FIR from high-z SMBH

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(SfedU & ASC & INASAN & RRI)

SMBH at high-z: census

more than 200 quasars at z>6

48	z>6.5
7	z>7
2	z>7.5 (Banados etal 2018)
	(Yang etal 2020)

"Pōniuā'ena"

most of them are powered by SMBH with M>1e9 solar masses

Object name	redshift	$\log(M_{BH}/M_{\odot})$	Reference
Pōniuā'ena	7.515	9.18	Yang et al. (2020)
ULASJ1342+0928	7.5413	8.89	Bañados et al. (2018)
ULASJ1120+0641	7.0842	9.39	Mortlock et al. (2011), Mazzucchelli et al. (2017)
SDSSJ0100+2802	6.3258	10.03	Wu et al. (2015)
PSOJ338+29	6.666	9.43	Venemans et al. (2015), Mazzucchelli et al. (2017)
SDSSJ1148+5251	6.4189	9.71	Fan et al. (2003), De Rosa et al. (2011)
VIKJ0109-3047	6.7909	9.12	Venemans et al. (2013), Mazzucchelli et al. (2017)
SDSSJ2310+1855	6.0031	9.62	Wang et al. (2013), Jiang et al. (2016)

Zubovas & King 2021

SMBH at high-z: growth

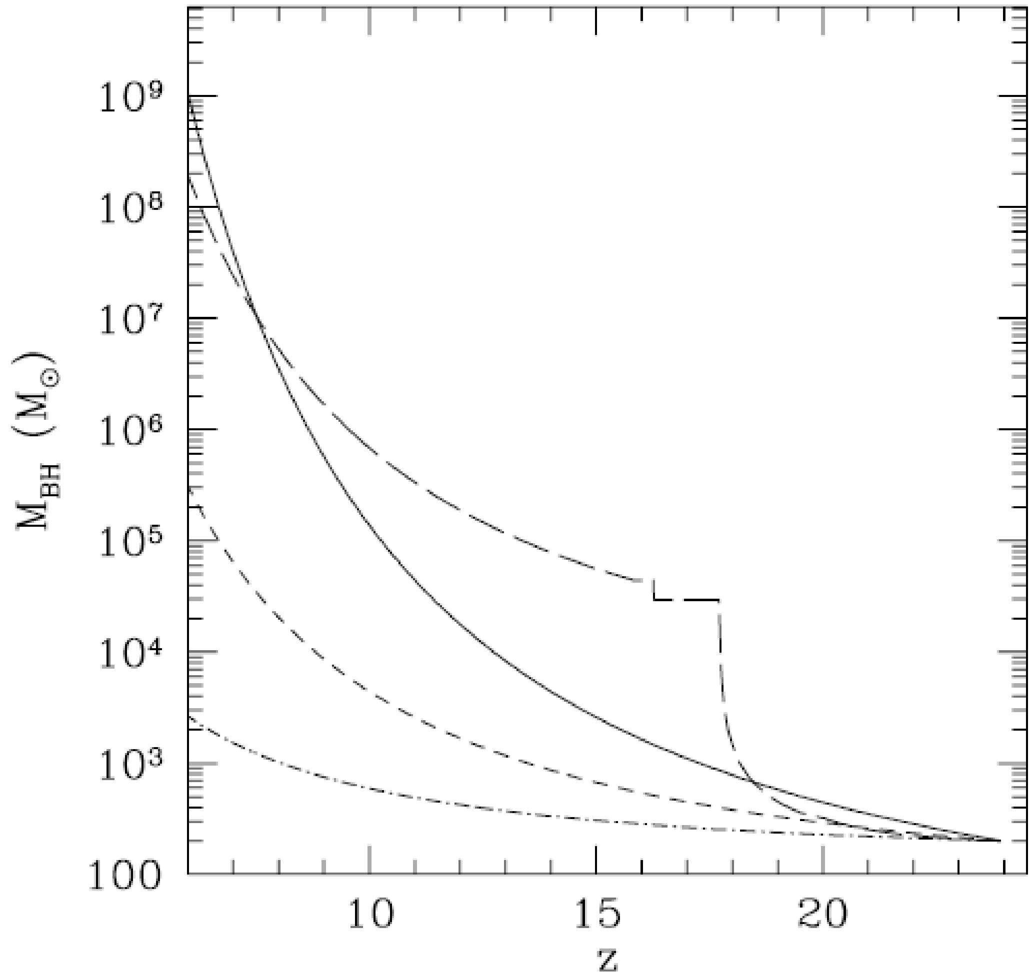


FIG. 1.— Growth of MBH mass under different assumptions for the accretion rate and efficiency: Eddington-limited accretion with $\epsilon = 0.1$ (*solid line*), $\epsilon = 0.2$ (*short-dashed line*), $\epsilon = 0.4$ (*dot-dashed line*), and supercritical accretion, as in Volonteri & Rees (2005; *long-dashed line*).

Volonteri & Rees 2006

BH growth rate

$$M(t) = M(0)\exp\left(\frac{1-\epsilon}{\epsilon}\frac{t}{t_{\rm Edd}}\right),$$

the Eddinghton time $t_{\rm Edd} = 0.45$ Gyr

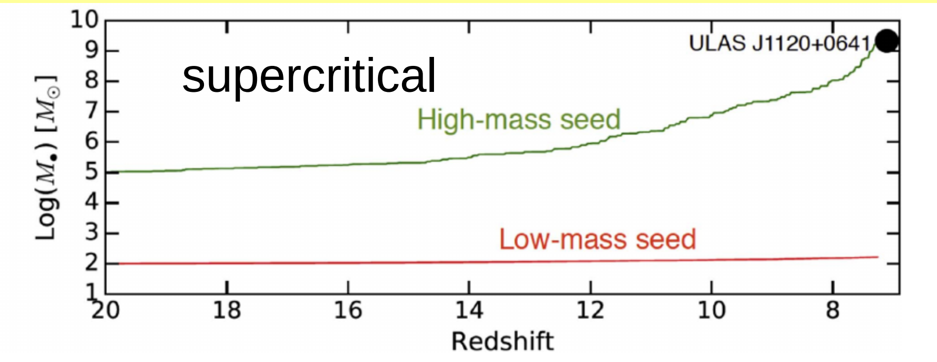
How to grow a SMBH?
- high mass of a seed
- high accretion rate (low ε)

For ε ~ 0.1 & M(0) = 1000 M_{sun}
BH grows to M ~ 10^9 M_{sun}
within 0.5 Gyr

SMBH at high-z: growth

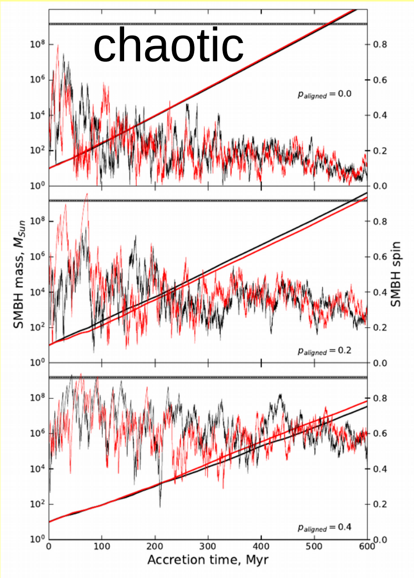
(1) a hierarchical assembly of pregalactic massive BH
(2) rapid growth of BHs with supercritical rate
(3) a direct-collapse black holes of intermediate mass

an **episodically** enhanced accretion:

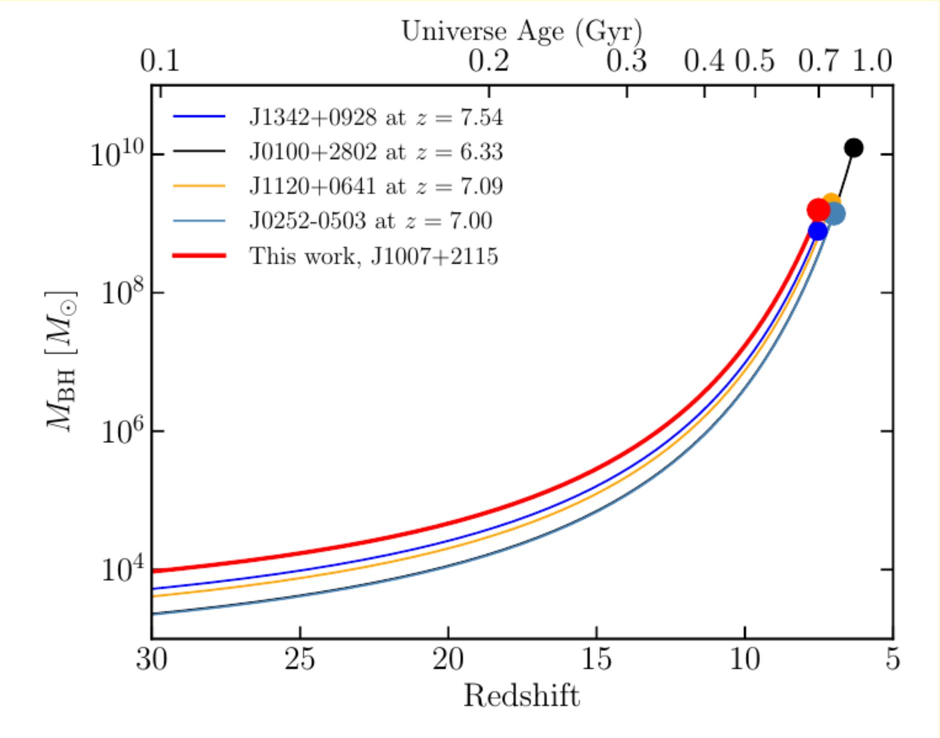


Pacucci etal 2017

- supercritical;
- critical, but with various radiative efficiency;
- chaotic

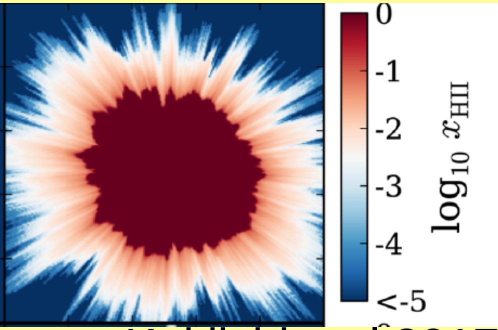


Zubovas & King 2021



Yang etal 2020, arxiv:2006.13452

ε ~ 0.05

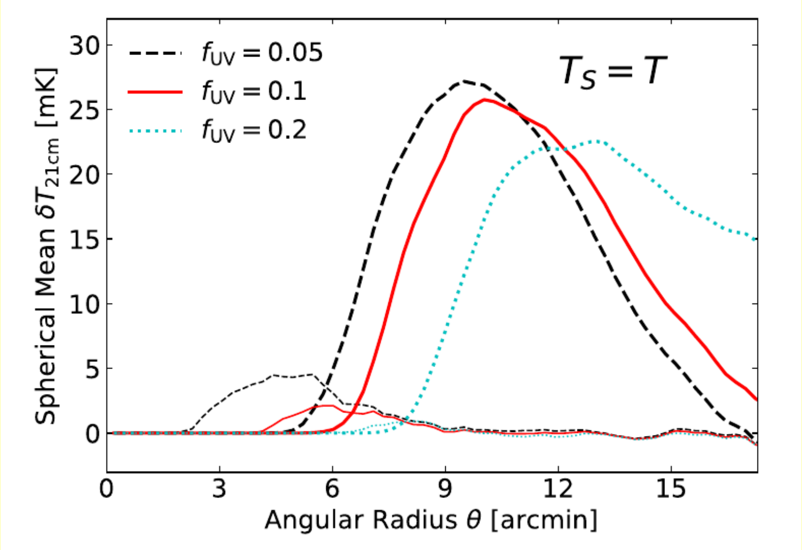


Kakiichi etal 2017

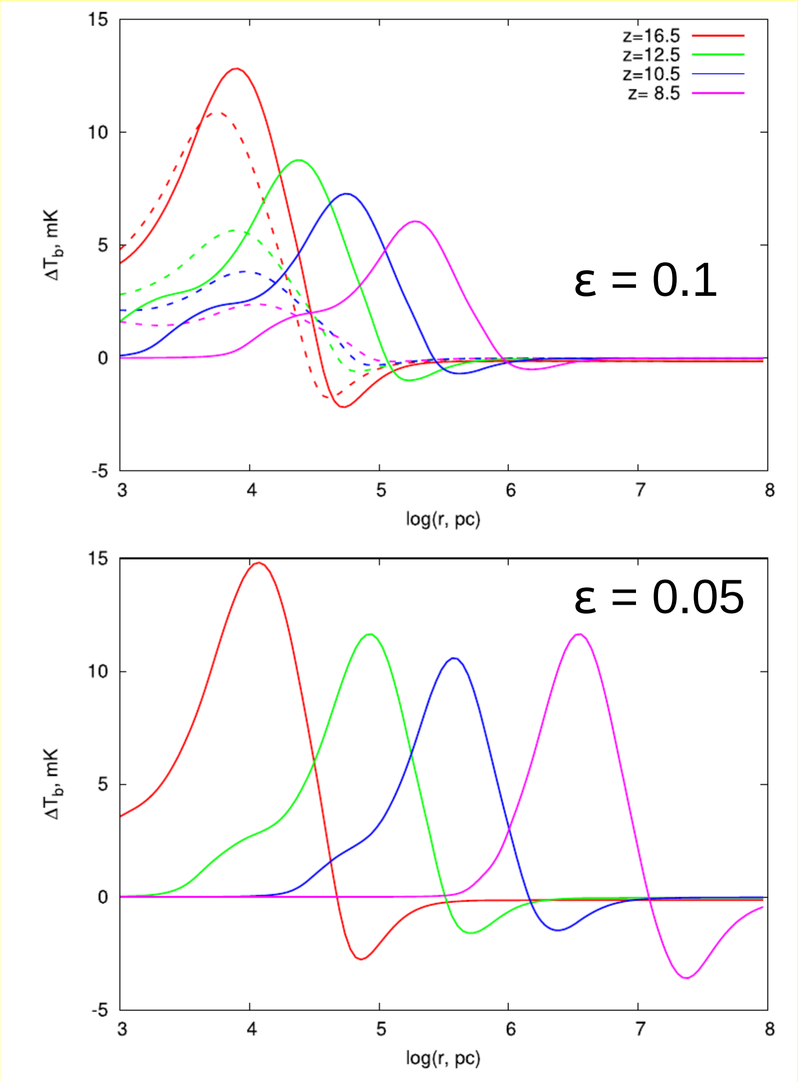
ionizing & heating of IGM

Mpc scales around a SMBH

HI 21 cm



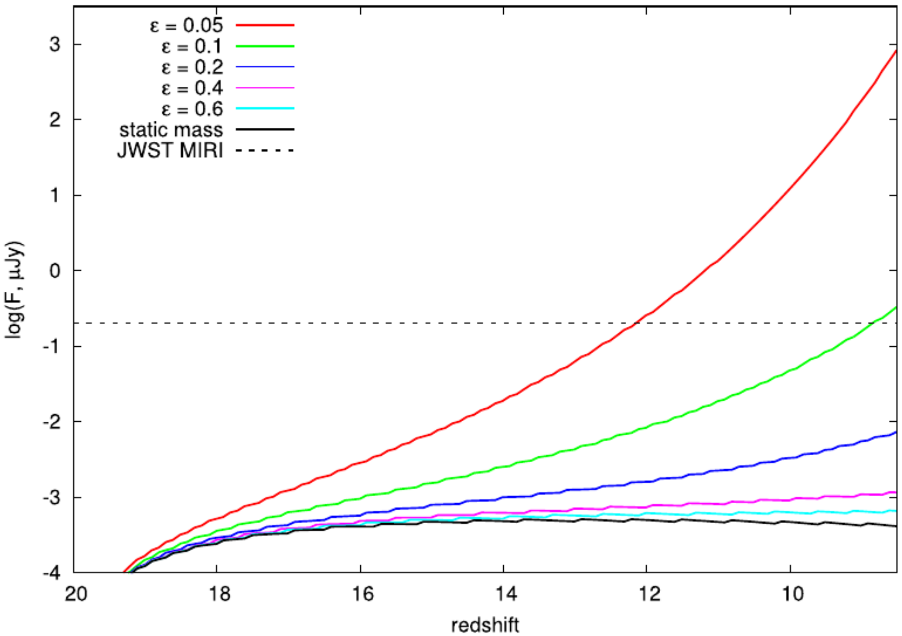
Ma etal 2020



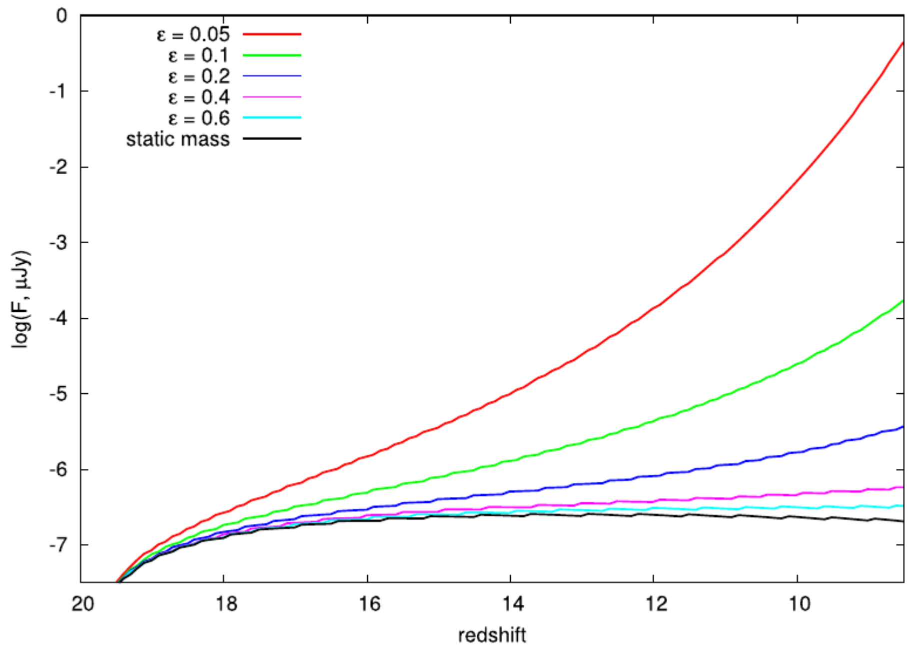
EV etal 2018

ε ~ 0.05 for J1007+2115
(Yang etal 2020)

H-alpha line



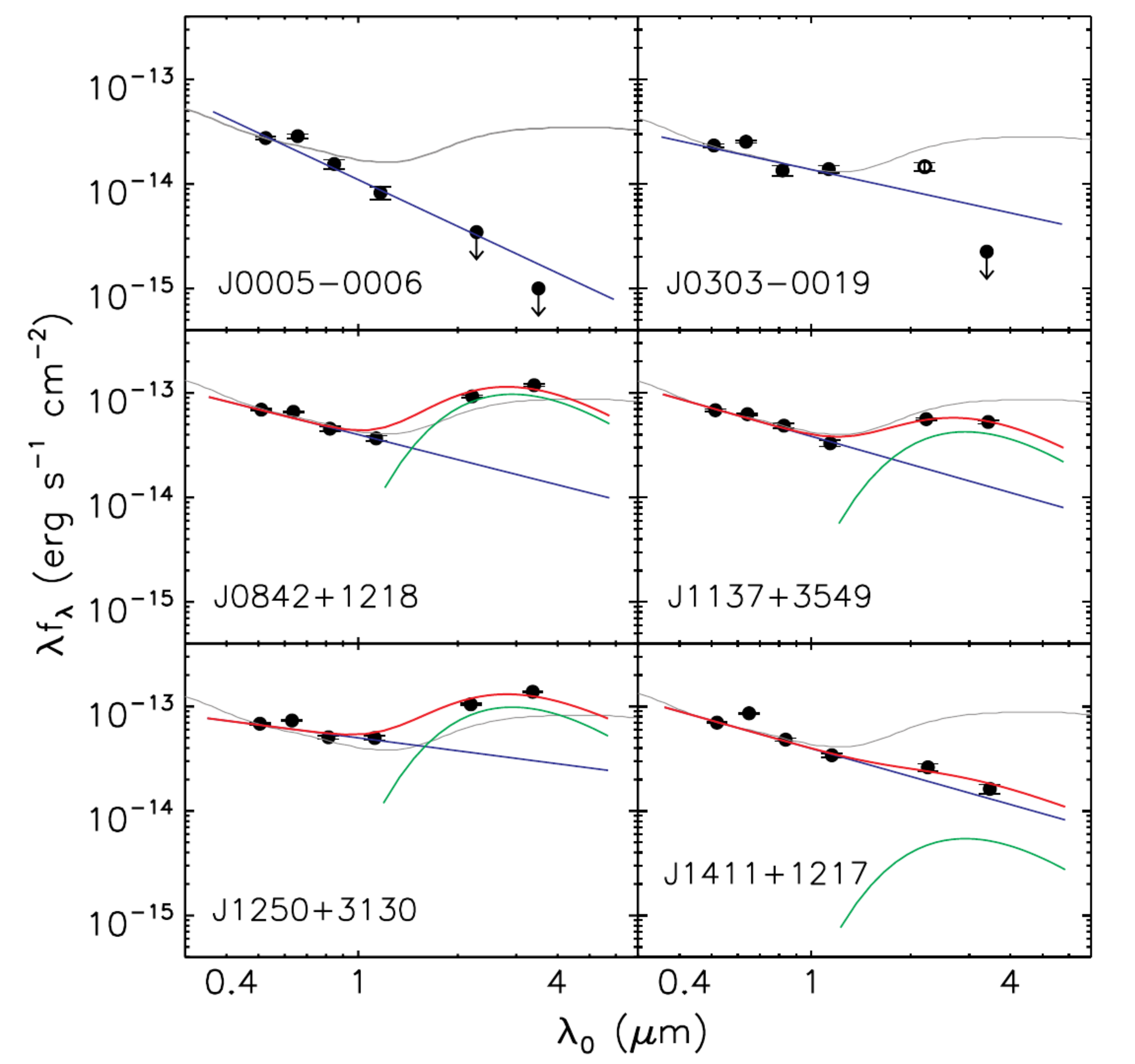
Hn-alpha line: n = 30



EV etal 2018

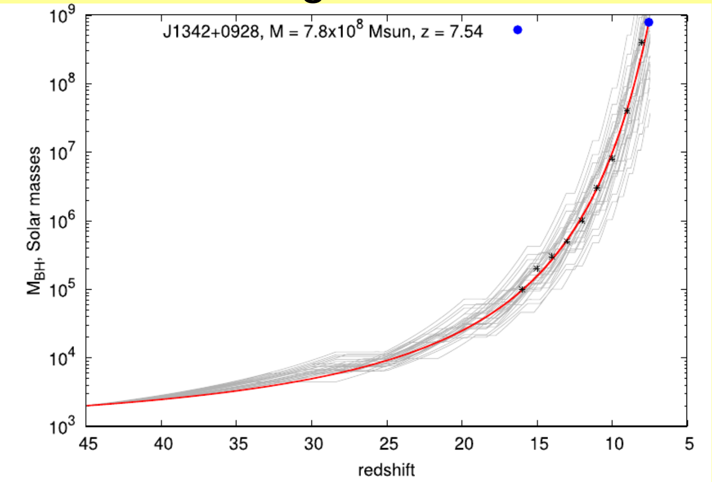
Spitzer SEDs of QSOs

z ~ 5.8 -- 6.4
M(1450 A):
– (27.9 – 25.4)

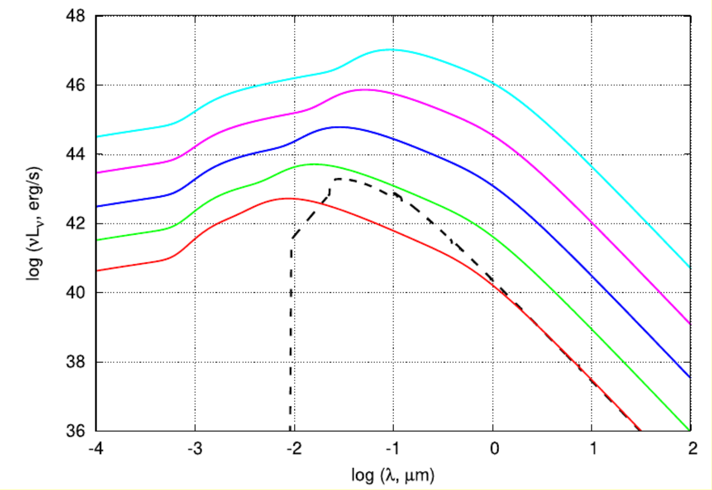


Jiang etal 2010

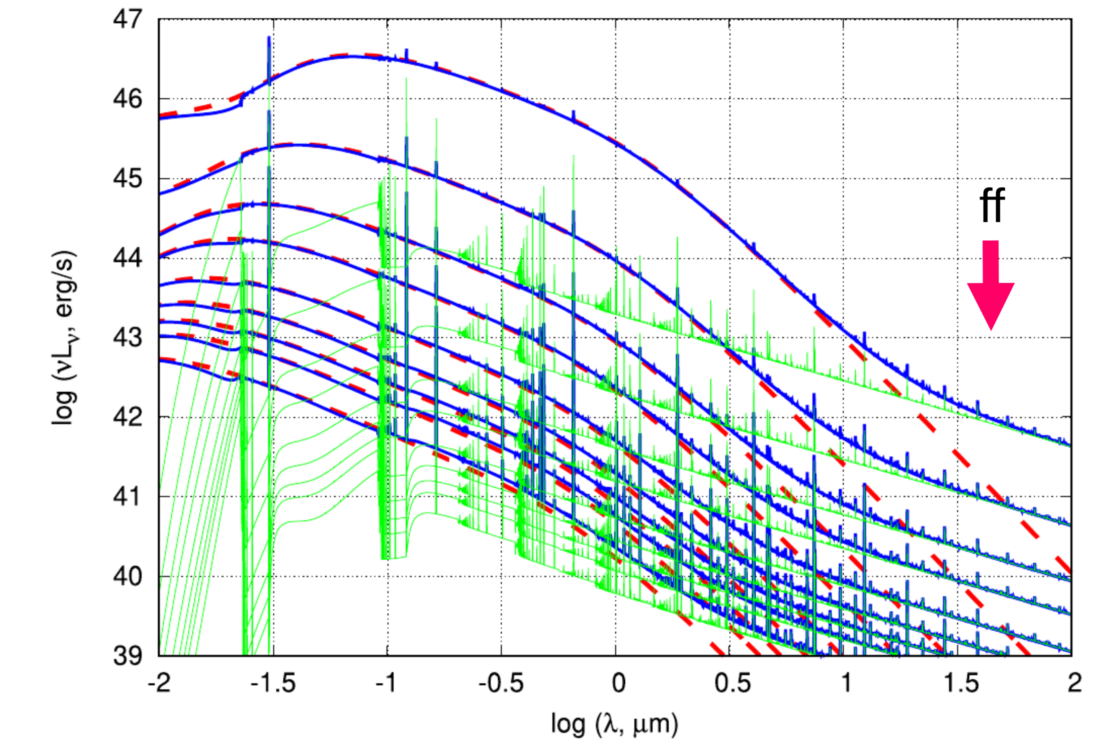
SMBH growth



BH SED (Kubota & Done 2018)

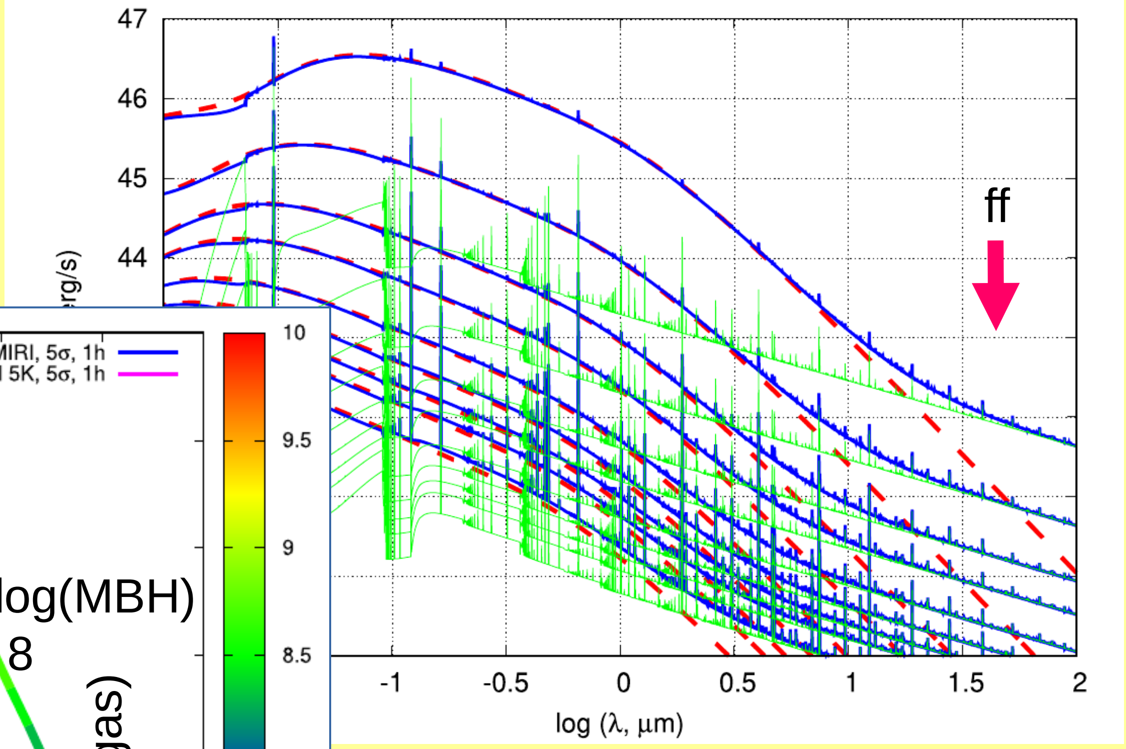


nebular emission for a growing BH: z = 16...8, step = 1

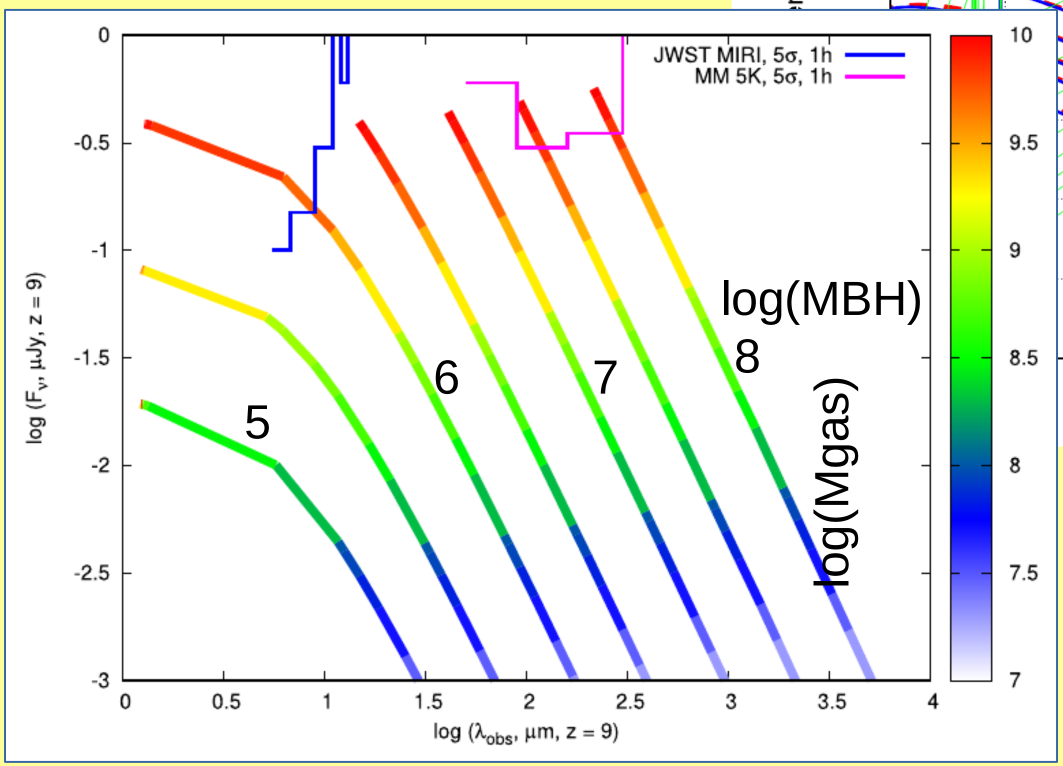


EV & Shchekinov 2019

SEDs for a growing BH: z = 16...8, step = 1



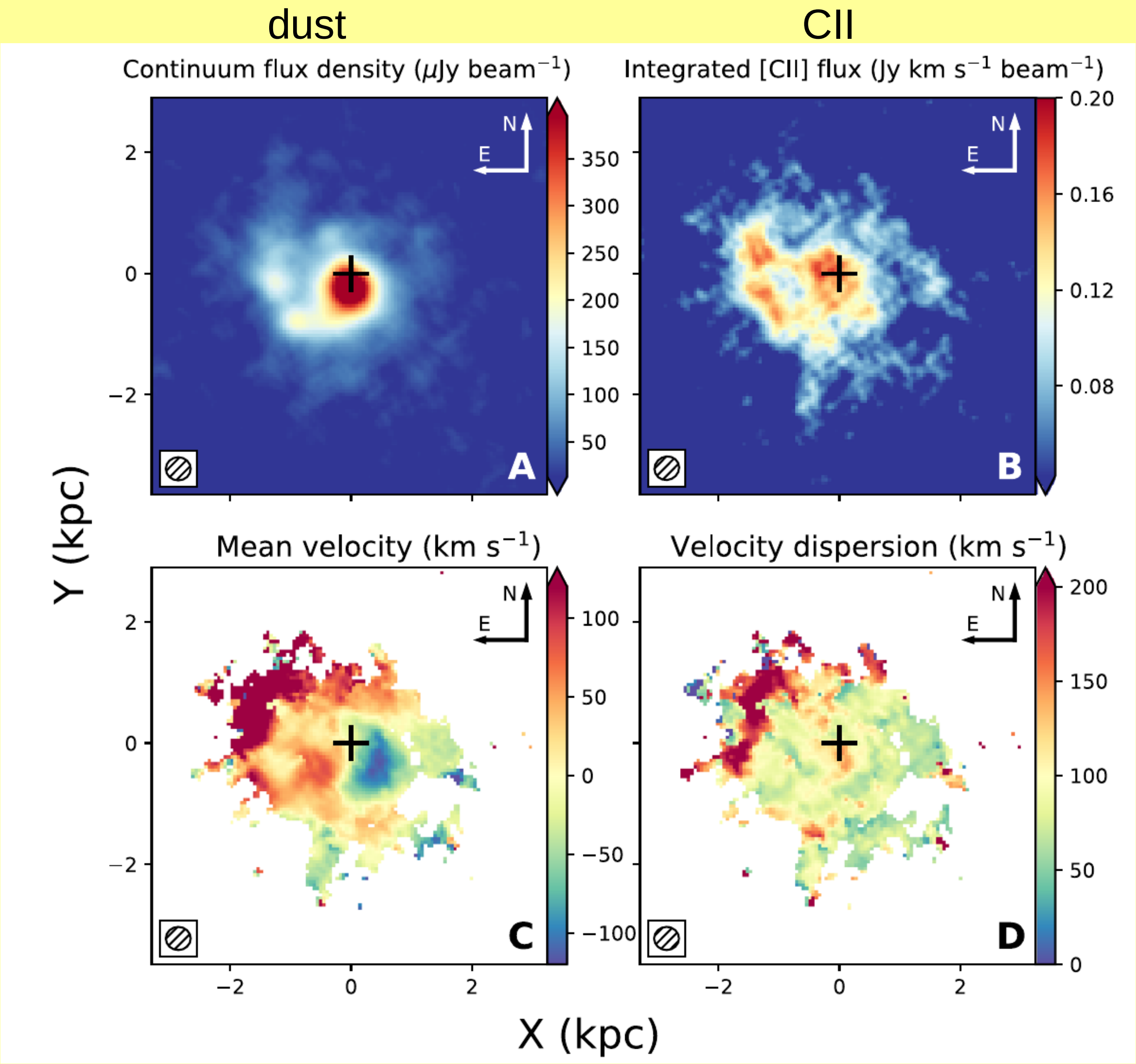
Flux at the inflection wavelength



EV & Shchekinov 2019

1h integration,
R~100

CO/CII/CI
in galaxies at
z ~ 7
(Venemans etal 2017)

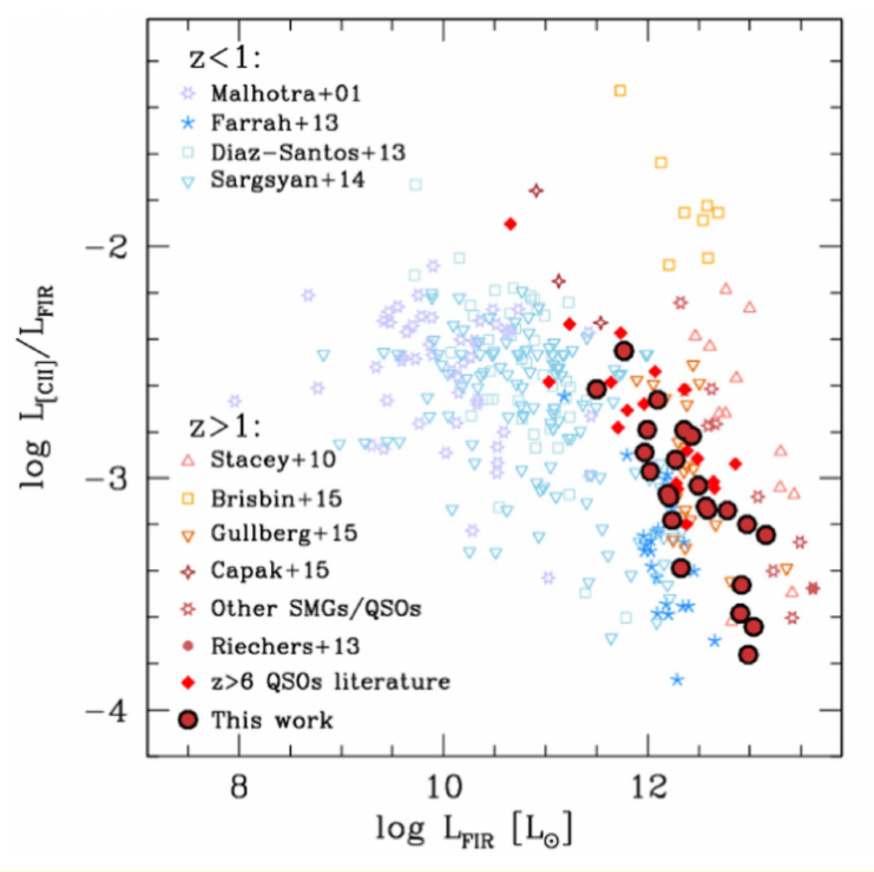


Venemans etal 2019

CII in high-z QSO host galaxies

27 QSOs at z>6

the CII-FIR relation



selection criteria

2. The [C II] Survey

2.1. The Main Sample

The parent sample of our ALMA survey was designed to include all the known quasars matching the following criteria:

(1) they lie at $z > 5.94$ (i.e., ν_{obs}([C II]) < 273.854 GHz), so that the [C II] line falls in ALMA band 6 ($\sim$1.2 mm);
(2) they are at declination decl. $< +15°$, so that they can be observed at high elevation from the ALMA site;
(3) they are more luminous than $M_{1450} = -25.25$ mag, where M_{1450} is the absolute magnitude derived from broad-band imaging observations of the rest-frame FUV continuum;
(4) they were not previously targeted in the [C II] line.

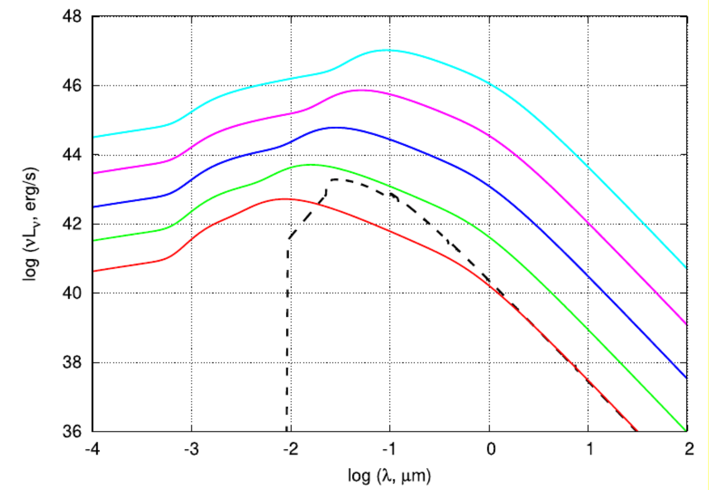
Decarli etal 2018

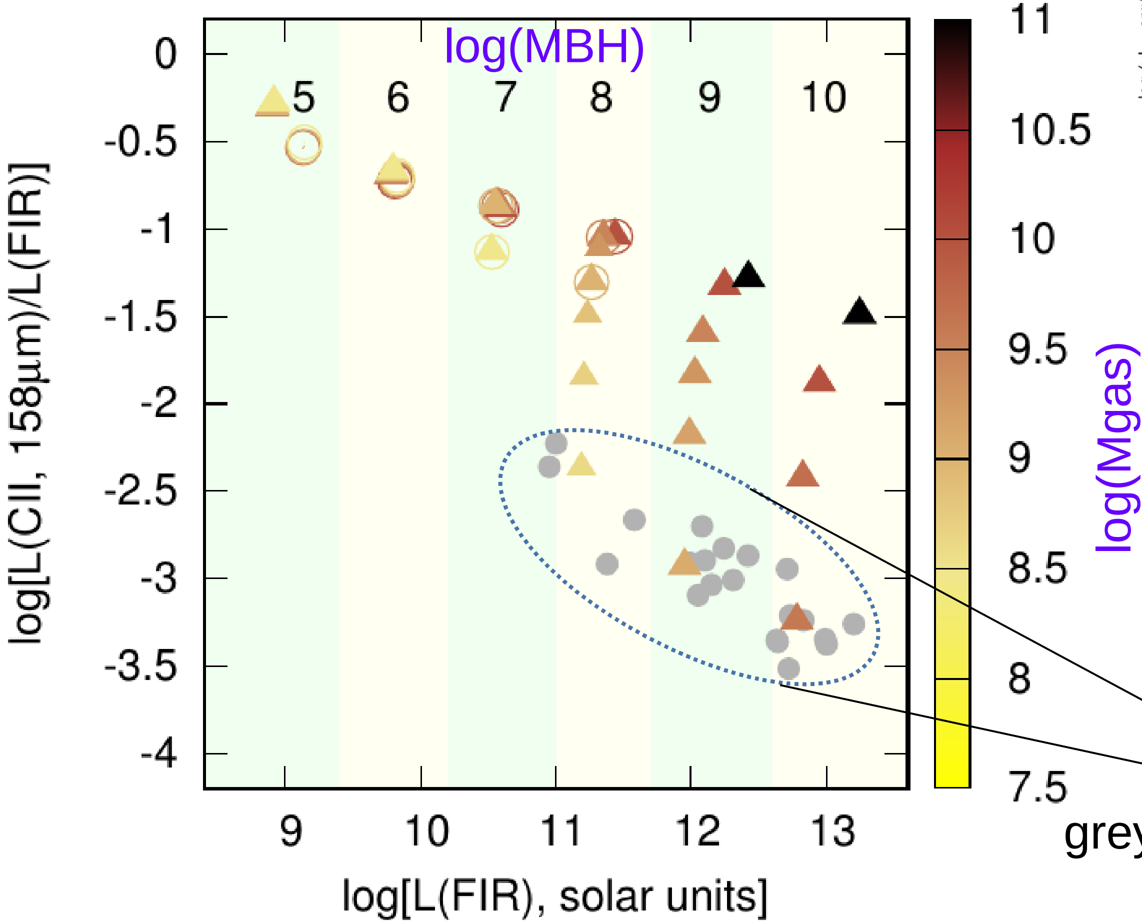
M(1450 A) < –25.25, at 1450 A – rest-frame UV continuum;

z > 6: [CII] 158 microns → ALMA 6 (~ 1.2 mm);

a gas is exposed to SMBH SED

BH SED (Kubota & Done 2018)



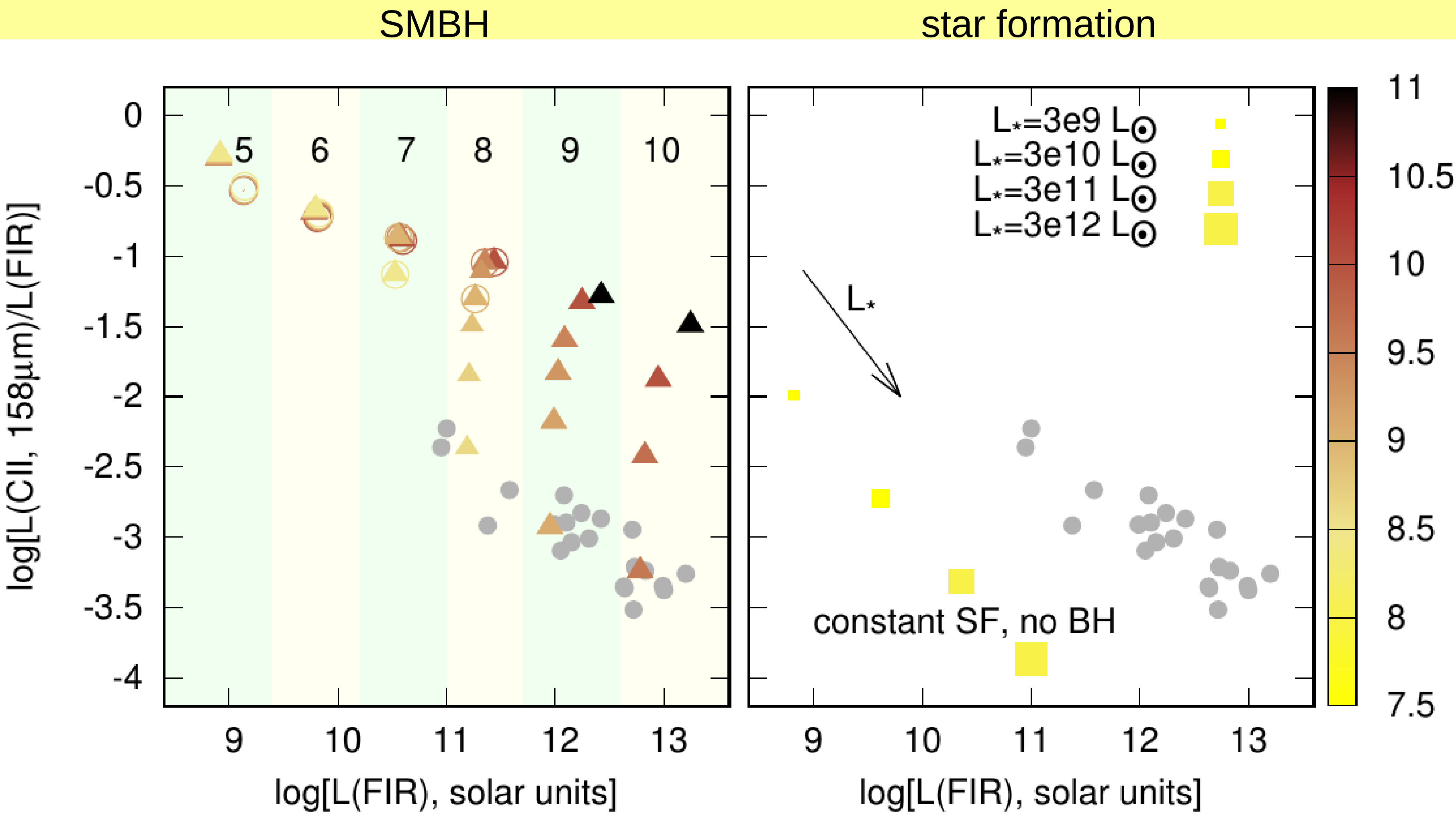


mildly-obscured SMBH
due to the selection criteria

grey points – Decarli etal 2017 data

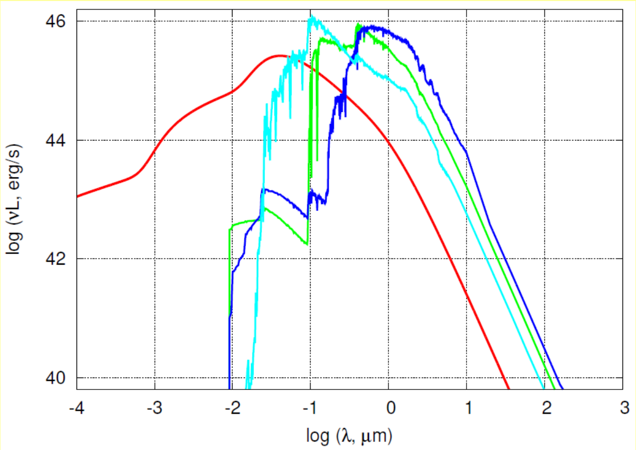
EV etal 2021, submitted

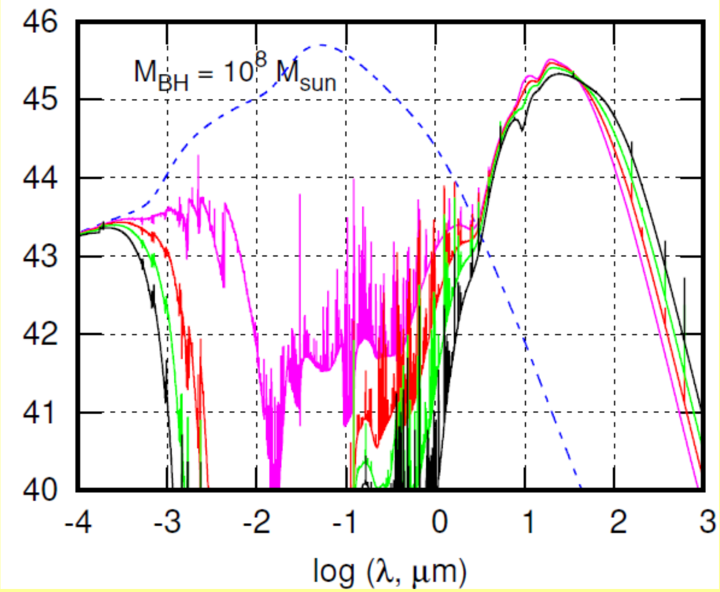
CII – FIR relation

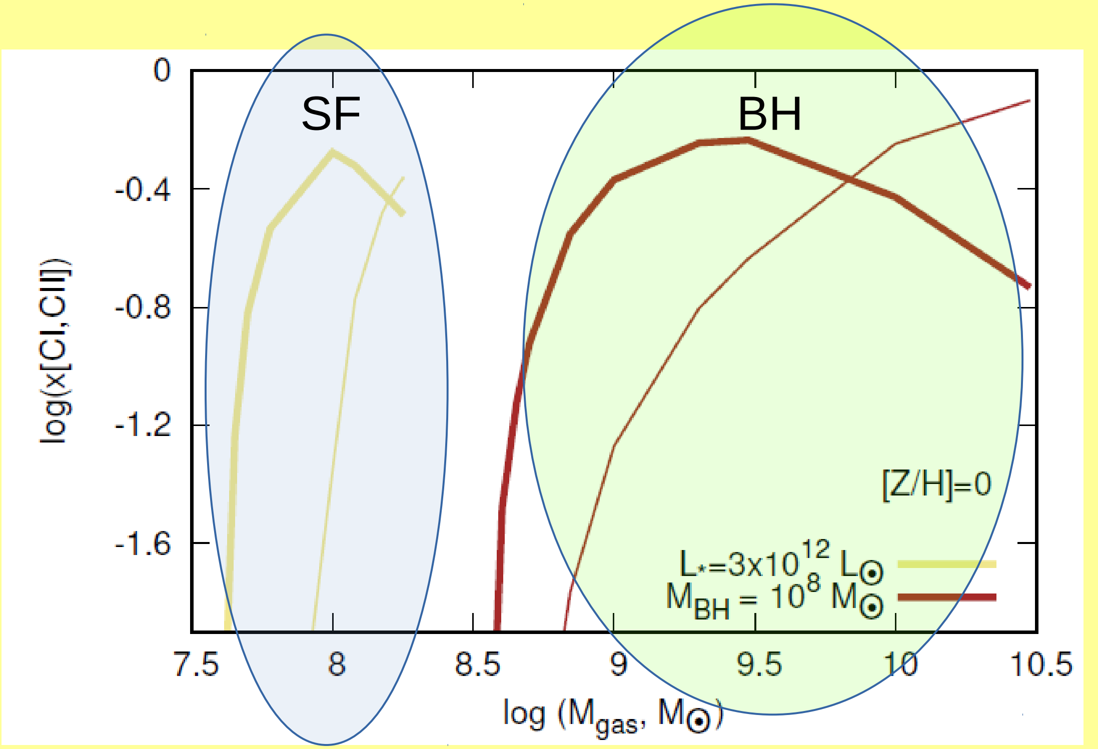


EV etal 2021, submitted

BH or SF?

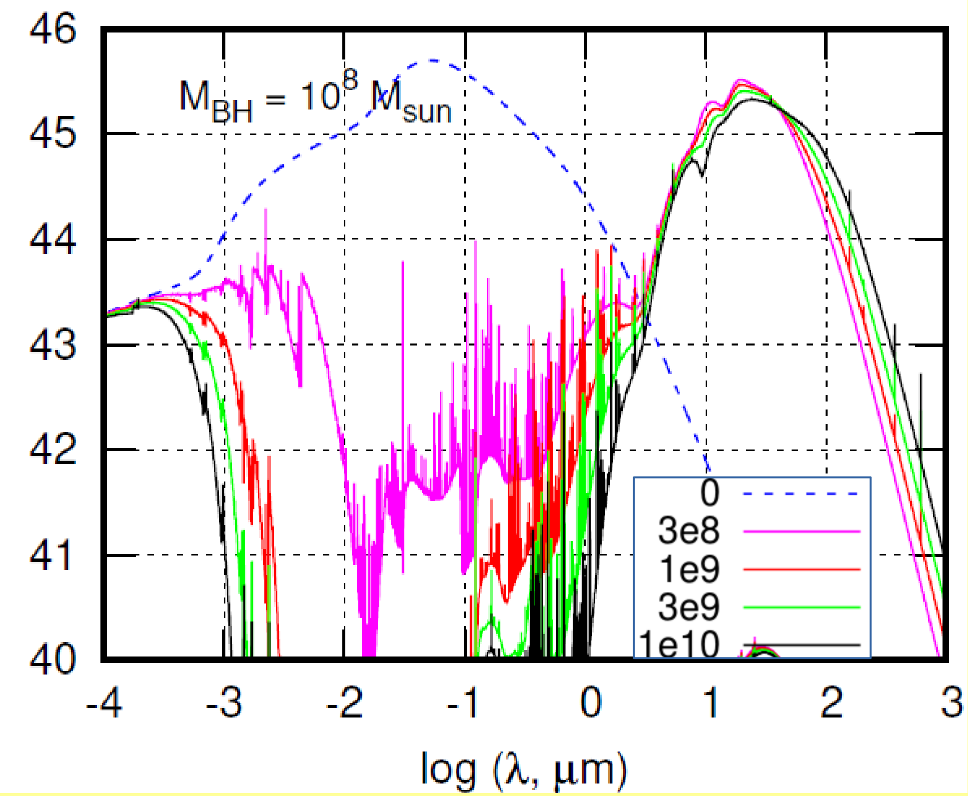




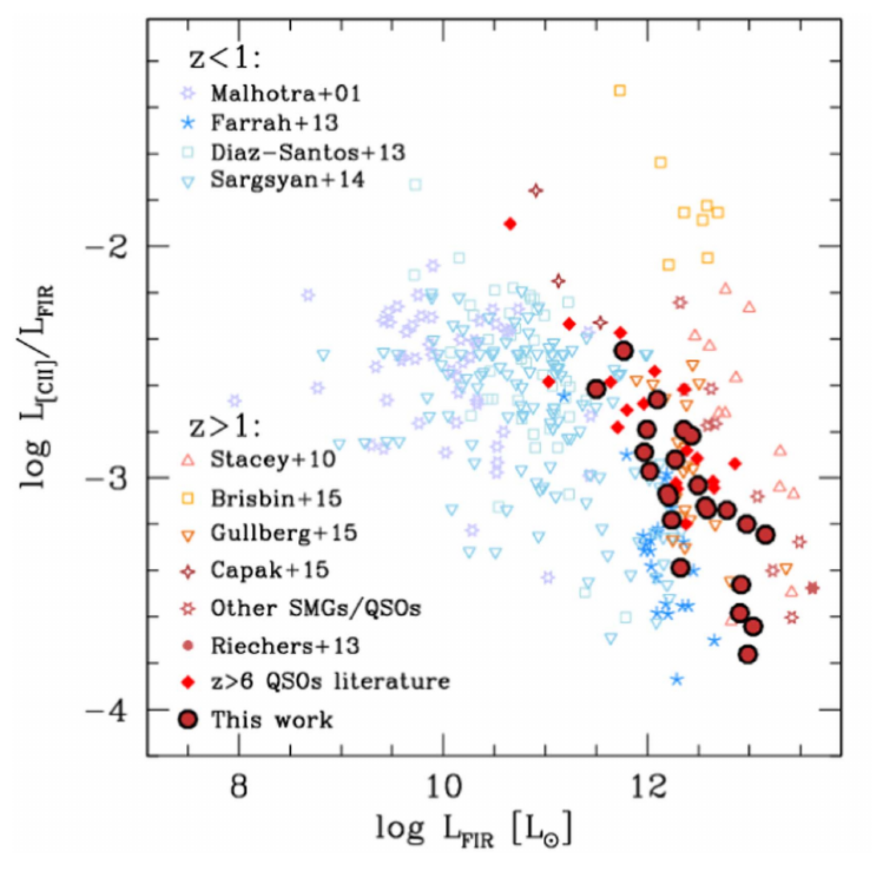


EV etal 2021, submitted

nebular emission for various Mgas



EV etal 2021, submitted



Decarli etal 2018

M(1450 A) < –25.25, at 1450 A – rest-frame UV continuum;

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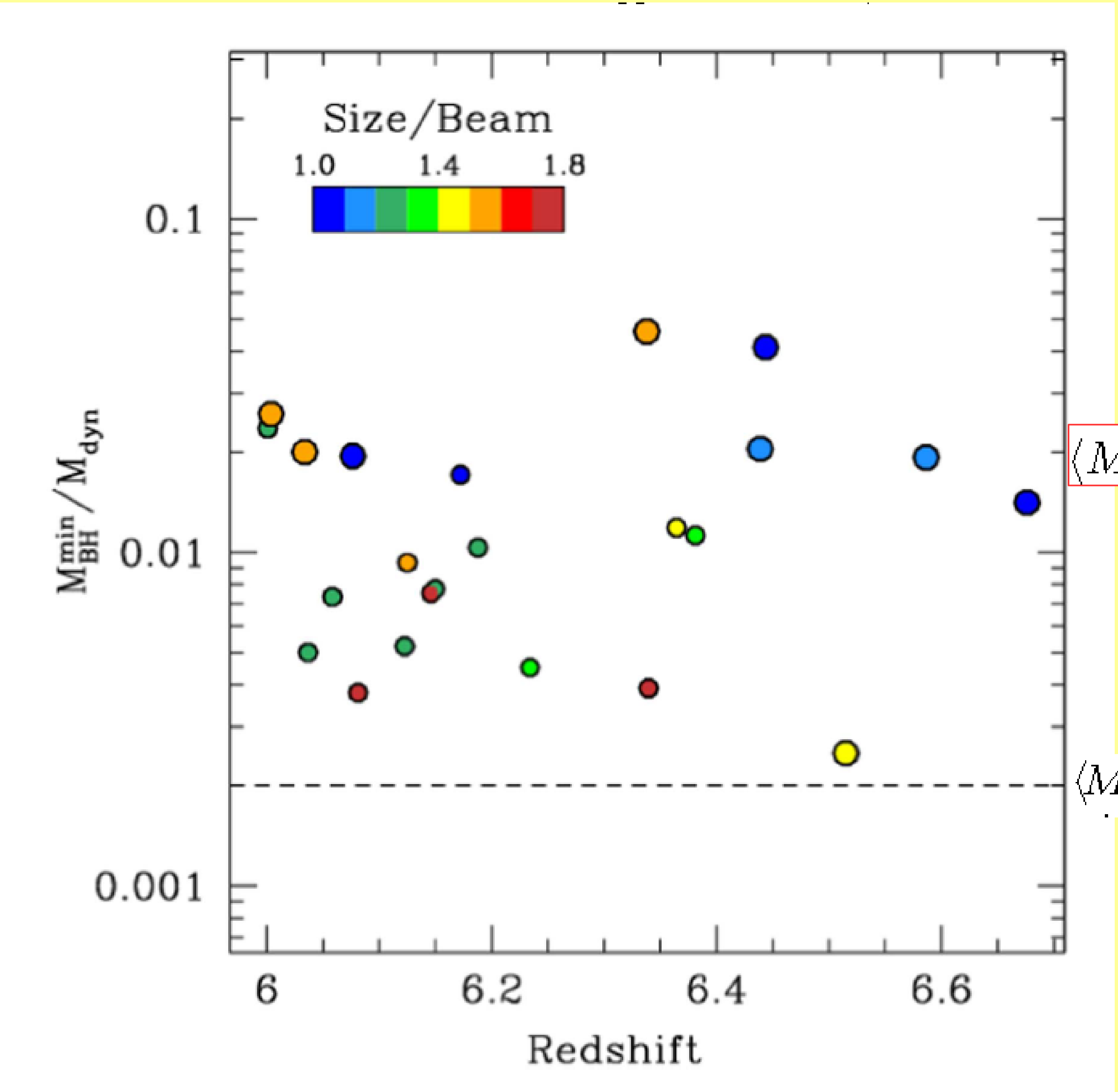


CII 158 мкм
ALMA

z~6-7

$\langle M_* / M_{dyn} \rangle \gtrsim 0.02$

z~0

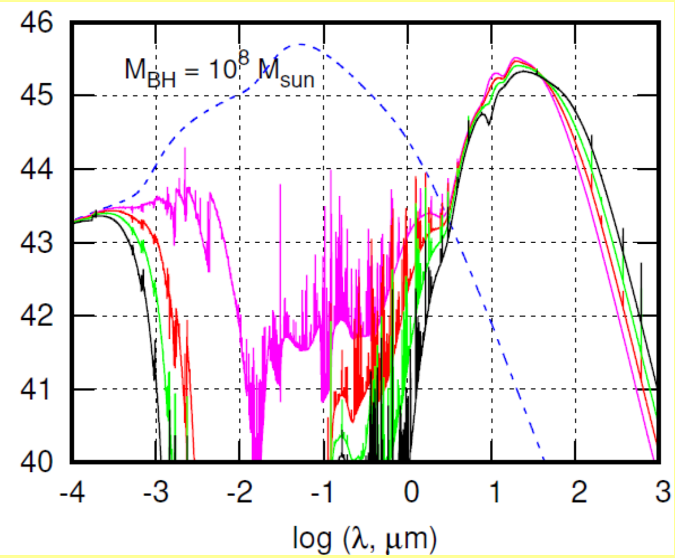
$\langle M_{BH} / M_{bul} \rangle \sim 0.002.$

Decarli etal 2018

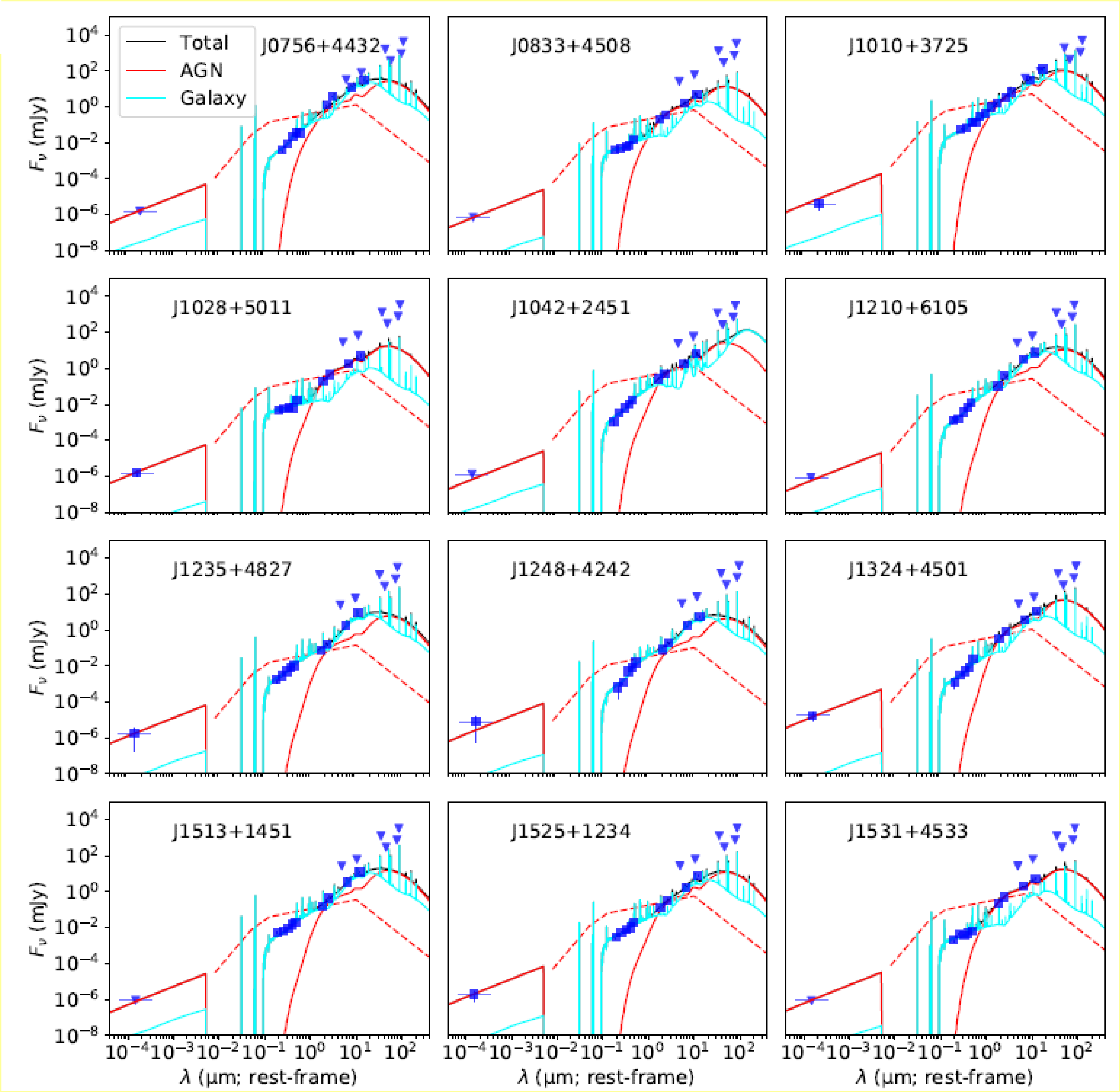
Dust obscured AGNs with Broad optical Line Emission

$0.3 \lesssim z \lesssim 1$

the simulated SEDs

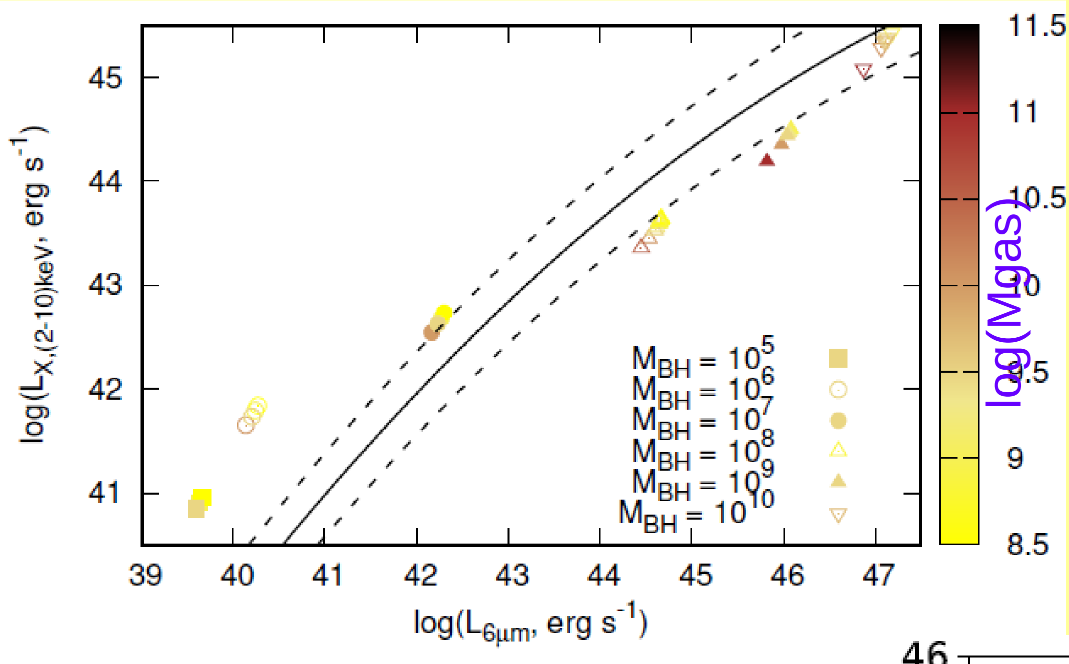


EV etal 2021, submitted



for highly-obscured AGNs there is a gap in the SEDs at UV/optical range

Zou + 2020



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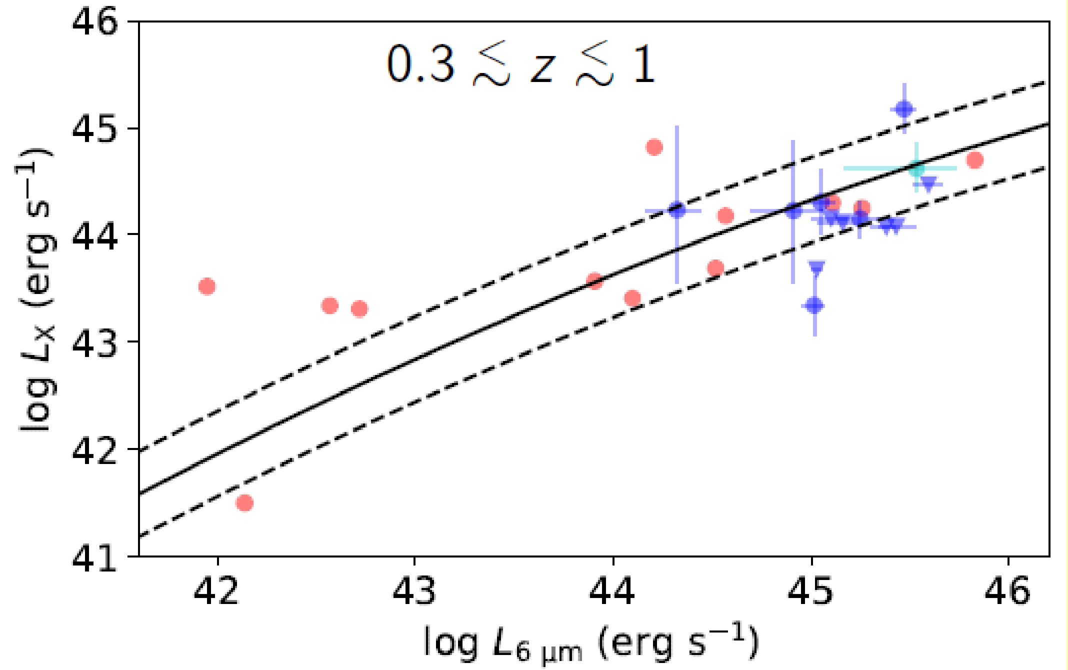
the degeneracy on gaseous mass

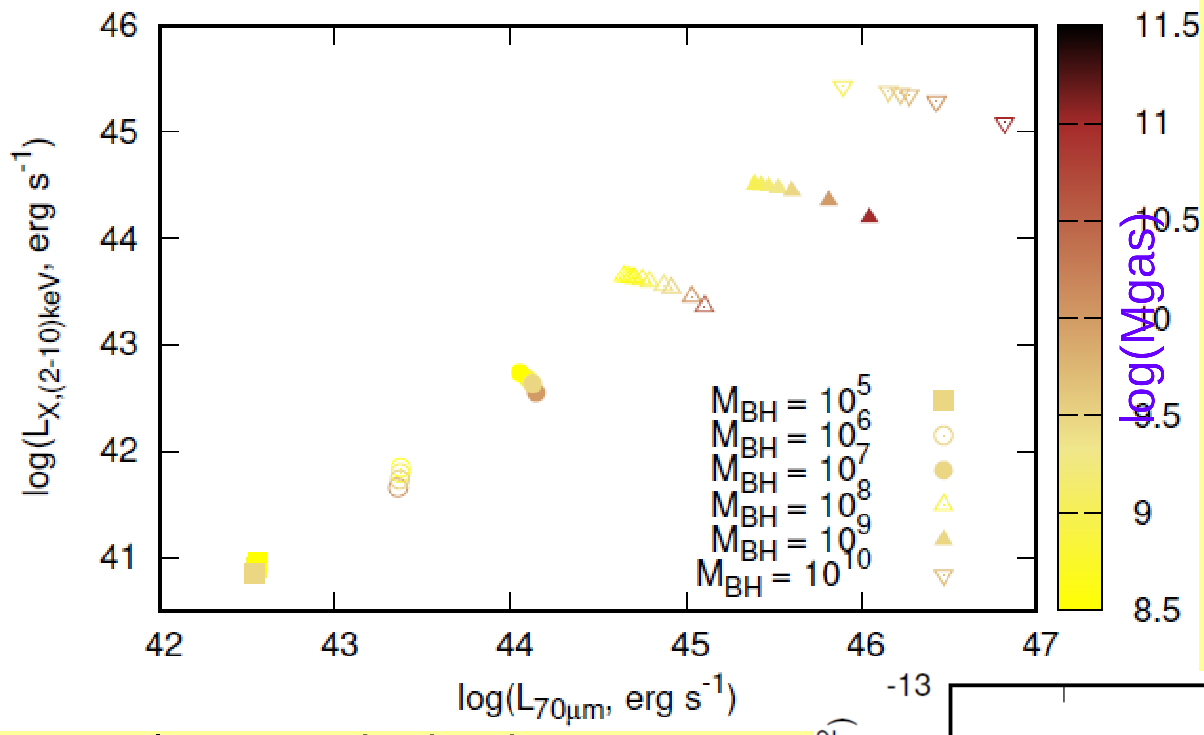
1-sigma scatter for the high-luminosity AGNs (Stern 2015)

- WISE
- Chandra

Zou + 2020

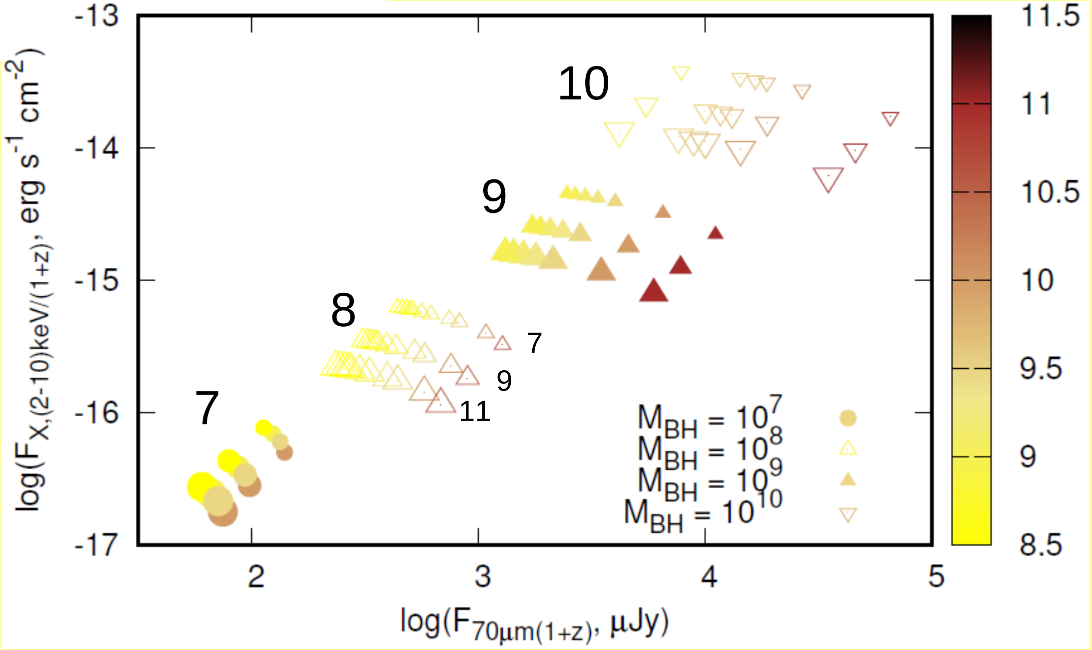


FIR – X-ray



EV etal 2021, submitted

no Mgas-degeneracy for high MBH



the presence of optically selected AGNs with such an enhanced «BH mass – dynamical mass» ratio indicates that many z>6 AGNs with smaller black hole to dynamical mass ratio may be hidden beneath strongly opaque dusty veil

joint FIR-mm and X-ray surveys of high-z QSOs

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Thank you!!!