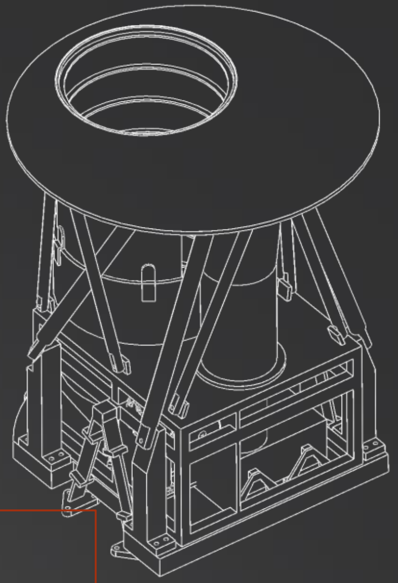
Nature of High-Redshift Dust-Obscured Galaxies in the ADF-S
- Preliminary Results -



Woong-Seob Jeong,
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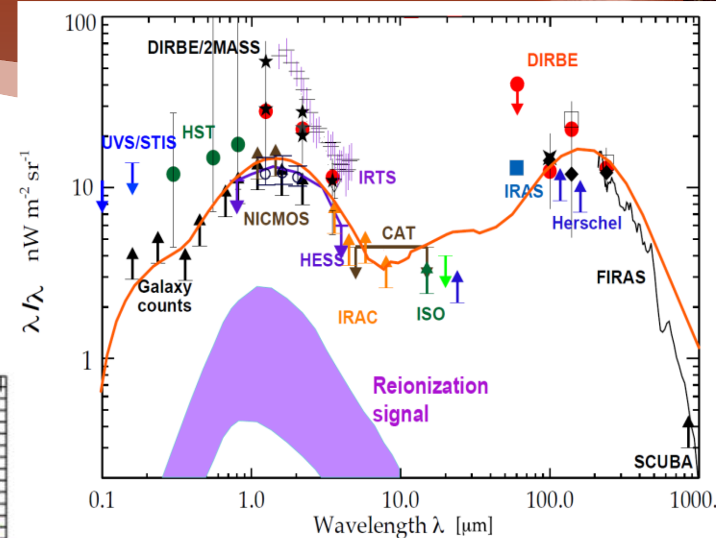
Origin of Extragalactic Background Light

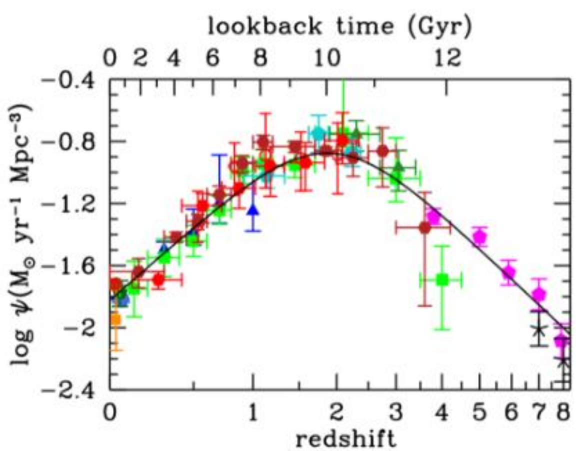
☞ **Epoch of Reionization**

→ **Search for High-z objects**

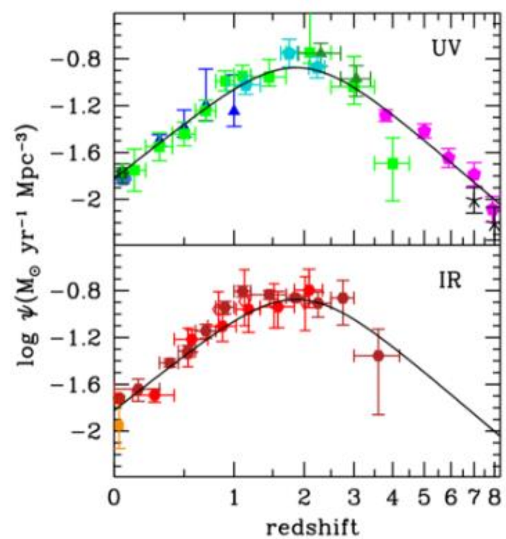
☞ **Epoch at the Peak of SFRD**

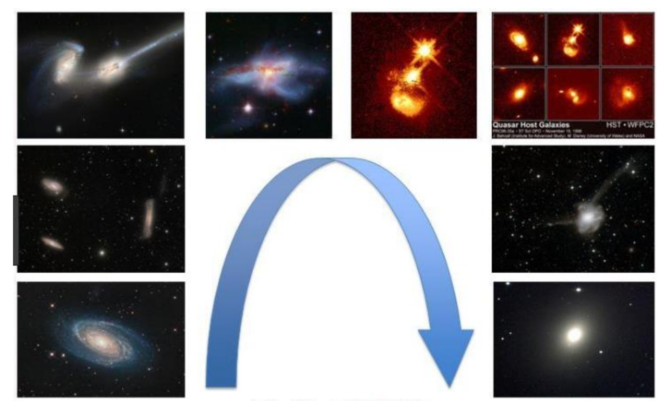
→ **Search for the most luminous objects**





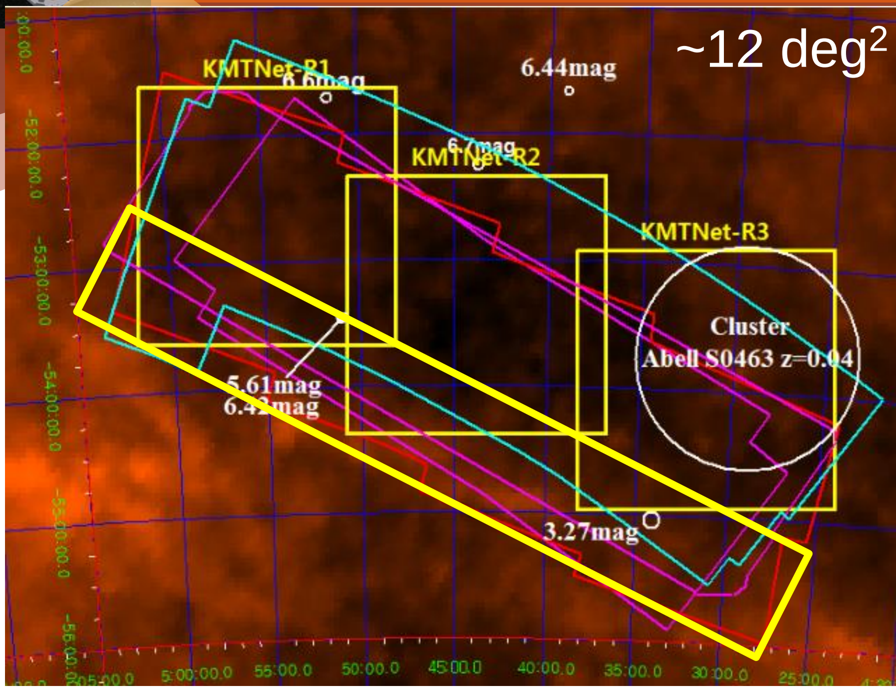
(Madau+14)

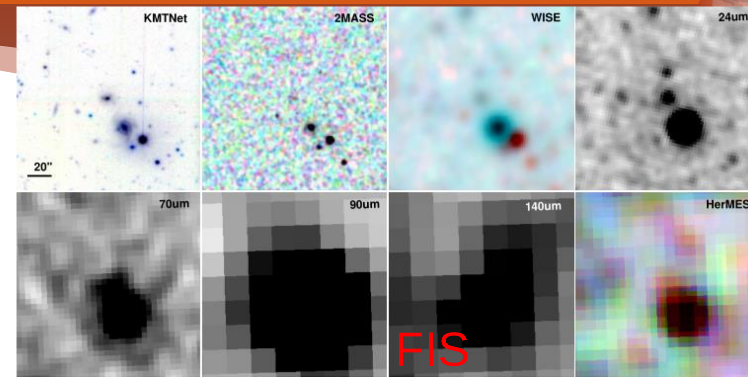


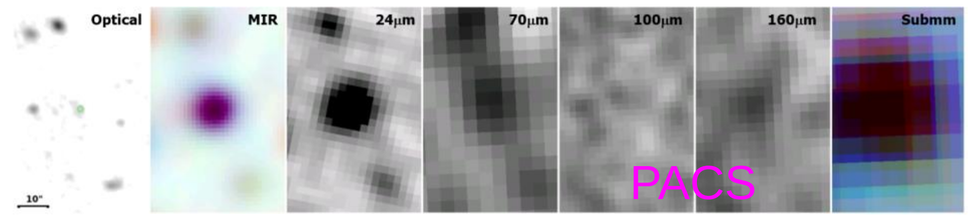


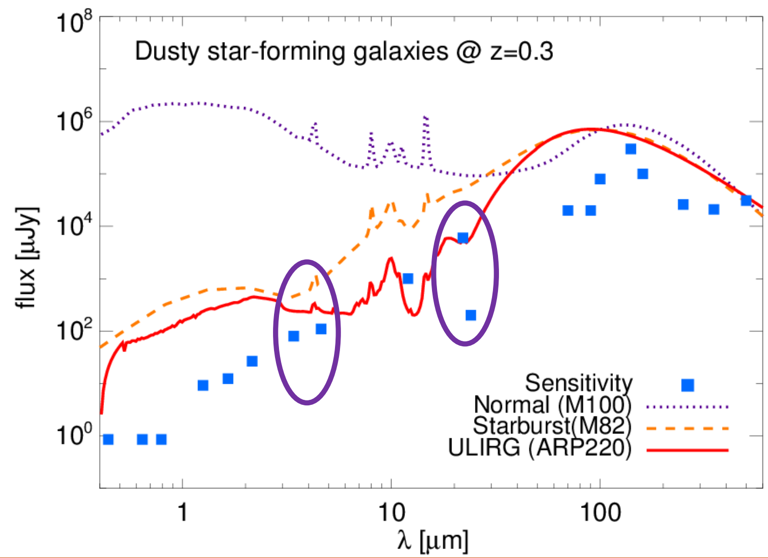
- **Excess emission in near- & far-infrared**
  - High-redshift objects: first stars or first galaxies
  - Low-redshift objects: merging galaxies or stars around galaxy

ADF-S (AKARI Deep Field – South)





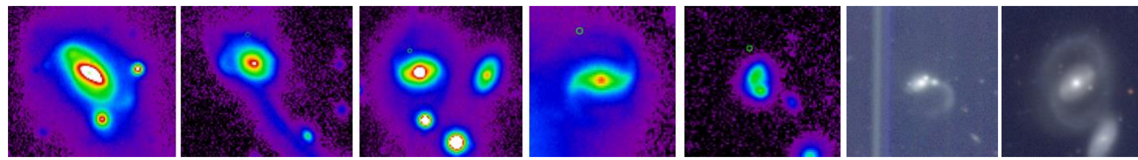




- **KMTNet in visible: B, R & I bands + DES**
- **VHS NIR Survey: J, H & Ks + NISS**
- WISE (MIR), Spitzer/MIPS (MIR & FIR)
- **AKARI FIS Pointed Observations**
  (65, **90**, 140 & 160μm)
- Herschel PACS & SPIRE (FIR & Submm) – HerMES, BLAST (submm)

Science Cases

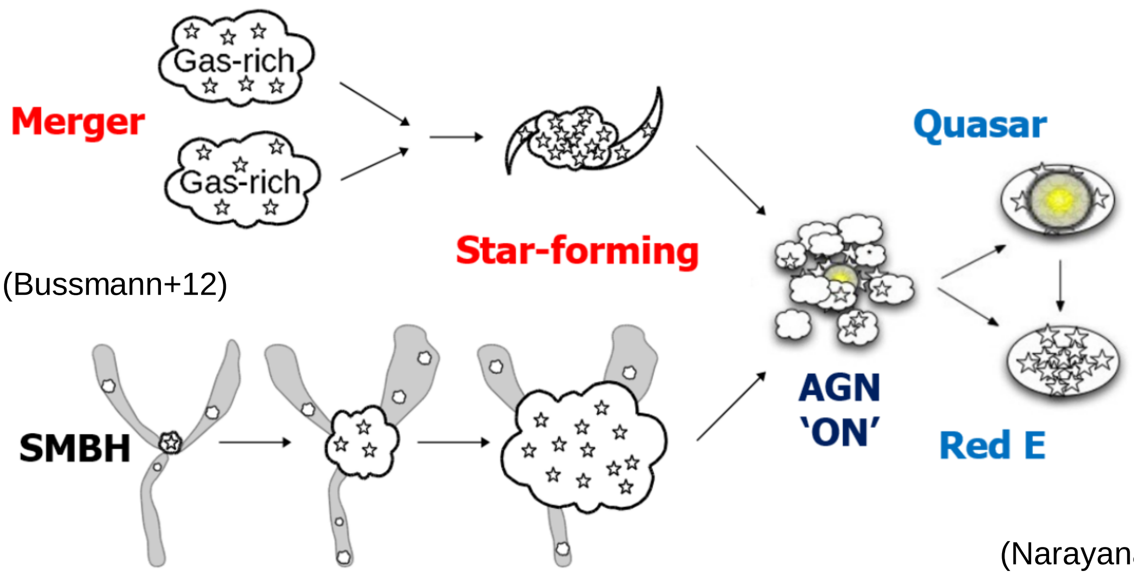
- Star formation activities in galaxy cluster Abell S0463 (z~0.04)
- Optical properties of Local (U)LIRG



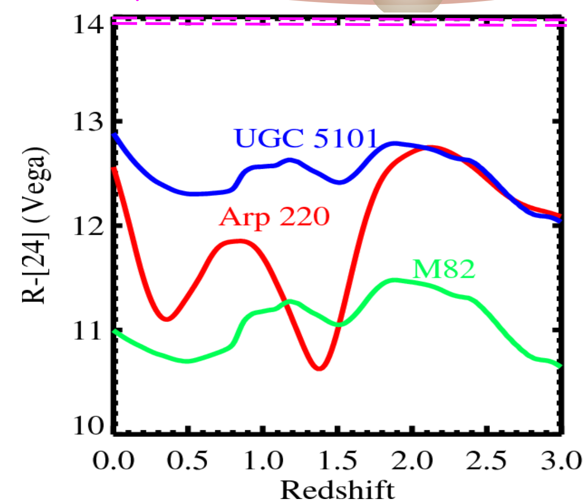
- **Dust-Obscured Galaxies @ z~1-3 in the peak of SFRD**
- Properties of High-z DSFGs @ z>2.5
  - Submm color, BzK galaxies, ERO, …
- Contribution to **CIB** from DSFG populations
  - The Deepest Galaxy Number Counts at 90um in the ADF-S
  - Searching the MIR drop-out objects identified in FIR

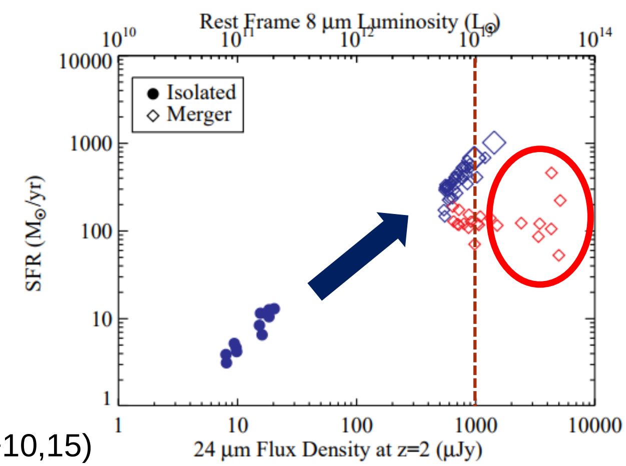
Why DOGs?

- 24μm-bright Dust-Obscured Galaxy (DOG): $f_{24\mu m}/f_R \sim 10^3$
- Importance of DOG
  - $z \sim 2 \pm 0.5$ @ peak of SFR: 10~30%
  - Merger → SMG → **DOG** → QSO / Elliptical
  - Type: bump (SF) → power-law DOG (AGN)
  - Heavily-obscured / massive system



(Bussmann+12)





(Narayanan+10,15)

SED Fittings for KMTDOGs

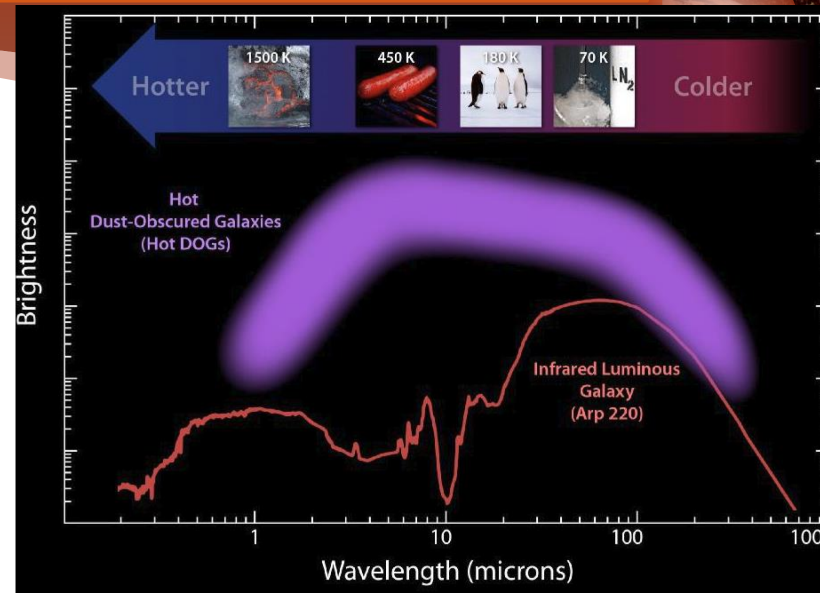
- Hot-DOGs: 60 — 120K

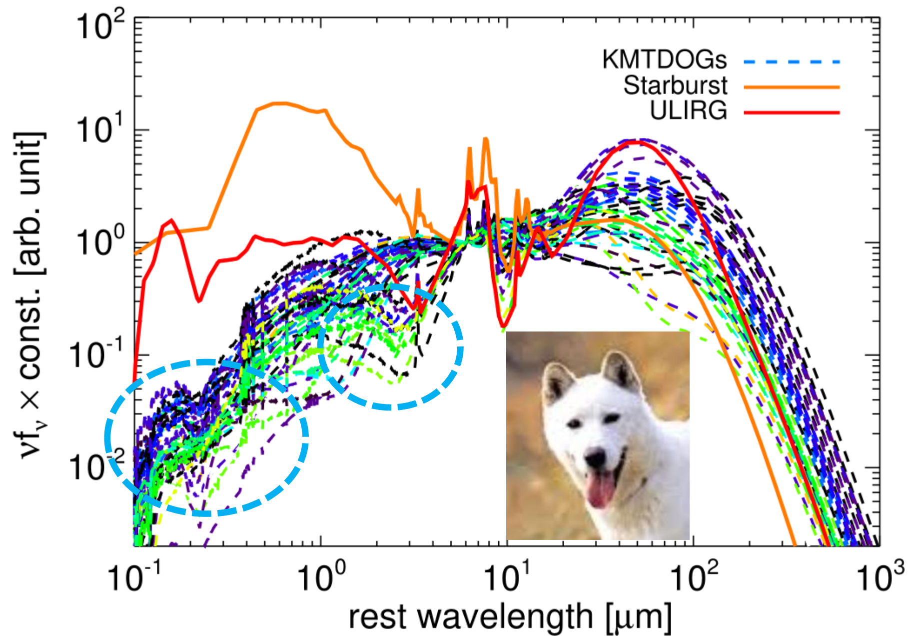
- New DOG sample: **$f_{24\mu m}$ >1mJy**
→ KMTDOG: DOGs identified by KMTNet

- Physical properties: z_{phot}, L_{IR}, M_*, f_{AGN}, T_{dust}, M_{dust}, SFR, …
  → ELIRG/HLIRG/ULIRG and/or Massive Galaxies

SED fitting with CIGALE
(Burgarella+15)
Implementing AGN
contribution (Fritz+06)

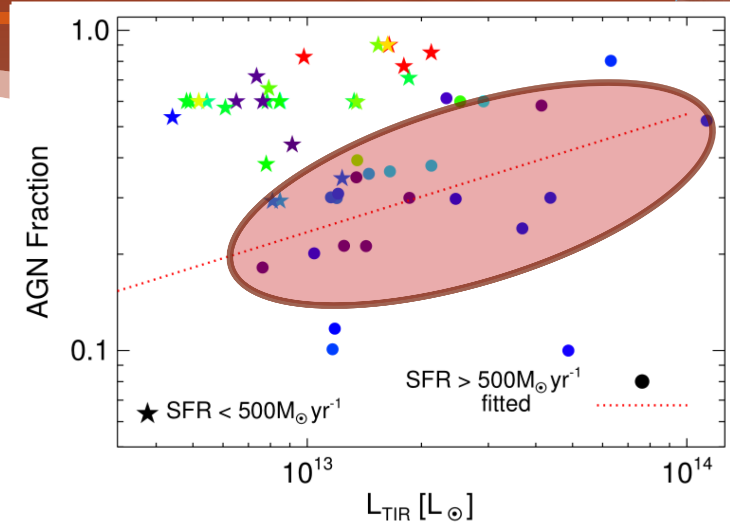
- z_{phot} = 1.7 ~ 2.6
- log L_{IR} = 12.8 ~ 14





FIR Properties of KMTDOGs

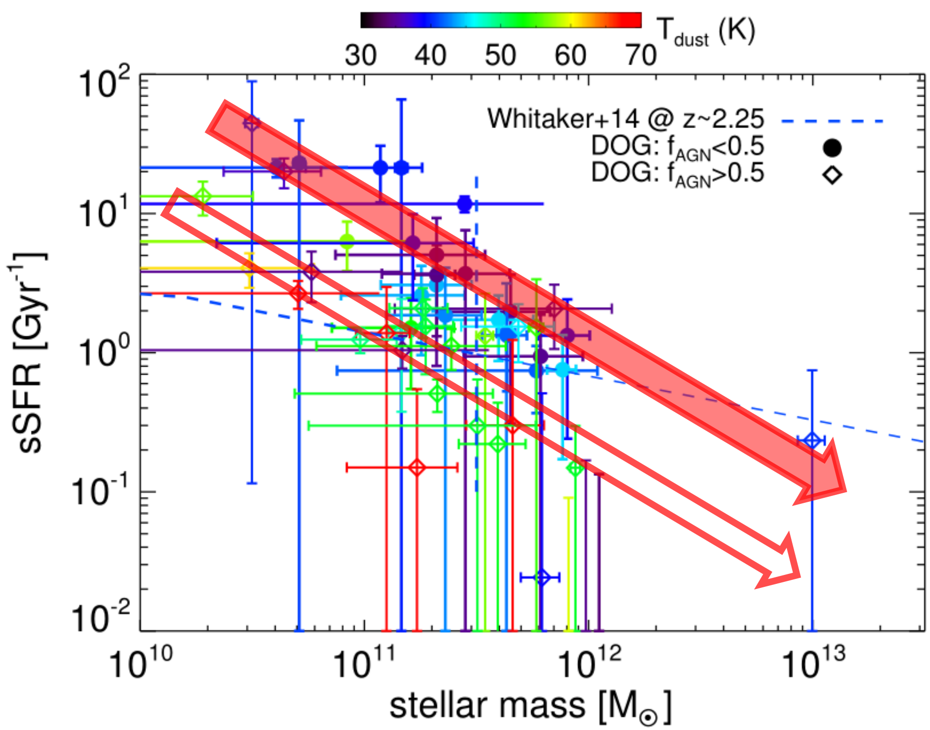
- Dust temperature: T_{dust}
  - Typical DOGs/SMGs
  - Higher T_{dust}: high f_{AGN}



- High T_{dust}, high f_{AGN} (symbol ○)

: less efficient SF

→ suppress SF by AGN



- NIR Spectroscopy: Hα
  - F2 (GEMINI-S)
  - Massive galaxies?
  - Dust obscuration: Hβ
  - SMBH Masses?

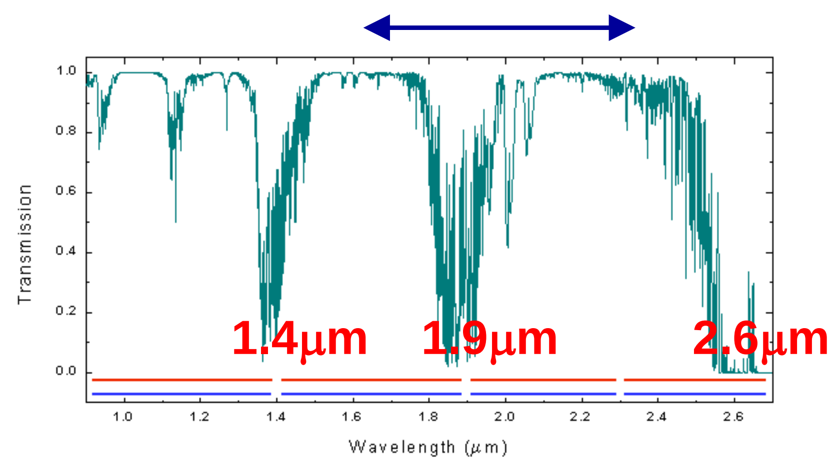
NIR Spectroscopic Follow-Ups

- Follow-up observations: Nov. 2017, Sep. 2018

- **14** out of 51 KMTDOGs (→ to be increased!)
  - High SFR: > 500 $M_\odot$/yr
  - High stellar mass: $>10^{10}\,M_\odot$
  - Hyperluminous objects: $>10^{13}\,L_\odot$

- **9** out of 14 KMTDOGs
  → Hα detection: ~64%

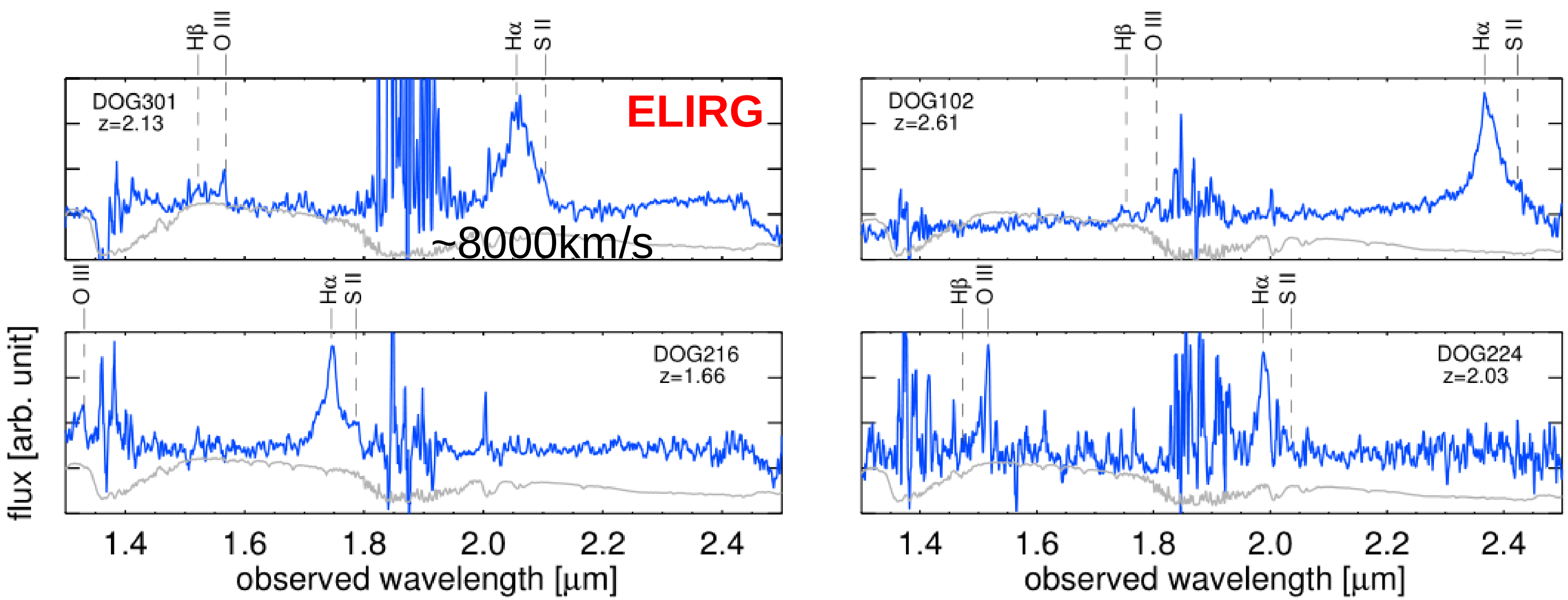
- photo-z vs. spec-z
  - $z_{phot} = 1.4 \sim 2.5$
  - $z_{spec} = 1.26 \sim 2.61$



z(Hα)= 1.1 1.9 3.0

Hyperluminous KMTDOGs: Broad Hα

- **8**/9 KMTDOGs: broad Hα (FWHM >2000km/s)
  → hosts **AGNs**!
  - [OIII]: outflows from AGN
  - No (faint) Hβ detection: very obscured

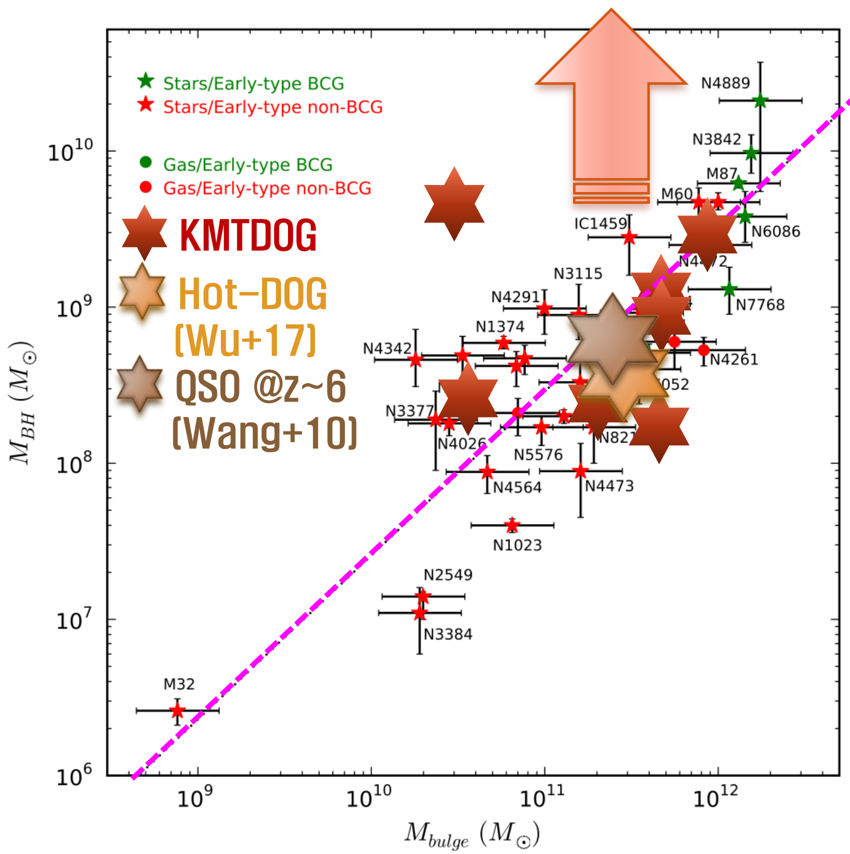


Estimated Mass of Black Hole

- M_{BH} - σ_*, M_{BH} - L_V &
  M_{BH} – M_{bulge} relation

$$M_{BH} = 9.7 \times 10^6 \cdot \left(\frac{\mathrm{L5100}}{1 \times 10^{44}[\mathrm{ergs/s}]}\right)^{0.59} \cdot \left(\frac{\text{line-width}}{1000[\mathrm{km/s}]}\right)^{2.06} M_\odot$$

(Peng+06)



- Line fitting → M_{BH}
- Two peculiar KMTDOGs
  - KMTDOG-102: Highest z (2.61)
  - KMTDOG-301: $M_* \sim 10^{13}$ $M_\odot$
- No extinction correction

- Hot-DOGs & QSOs @ z~6: hosted by similar kinds of galaxies with (Wu+17)?

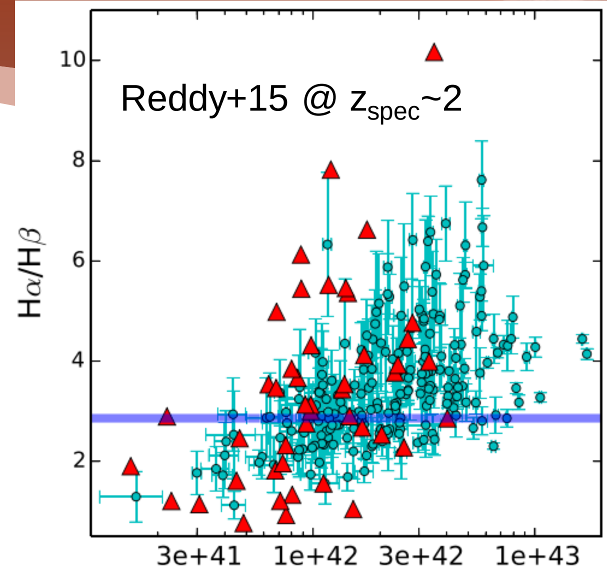
Extinction Correction

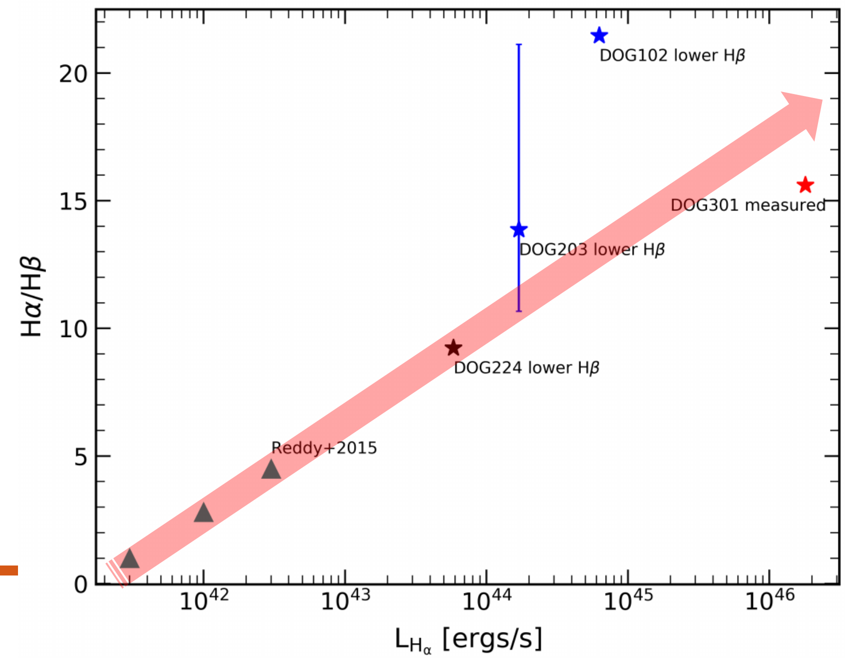
- No extinction correction!

  (e.g., E(B-V)~1 → 13% BH Mass)

- SED fitting for KMTDOGs
  - E(B-V) = 0.6 ~ 2.5 (typically ~1.0)
  - e.g., red QSOs E(B-V) < 1.5

- Balmer decrement
  - case B recombination & T=10^4K
  - flux ratio Hα/Hβ = 2.86
  - $E(B-V) = 1.97 \log_{10}[(\frac{H\alpha\_obs}{H\beta\_obs})/2.86]$



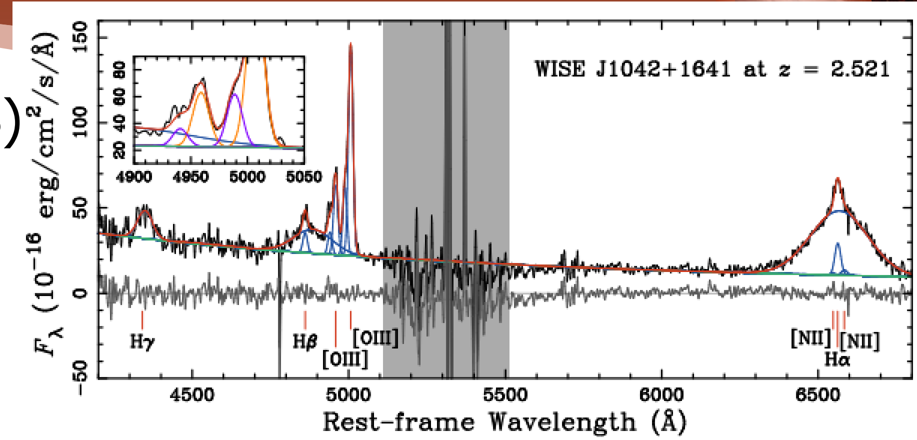


Discussion: Lensing Case

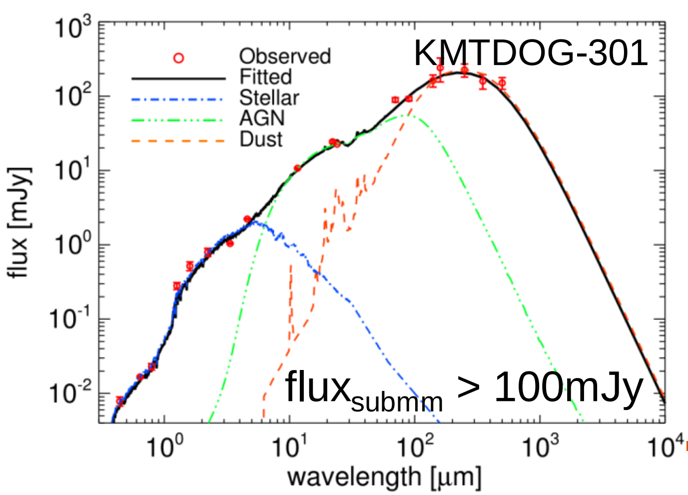
- Radio of BH mass to galaxy mass for Hot-DOG @ z=2.52 (Matsuoka+18)
  - M_{BH} $10^{10.8\text{-}11.2}$ & $M_\star$ $10^{13.55}$ $M_\odot$

  c.f. KMTDOG-301 @ z=2.13

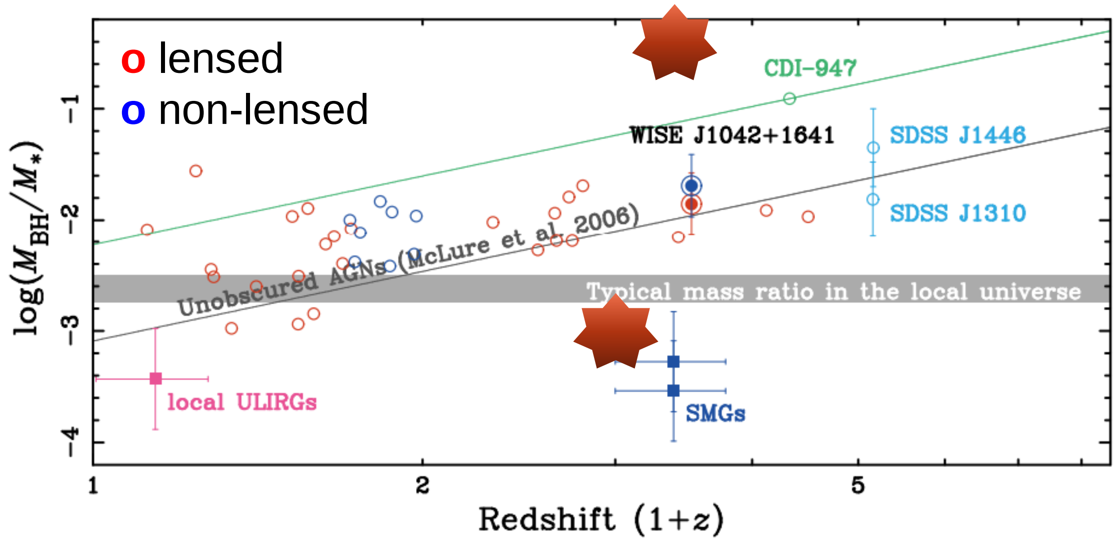
  M_{BH} $\sim 10^{10}$ & $M_\star$ $\sim 10^{13}$ $M_\odot$



- Lensing: confirmed (HST)
  - 4 faint sources: ~1.6″
  - Eddington ratio: -0.32
  - μ = 53 - 122

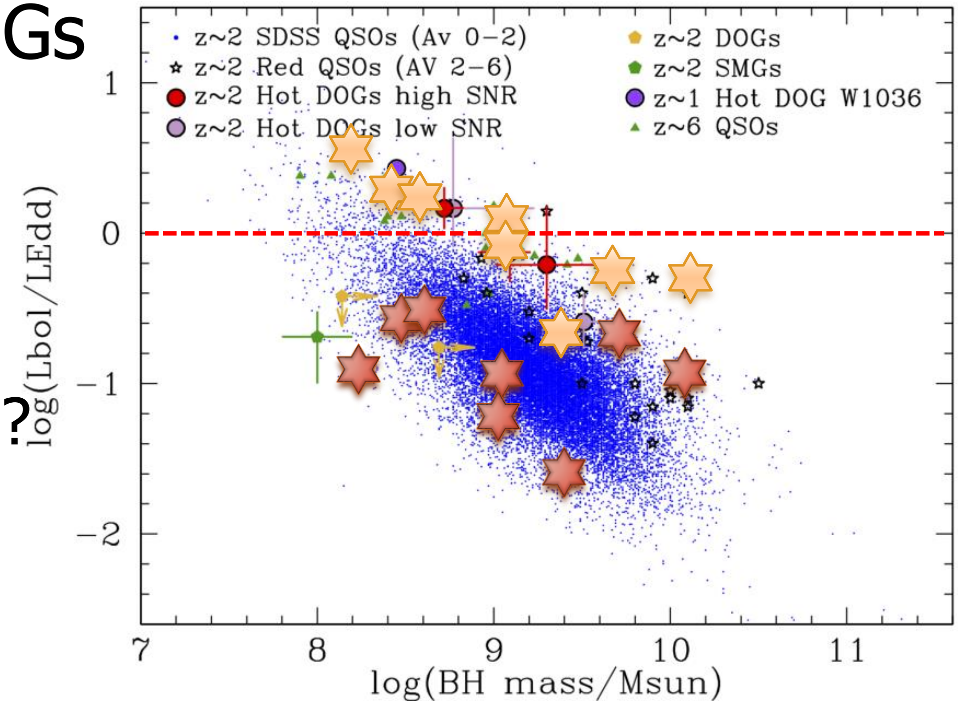


Ratio of KMTDOG-301: close to SMG



Discussion: Eddington Ratio

- Eddington luminosity $L_{Edd} = 3.28 \times 10^4 (\frac{M_{\rm BH}}{M_\odot}) L_\odot$
  → Eddington ratio η
- Hyperluminous (hot) DOGs
- Implications (Wu+17)
  - Highest Eddington ratio stage before the red QSO?
  - High accretion?



Hyperluminous Hot DOGs (Wu+17)

Summary

- ADF-S: Unique deep filed – IR space data sets!
  → Local (U)LIRGs, DOG, High-z SFGs, finally CIB?

- Hyper-luminous / dust-obscured galaxies: KMTDOGs
  - Broad Hα → AGN: Supermassive Black Hole (> 10^8 $M_\odot$)
  - M_{BH} – $M_\star$: local relation
  - Lensing case?
  - High Eddington ratio: high accretion?

- Follow-up observations: NIR Spectrscopy, Submm imaging/spectroscopy, …