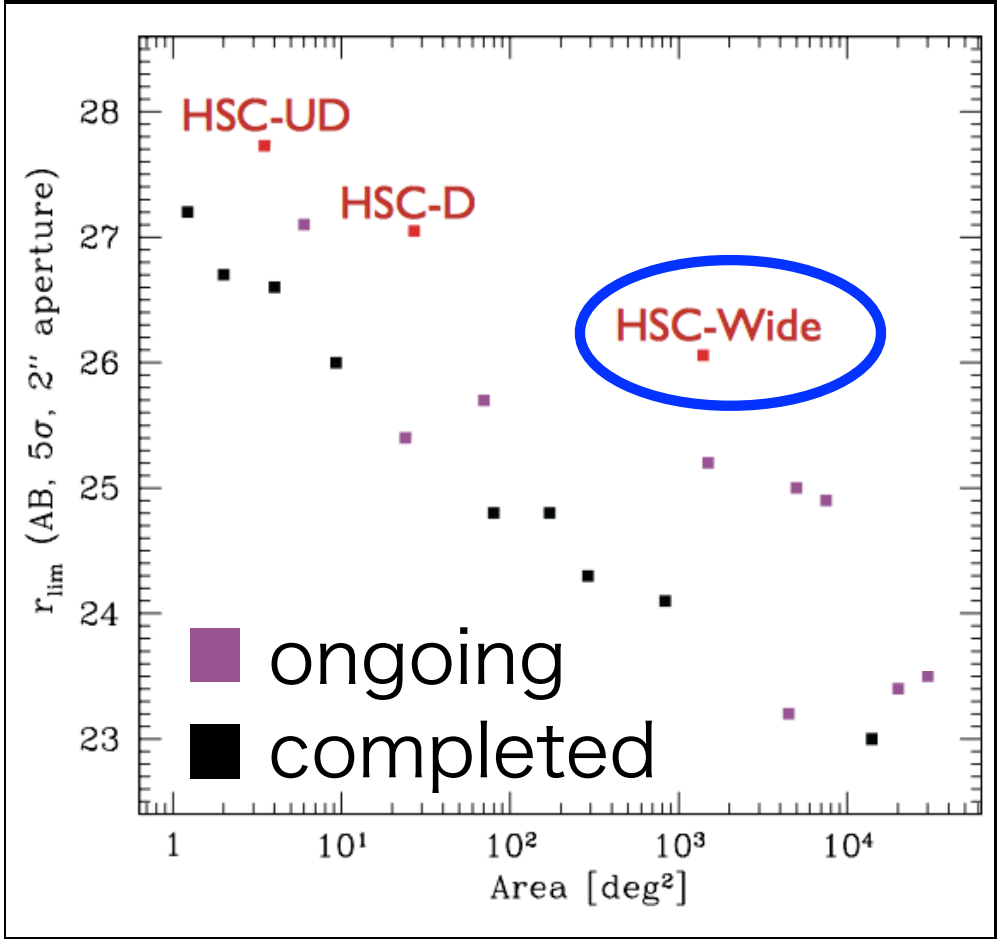
Are there not only blue-excess Hot DOGs, but also **blue-excess** DOGs?

This work

We searched for **blue-excess DOGs** with **Subaru Hyper Suprime-Cam**, VIKING (near-IR), and WISE (mid-IR).

Sample selection

Hyper Suprime-Cam



http://hsc.mtk.nao.ac.jp/ssp/wp-content/uploads/2016/05/hsc_ssp_rv_jan13.pdf

Hyper Suprime-Cam (HSC)

The properties of the HSC SSP survey are the following:

deeper *i*-band limiting mag 25.9 [AB mag]

wider Future 1400 [deg^2]
This work 105 [deg^2]

Best data for exploring DOGs which are optically faint and rare.

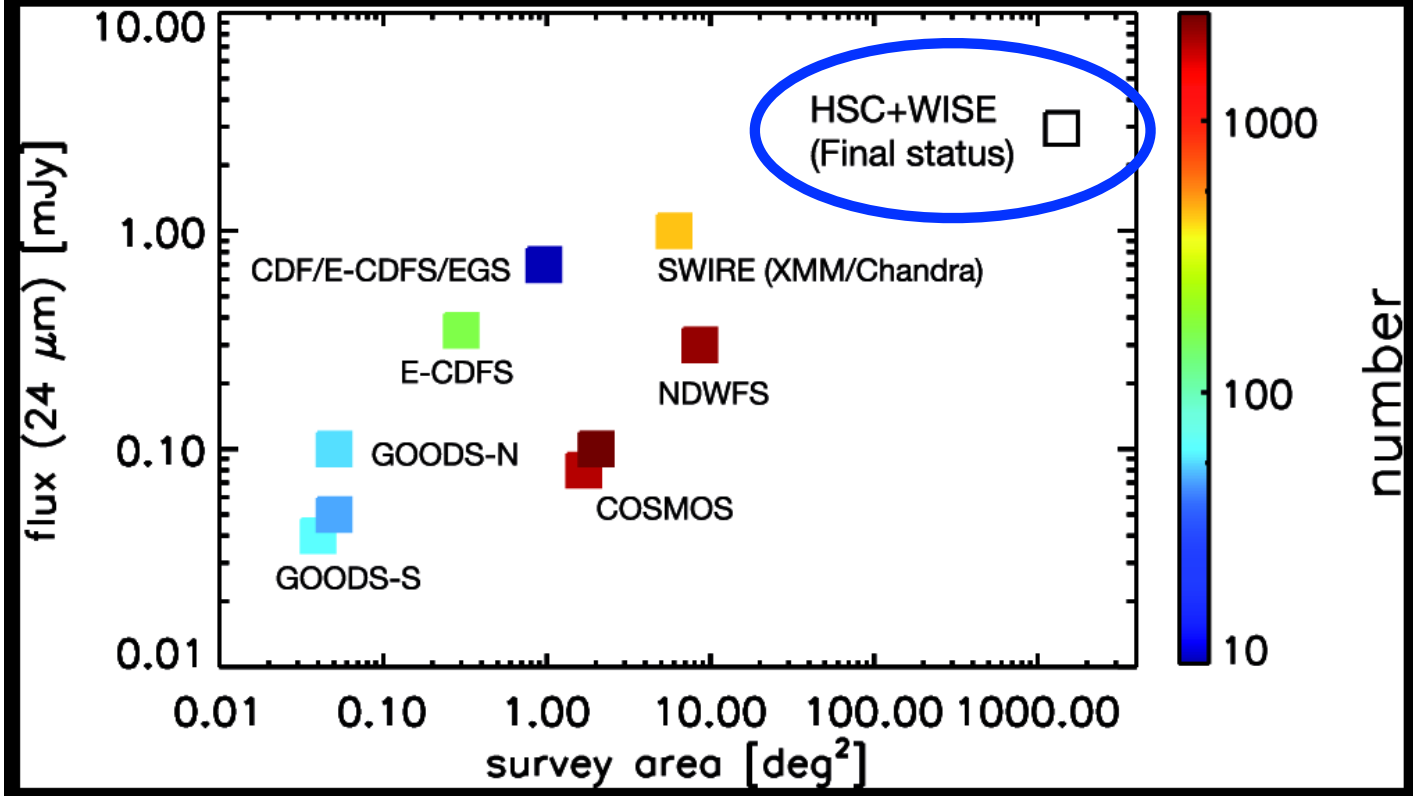
Data and sample selection

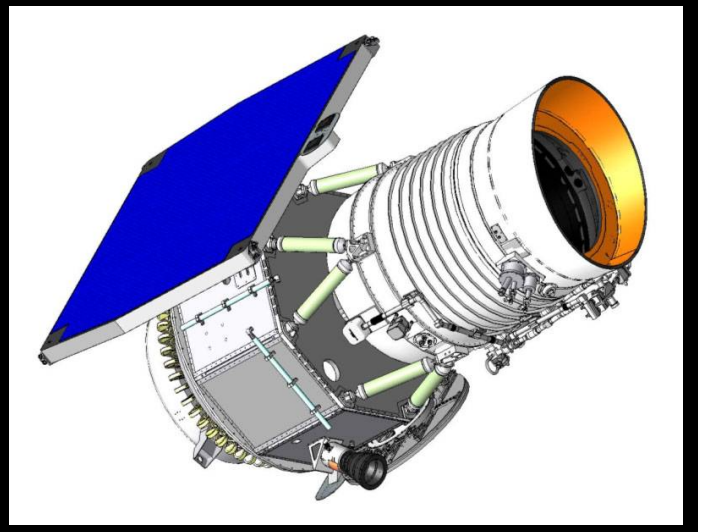
ALLWISE

Wide-field Infrared Survey Explorer (WISE)

ALLWISE catalog

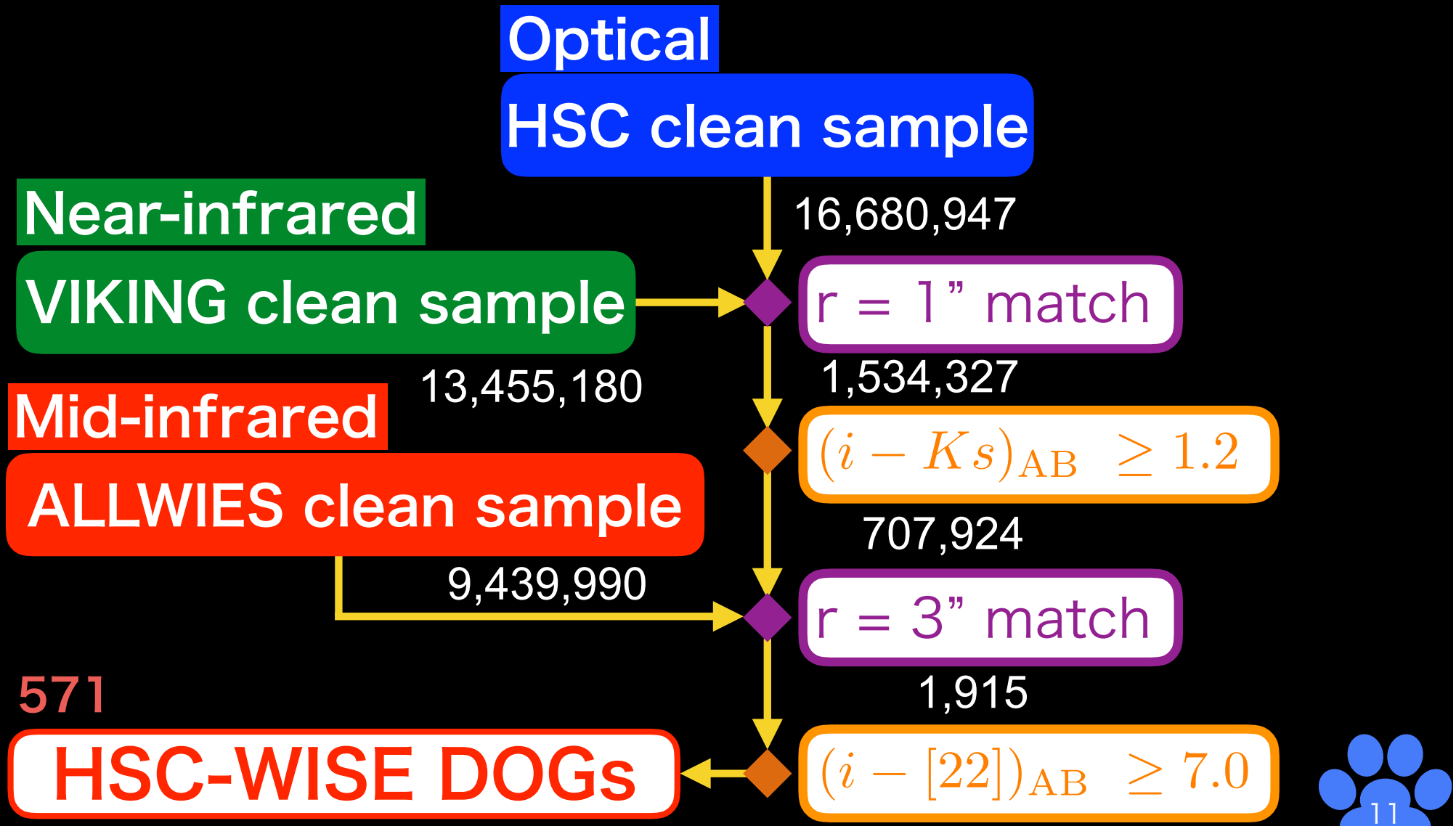
- All-sky survey catalog (Wright+10)
- WISE has 4 bands (3.4, 4.6, 12, and 22 μm)





Toba+15

Sample selection of IR-bright DOGs

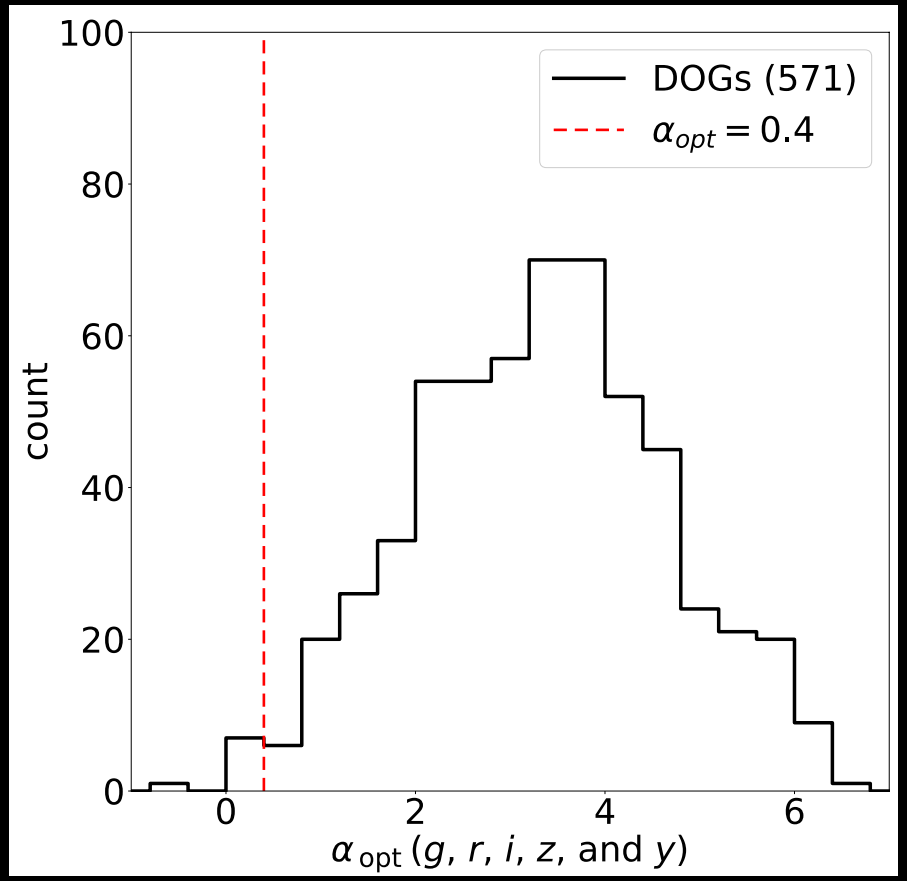


Sample selection of blue-excess DOGs

Our definition of **blue-excess DOGs (BluDOGs)** is as follows:

$$\alpha_{\mathrm{opt}} < 0.4,$$

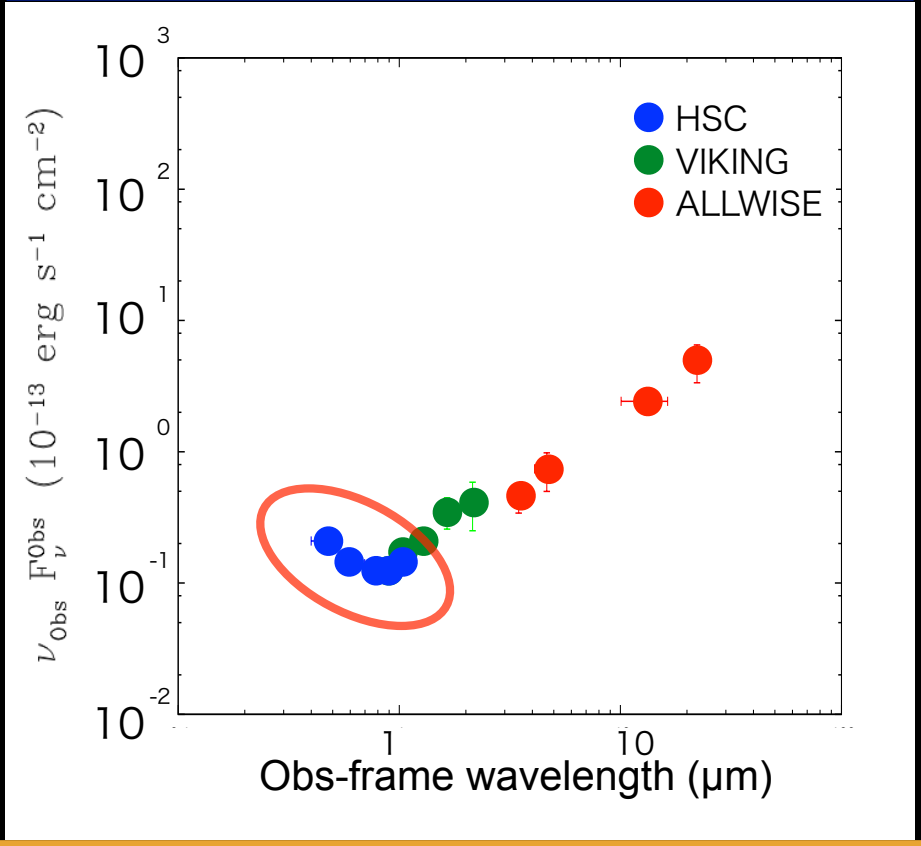
where α_{opt} is a slope of $\log f_{\mathrm{opt}} = \beta + \alpha_{\mathrm{opt}} \times \log \lambda_{\mathrm{opt}}$ for the 5 HSC bands.



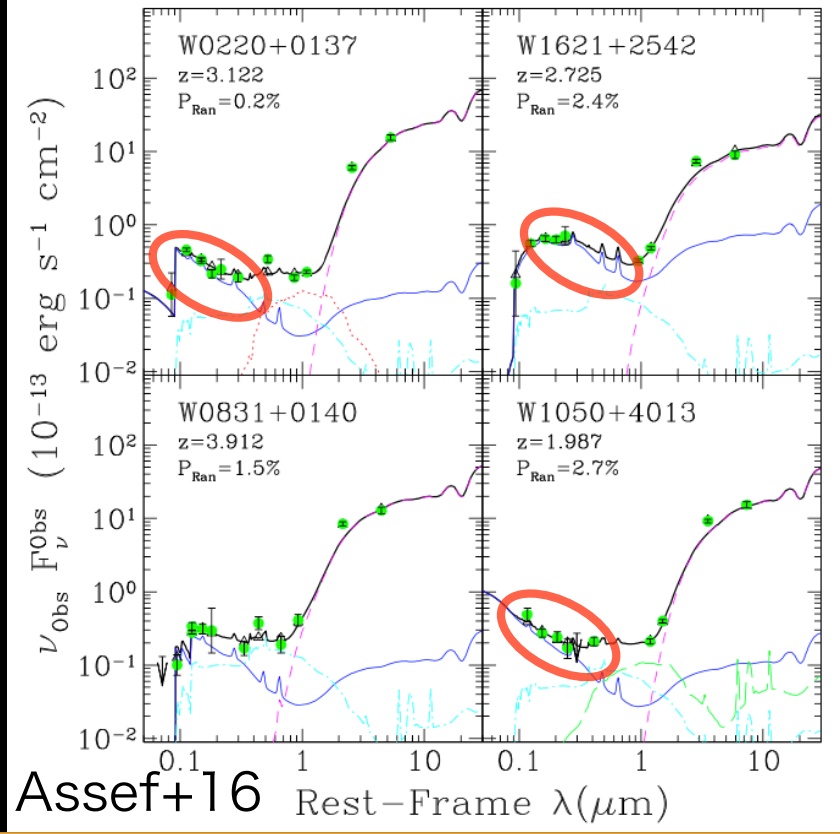
We selected **8 BluDOGs.**

Selection results

The averaged SED of BluDOGs



The SEDs of blue-excess Hot DOGs



Assef+16

The shape of the optical SED of BluDOGs is very similar to that of these blue-excess Hot DOGs.

Are there **blue-excess** DOGs?

Question

Are there not only blue-excess HotDOGs,
but also **blue-excess** DOGs?

Answer

Yes, there are **8 BluDOGs**.

We suggest that
DOGs do not necessarily evolve into quasars through the Hot DOGs phase.

The lifetime of BluDOGs

From results

- **8 BluDOGs** out of **571 IR-bright DOGs**
- The number fraction of BluDOGs = **~1%**

The lifetime of BluDOGs

Assumption:
DOGs lifetime of 100 Myr (Narayanan+10),

- **The estimated lifetime of BluDOGs** is **a few Myr**.
- If the blue-excess comes from the leaked AGN light, the timescale of the outflow phase could be **a few Myr**.

What is the origin of blue excess of BluDOGs?

Possibilities

- The **leaked AGN light**
- **Stellar UV light** from starbursts

Future plan

- **An identification of the origin** based on spectroscopic observations of bload emission lines.

Summary

There are not only blue-excess HotDOGs,
but also blue-excess DOGs.

Results / Discussion

- We found **8 BluDOGs out of 571 IR-bright DOGs**.
- The timescale of BluDOGs
  is estimated to be about **a few Myr**.
- **The possible origins** of their blue excess are
  the **leaked AGN light** and/or **stellar UV light**
  from starbursts.

Next step

- We have to obtain their optical spectra.

-> A VLT proposal for BluDOGs was executed!