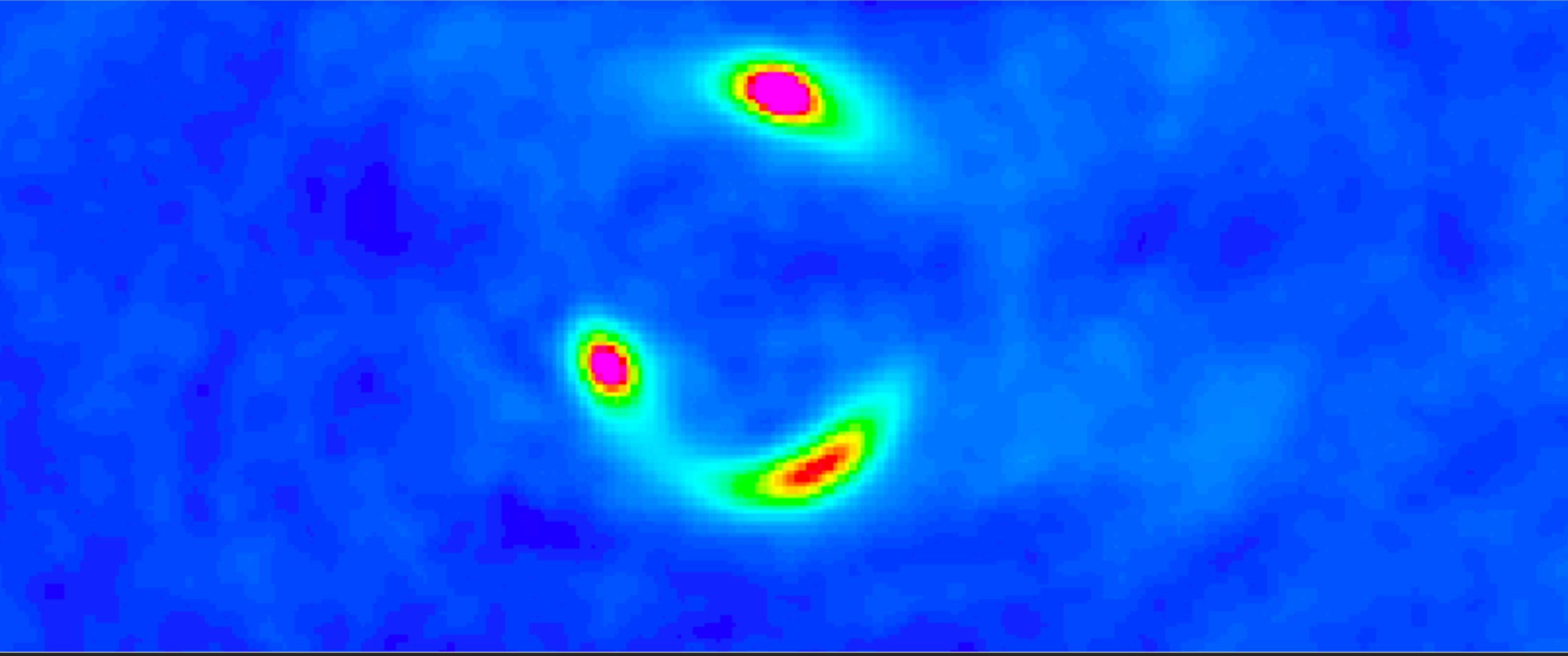


A Sub-Dominant Starburst-Driven Outflow at z~5.7

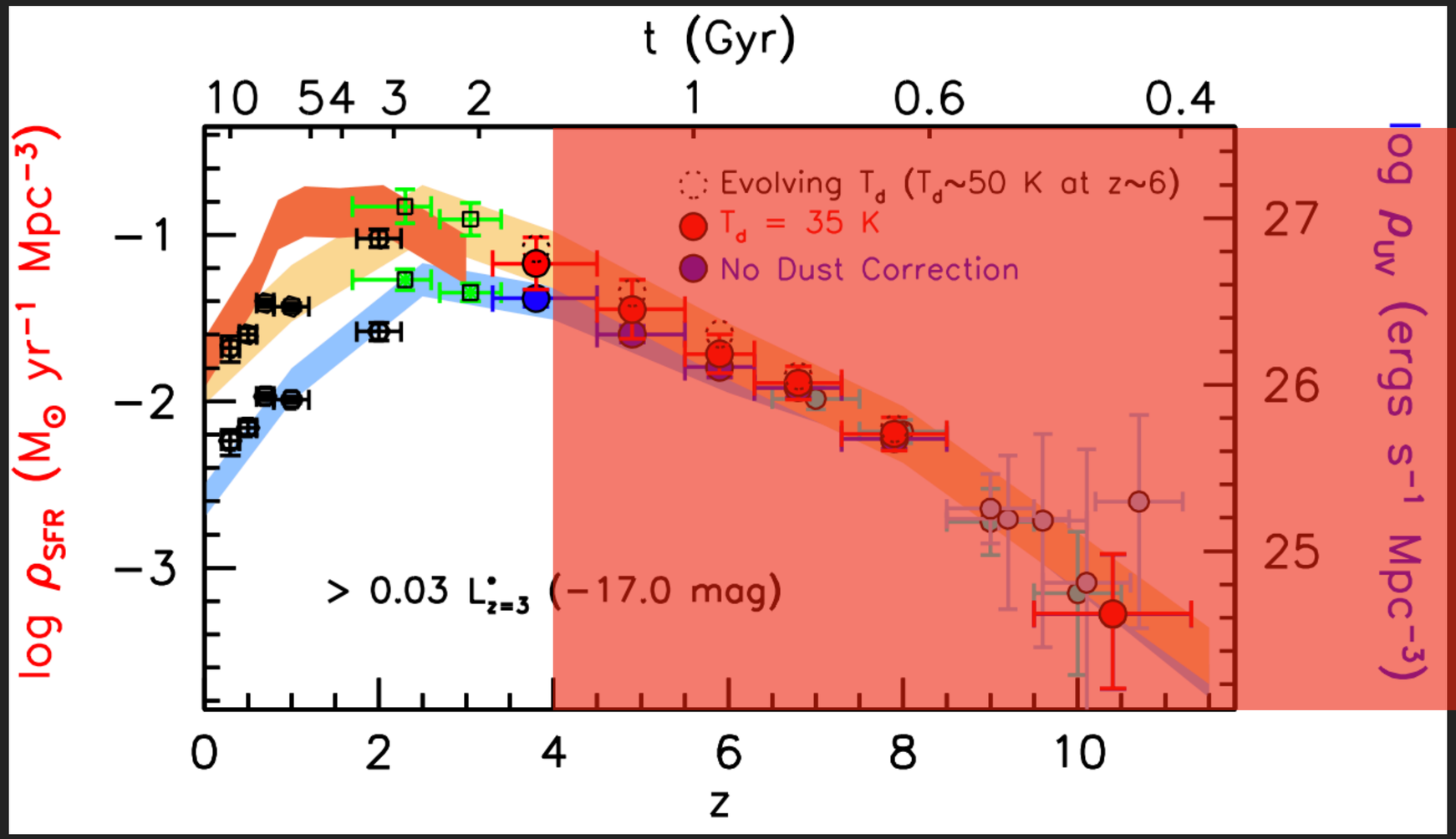
Gareth Jones - Epoch of Galaxy Quenching 2020 - 10 September, 2020

With Roberto Maiolino, Paola Caselli, Stefano Carniani

Kavli Institute for Cosmology Cambridge KICC

UNIVERSITY OF CAMBRIDGE

THE RAMP-UP EPOCH (z>4)



Bouwens+ 2016

A MULTITUDE OF EARLY STARBURSTS

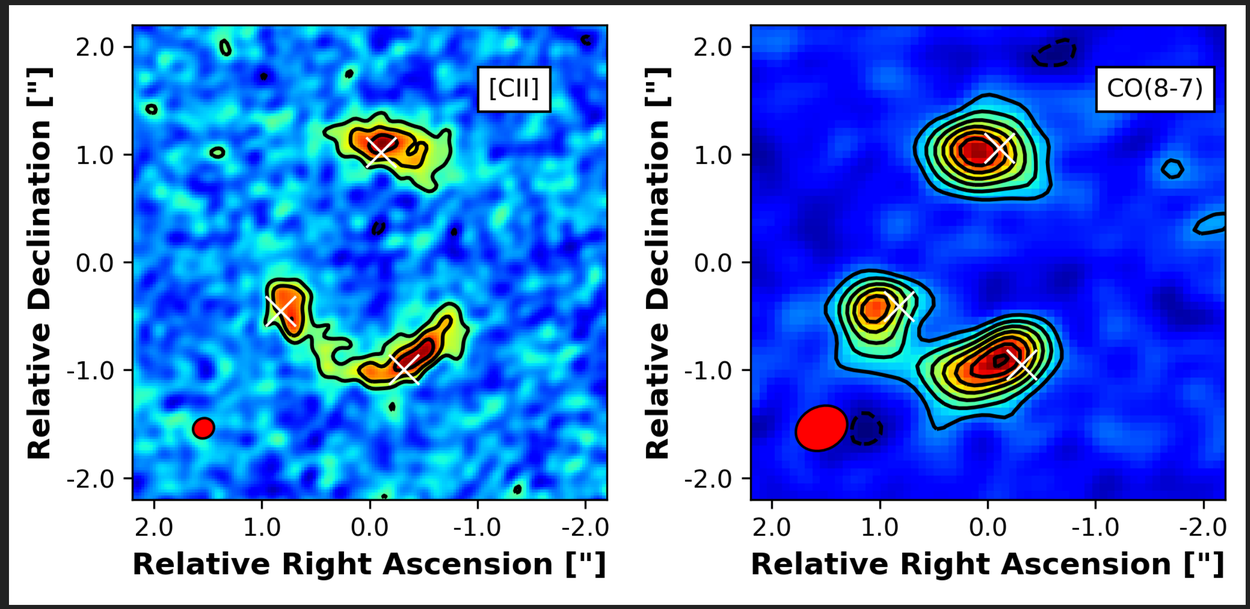
$$z > 4$$
$$\mathrm{SFR} > 1000\,\mathrm{M}_{\odot}\,\mathrm{year}^{-1}$$

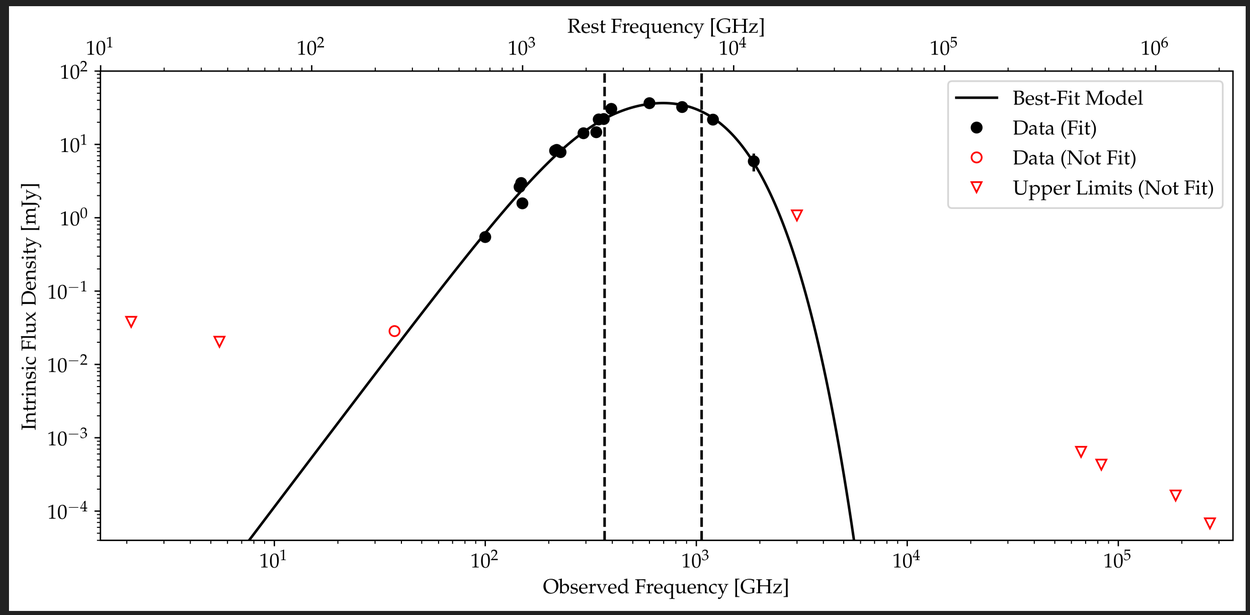
Source	z	SFR	Ref
GN20	4.05	1890 ± 90	Tan et al. (2014)
ID141	4.240	$\sim 2000 \pm 400$	Cheng et al. (2020)
BRI 1335-0417	4.407	5040 ± 1304	Wagg et al. (2014)
BRI 1202-0725 SMG	4.693	6900 ± 2070	Lu et al. (2017)
BRI 1202-0725 QSO	4.695	5100 ± 1530	Lu et al. (2017)
AzTEC-3	5.298	2500 ± 700	Riechers et al. (2020)
GN10	5.303	1030^{+190}_{-150}	Riechers et al. (2020)
SPT0346-52	5.656	3800 ± 100	Jones et al. (In Press)
PSOJ215-16	5.73	1100 ± 900	Li et al. (2020)
SDSS J2310+1855	6.003	4100 ± 600	Carniani et al. (2019)
ULAS J1319+0959	6.133	2500 ± 1700	Carniani et al. (2019)
HFLS3	6.34	~ 2900	Riechers et al. (2013)
SDSS J1148+5251	6.4	3200 ± 1500	Carniani et al. (2019)
J0305-3150	6.6145	1020 ± 160	Li et al. (2020)

+ Dozens from Reuters et al. (2020) and other works

SPT0346-52

- Originally detected in SPT survey
- $z = 5.656$ (~1Gyr after BB)
- $\mu \sim 5.6$
- $\mathrm{SFR} \sim 4000\,\mathrm{M}_\odot\,\mathrm{year}^{-1}$
- $\mathrm{L_{FIR}} > 10^{13}\mathrm{L}_\odot$ (HyLIRG)
- $\mathrm{M_{H_2}} \sim 10^{11}\mathrm{M}_\odot$
- Detected in CO(2-1, 5-4, 6-5, 8-7, 9-8), $\mathrm{H_2O}(2_{0,2} - 1_{1,1},\ 2_{1,1} - 2_{0,2})$, [CII]158$\mu$m





Carlstrom et al. (2011), Weiss et al. (2013), Ma et al. (2015), Spilker et al. (2015), Ma et al. (2016), Spilker et al. (2016), Aravena et al. (2016), Litke et al. (2019), Dong et al. (2019), Apostolovski et al. (2019), Jones et al. (In Press)

AN EARLY STARBURST

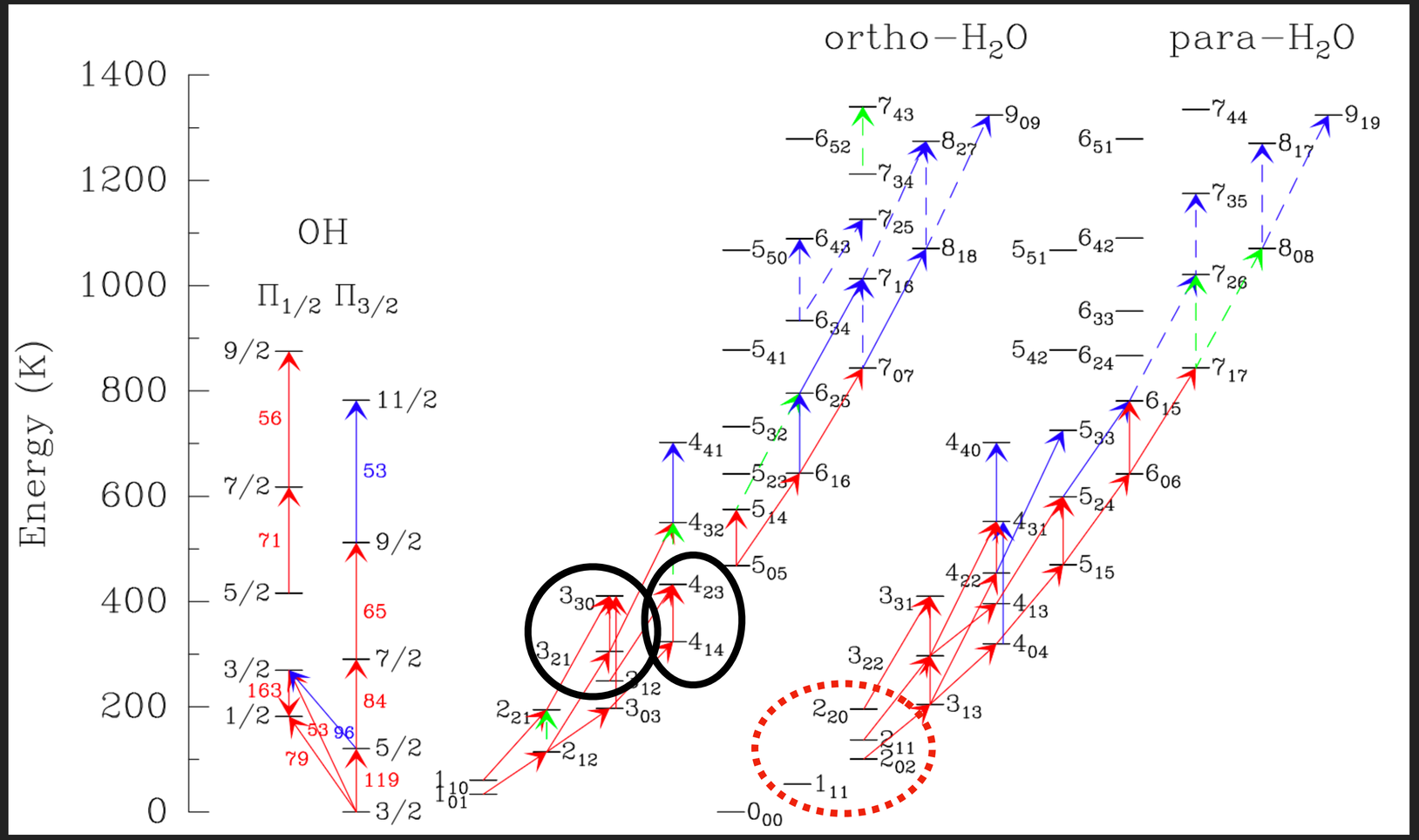
Source	z	SFR	M(H2)	Ref
SPT0346-52	5.656	3800 ± 100	$\sim 10^{11}$	Jones et al. (In Press)

- Star formation only:
  - $t_{depl} \sim 30\,\mathrm{Myr} \rightarrow z \sim 2 - 4$ passive galaxy
- New gas (Filamentary accretion, major/minor mergers):
  - $\uparrow t_{depl}$
- Quenching:
  - $\downarrow t_{depl}$: Removal of intrinsic gas (AGN/SF feedback), Shutoff of gas source (strangulation), Stripping (environmental, ram pressure)
  - $\uparrow t_{depl}$: Unsuitable conditions for SF (AGN/SF feedback, shock heating)

How is this early starburst quenched?

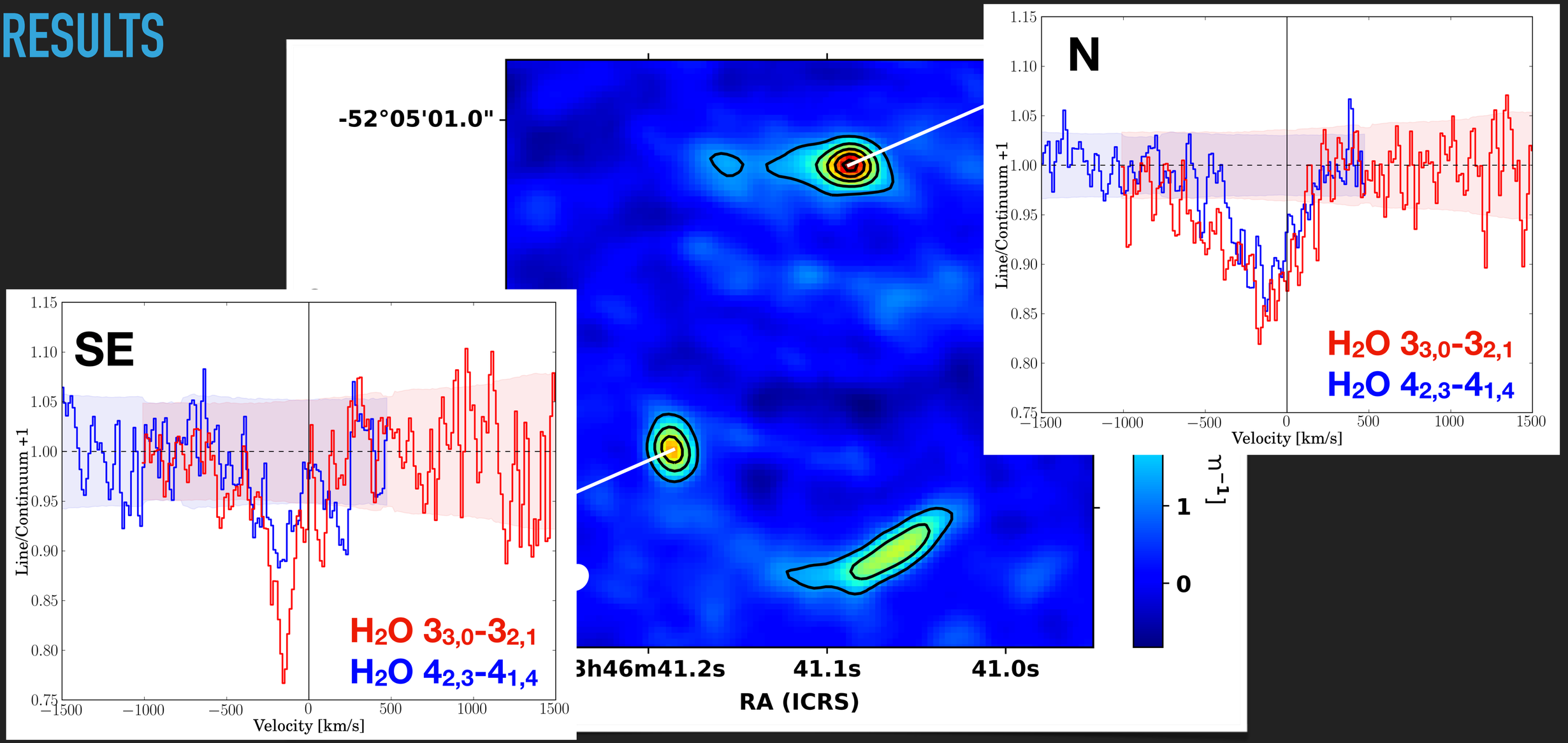
OBSERVATIONS

- ALMA band 7, cycle 4
- 1.95 hours on-source
- Beam $0.19'' \times 0.17''$
  - $\sim 1.0 \times 1.1$ kpc
- $H_2O(4_{1,4} - 4_{2,3})$
- $H_2O(3_{3,0} - 3_{2,1})$

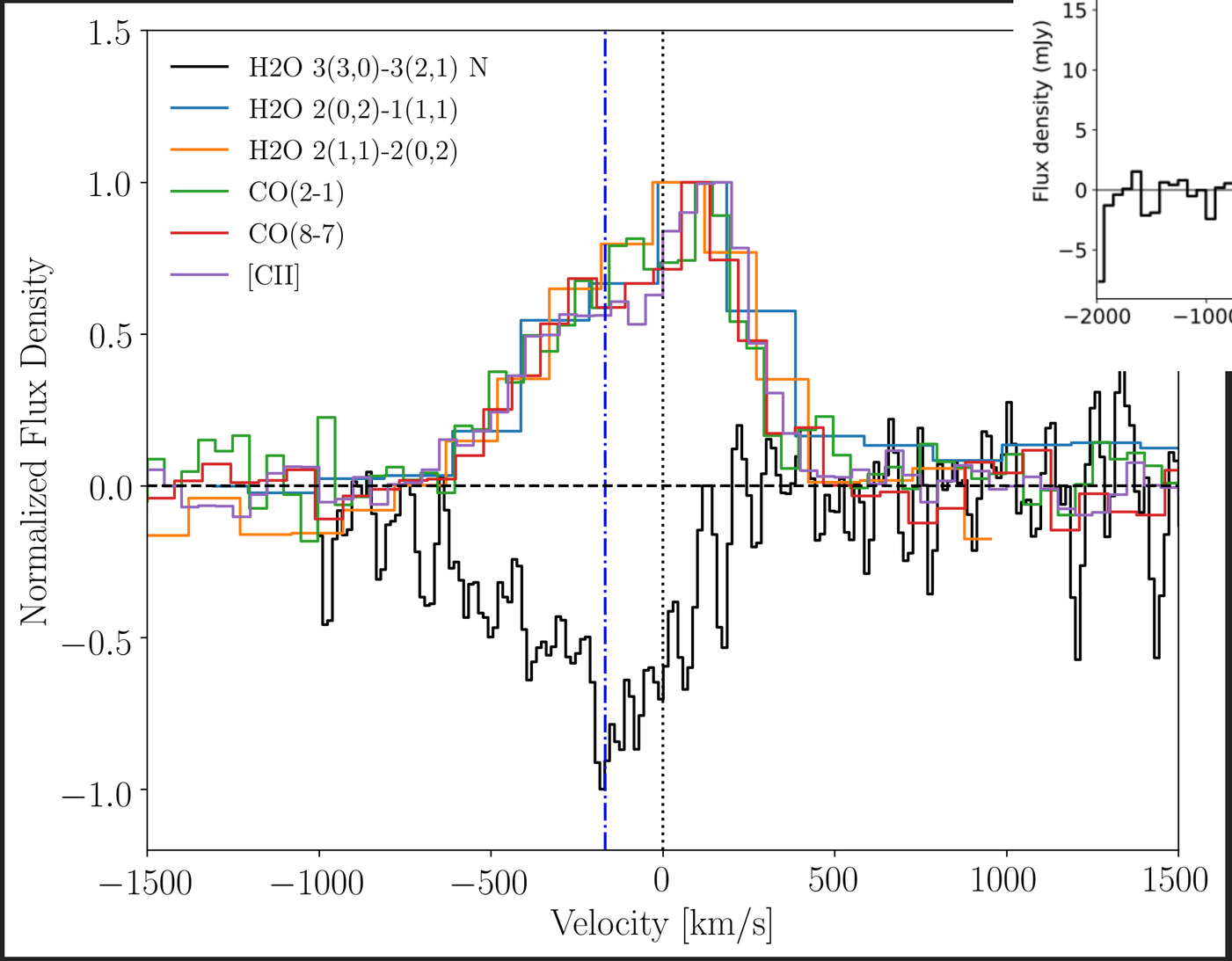


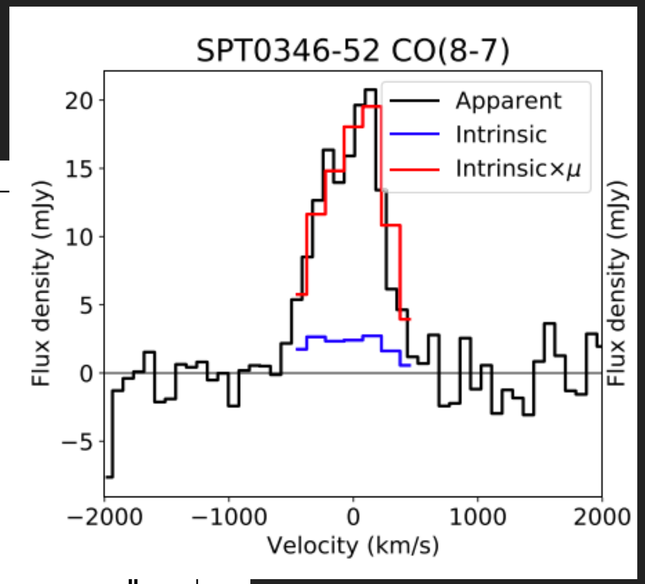
González-Alfonso et al. (2012)

RESULTS

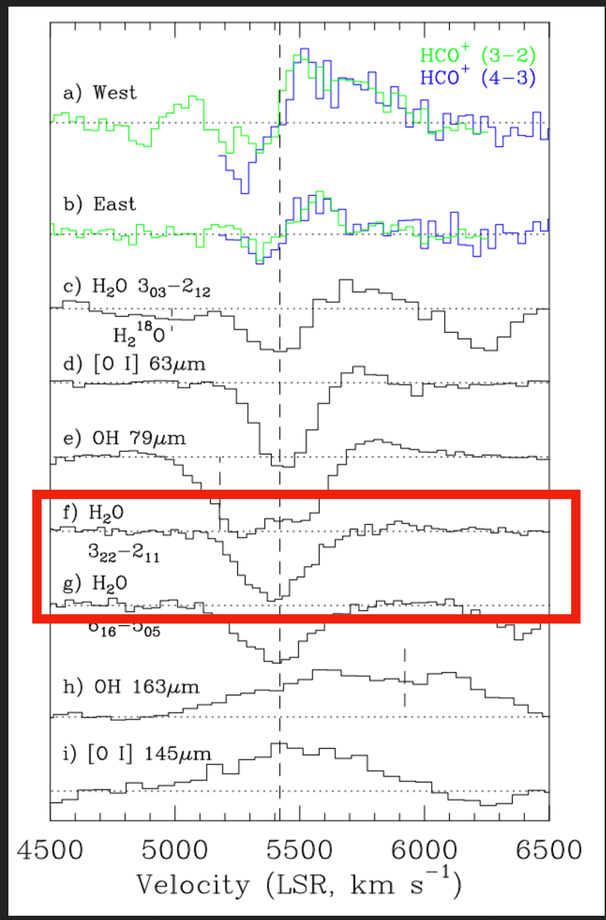

-52°05'01.0"
3h46m41.2s
41.1s
41.0s
RA (ICRS)
1
0
SE
N
Line/Continuum +1
Velocity [km/s]
H2O 33,0-32,1
H2O 42,3-41,4

RESULTS





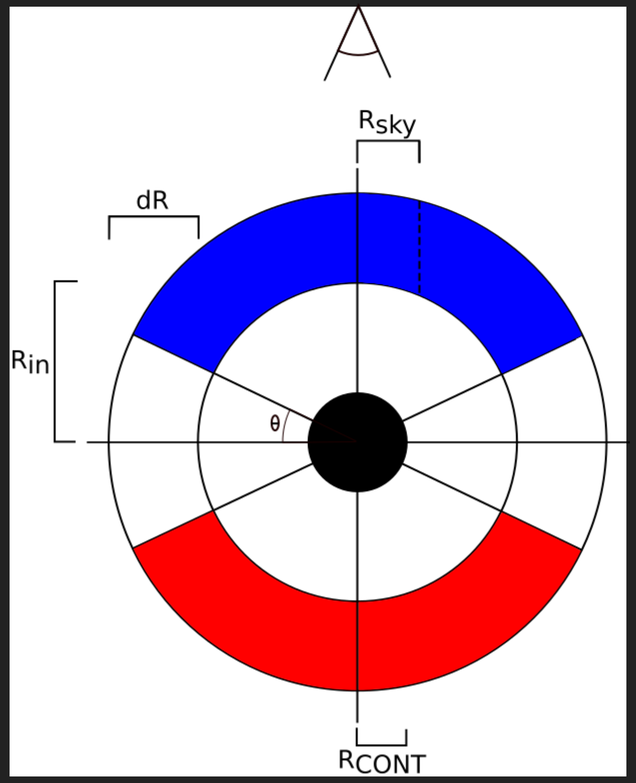
Dong et al. (2019)



Gonzalez-Alfonso et al. (2012)

OUTFLOW MODELLING

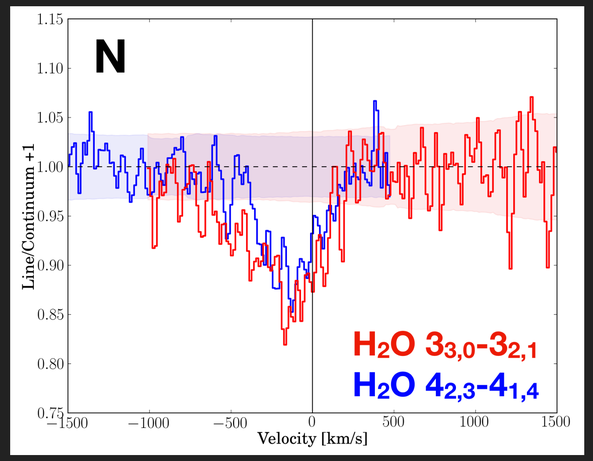
Model



+

Application

$$\tau(r) = \frac{\pi e^2 f_{lu} \lambda_{lu} \rho_l(r)}{m_e c m_{H_2O} \left| dv/dr \right|} \qquad B = 1 - e^{-\tau(r)}$$

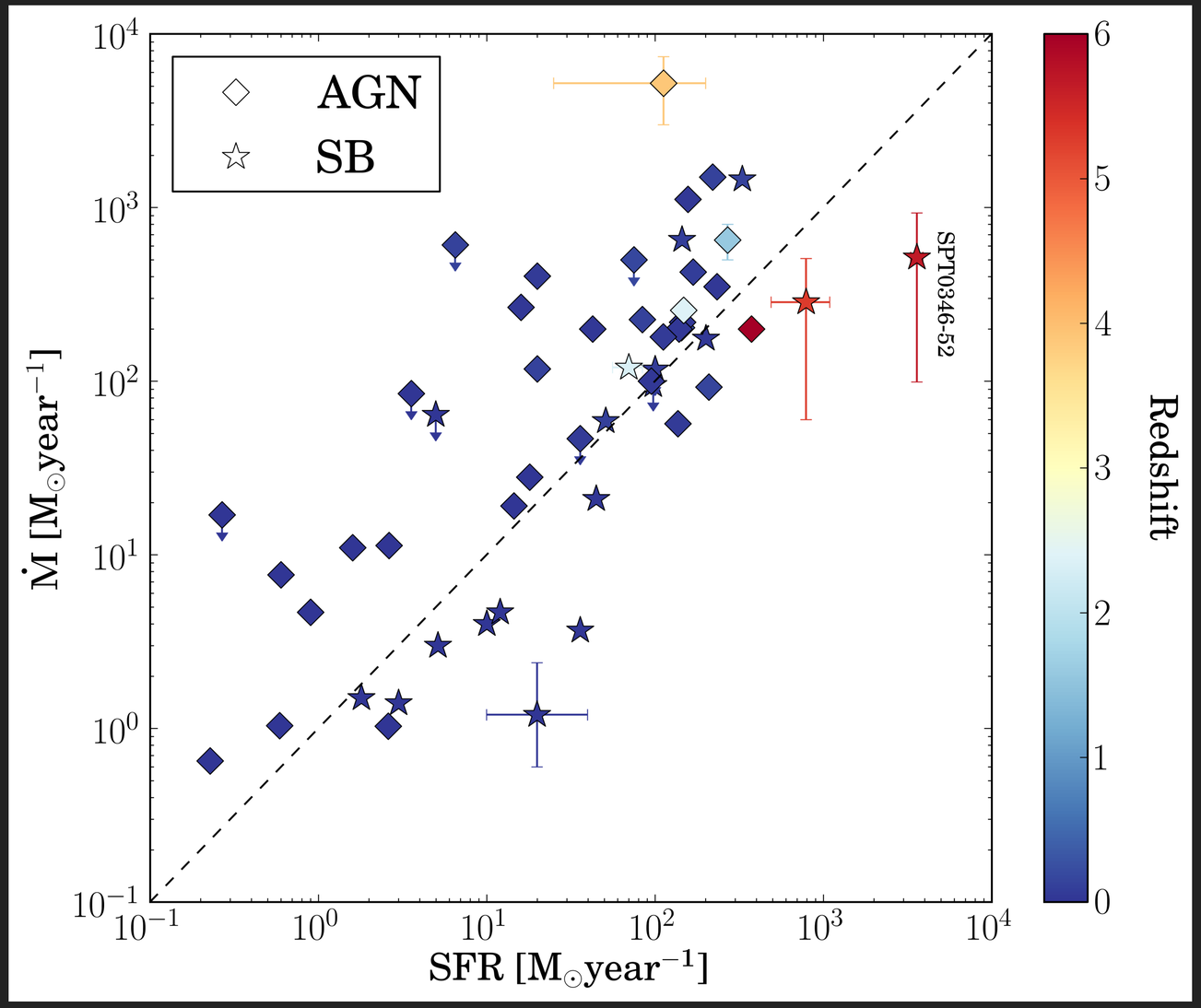


PyMultiNest

=

$$\dot{M}_{H_2}$$

OUTFLOW MODELLING



CONCLUSIONS

- Detection of two water absorption lines in an early (z~5.7) starburst (SFR~4000)
- Find evidence for highest-SFR molecular outflow
- Using spherical shell outflow model, find $\dot{M} < SFR$

How is this early starburst quenched?

- For gas depletion, starburst >> outflows
- Accretion, group effects, SF conditions also matter

- Next: Additional high-excitation OH/H_2O observations of z>4, SFR>1000 galaxies

"Detection of a high-redshift molecular outflow in a primeval hyperstarburst galaxy"
Jones G. C., Maiolino R., Caselli P., Carniani S., 2019, A&A, 632, J7
https://arxiv.org/pdf/1911.09967.pdf