

Submillimeter Galaxies at High Resolution

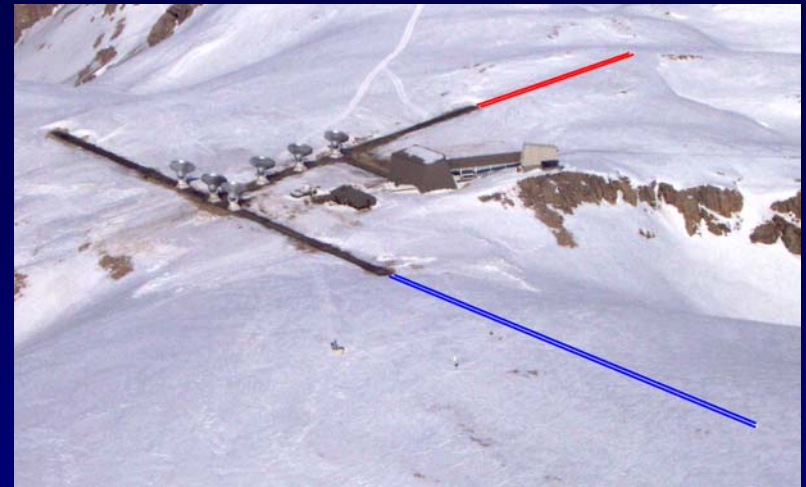
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A. Omont, I. Smail*

- I. PdBI SMG CO Survey*
- II. Evidence for Merger Induced “Maximum” Starburst*
- III. Subsequent Evolution of SMGs*
- IV. SMGs are Dissipative Major Mergers*

*Gas Accretion in Galaxies, MPA/ESO/MPE/USM Conference
Garching – September 14, 2007*

PdBI CO Survey of Submillimeter Galaxies (SMGs)



- *submm sources with VLA 1.4 GHz counterparts (tens of μJy)*
- *Keck follow up spectroscopy with LRIS-B: 85 redshifts: $\langle z \rangle \sim 2.3$ (Chapman et al. 2003, 2005)*
- *PdBI CO to confirm redshift (10-20 hours on source)*
- *high resolution PdBI follow-up for spatially resolved CO emission (another ~ 20 hours on source)*
- *~ 20 CO detections of SMGs between $z \sim 1$ and 3.5 (out of ~ 30 sources)*

This Survey: Neri et al. 2003, Greve et al. 2005, Tacconi et al. 2006, 2007, Smail et al. 2007

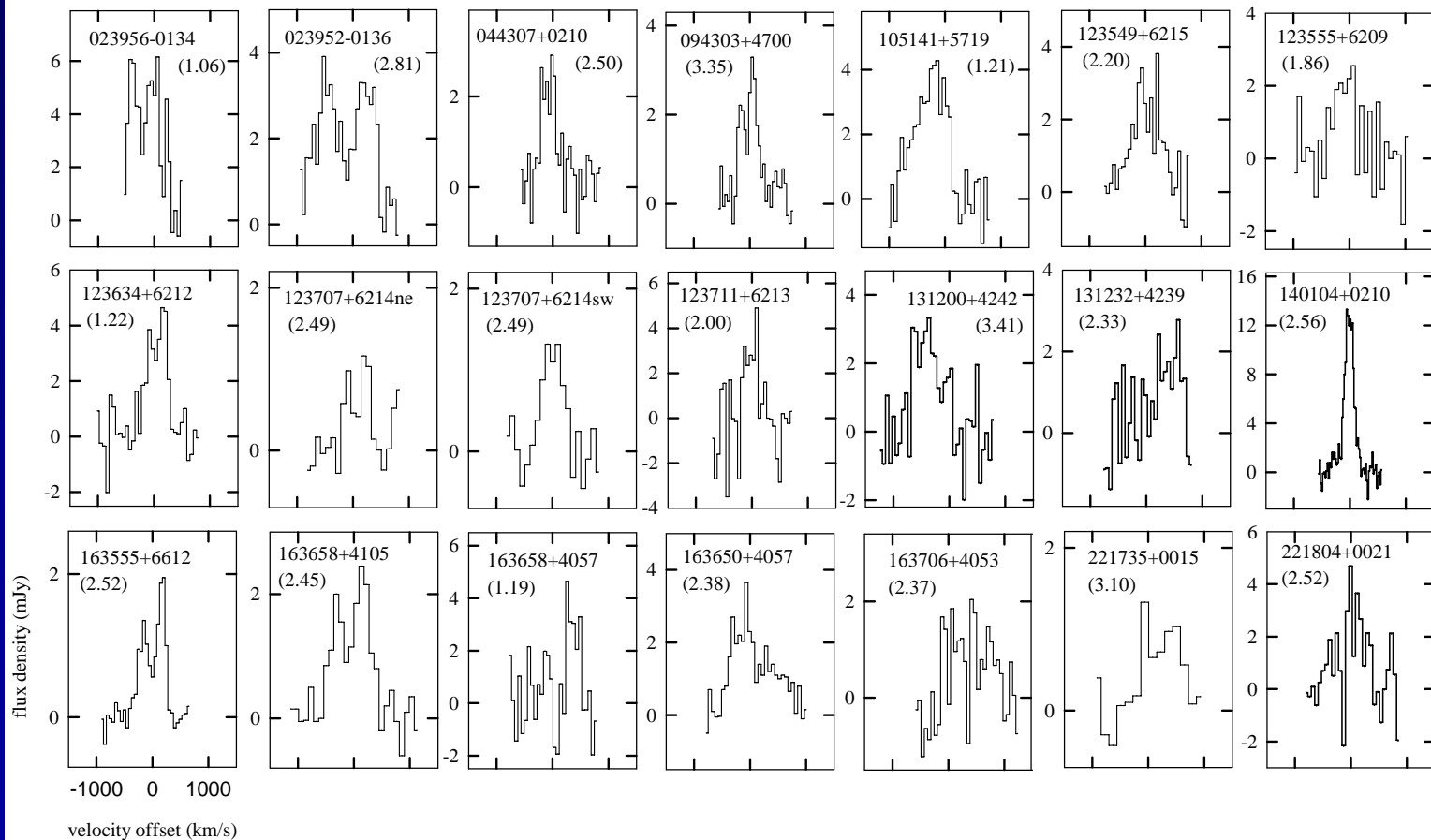
Other CO work: Frayer et al. 1998, 1999, Andreani et al. 2000, Ivison et al. 2002, Downes & Solomon 2003, Genzel et al. 2003, Sheth et al. 2004, Kneib et al. 2005, Weiss et al. 2005, 2007, Solomon & Vanden Bout 2005, Hainline et al. 2006, Iono et al. 2006...

SMG Survey

IRAM PdBI

2002-2006

*Downes & Solomon 2003, Genzel et al. 2003,
Neri et al. 2003, Kneib et al. 2005, Greve et al.
2005, Tacconi et al. 2006, Smail et al. 2007*

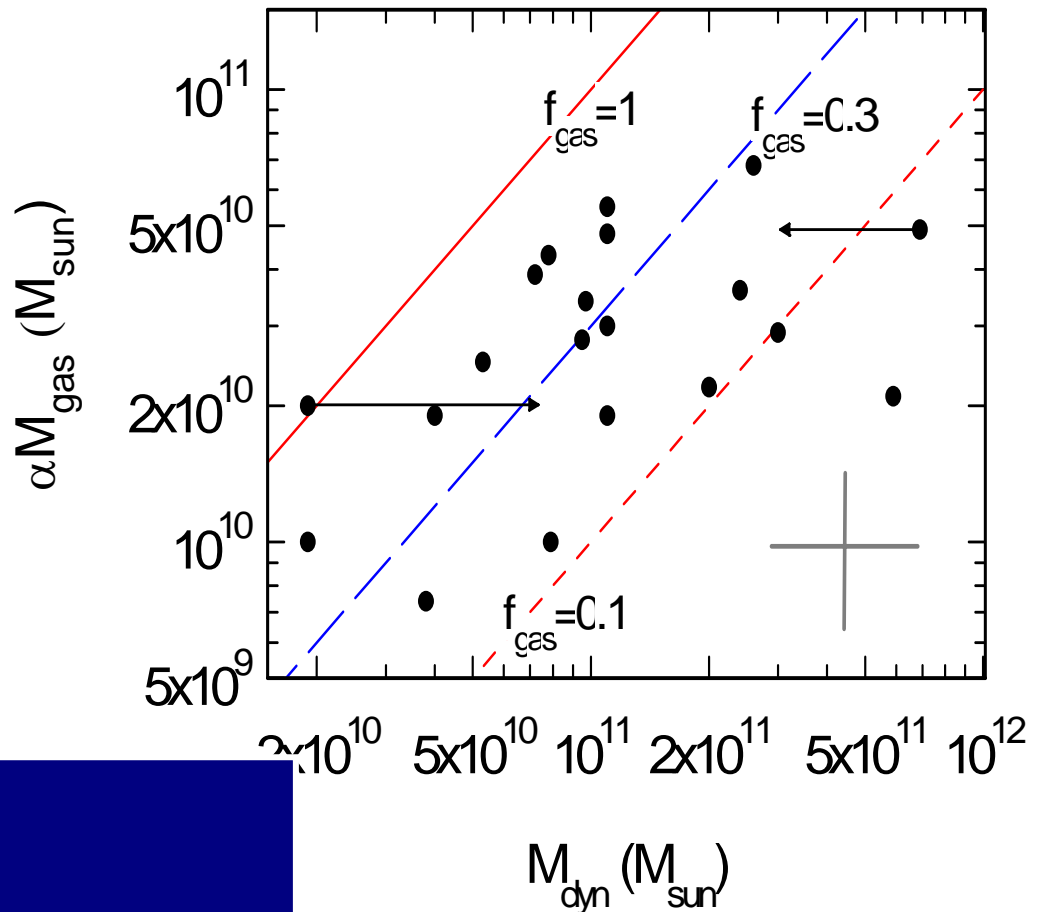


SMG Survey

IRAM PdBI

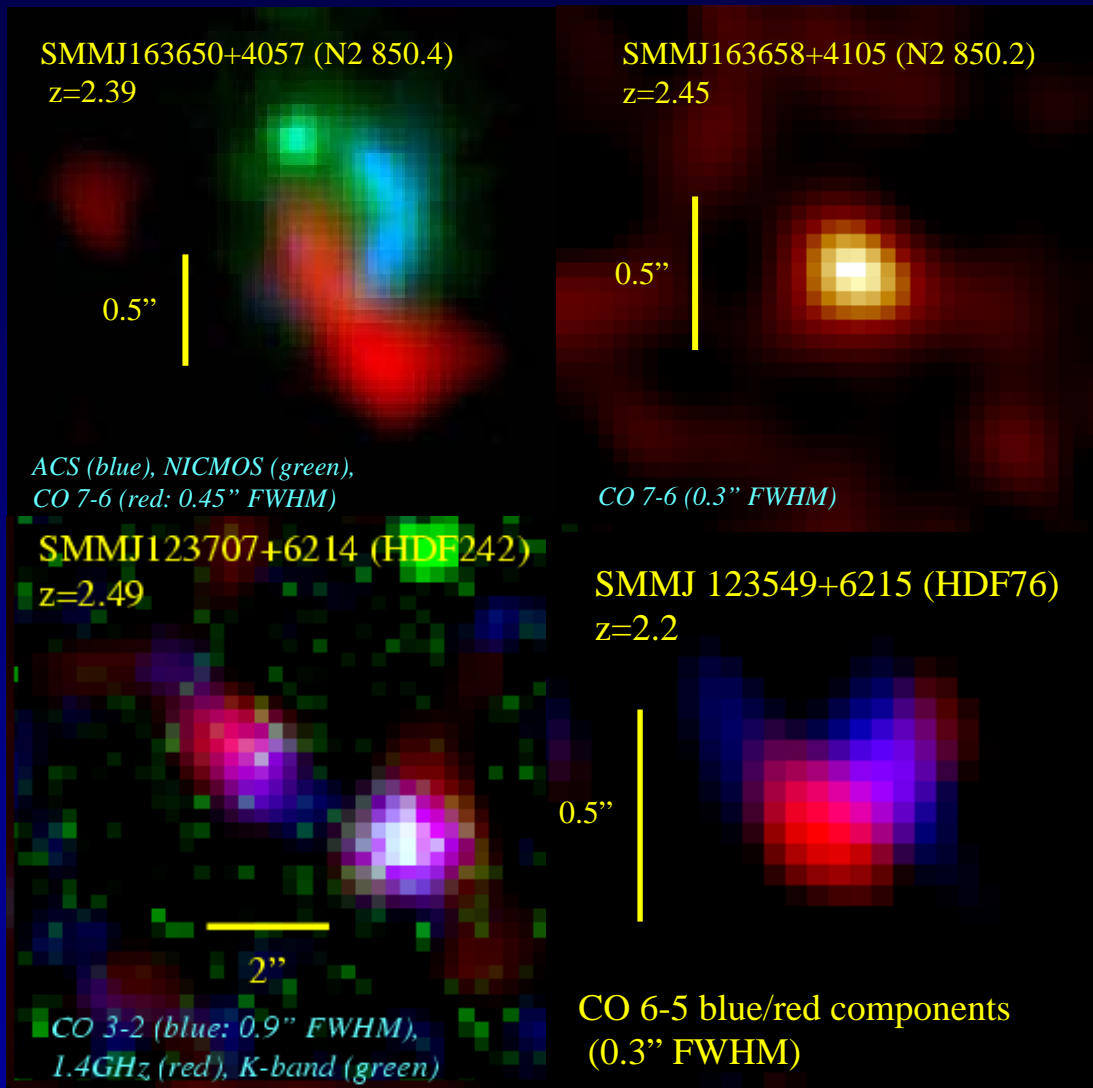
2002-2006

Downes & Solomon 2003, Genzel et al. 2003,
Neri et al. 2003, Kneib et al. 2005, Greve et al.
2005, Tacconi et al. 2006, Smail et al. 2007



- $\langle v_c \rangle = 400 \text{ km/s}$
- $M_{\text{dyn}} \sim 10^{11} M_{\odot}$ within CO regions
- $\langle M(\text{H}_2) \rangle = 3.0 \pm 1.6 \times 10^{10} M_{\odot}$
- $f_{\text{gas}} \sim 0.2-0.5$
- $\langle R \rangle_{1/2} < 0.25''$ (2 kpc)

Sub-arcsec Interferometry of SMGs



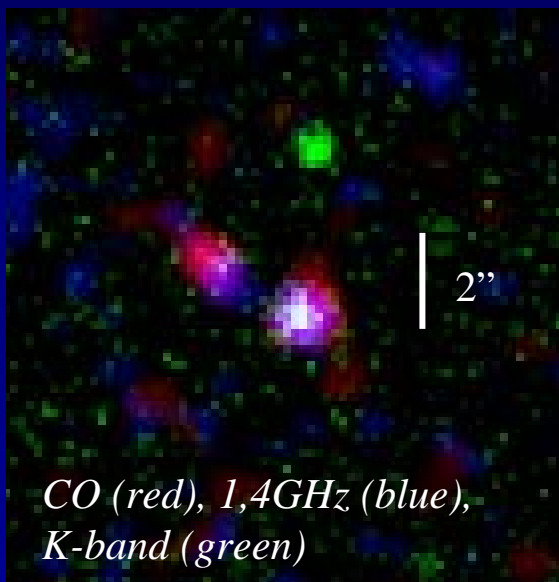
- *IRAM Plateau de Bure Interferometer*
- *800 meter baselines*
- *~0.3-0.5'' resolution at 1mm*

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IRAM SMG Team: R.Genzel, F.Bertoldi, A.Blain, S.Chapman, P. Cox, T.Greve, R. Ivison, R.Neri, A.Omont, I.Smail, L. Tacconi

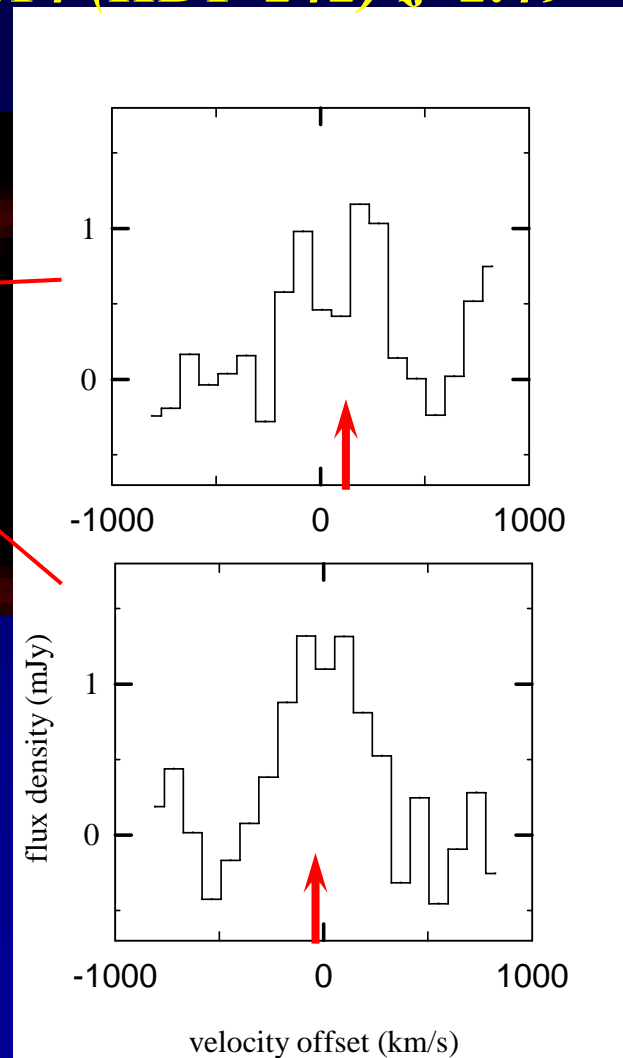
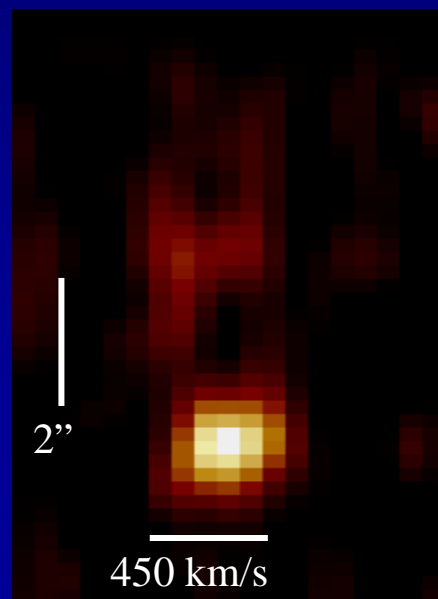
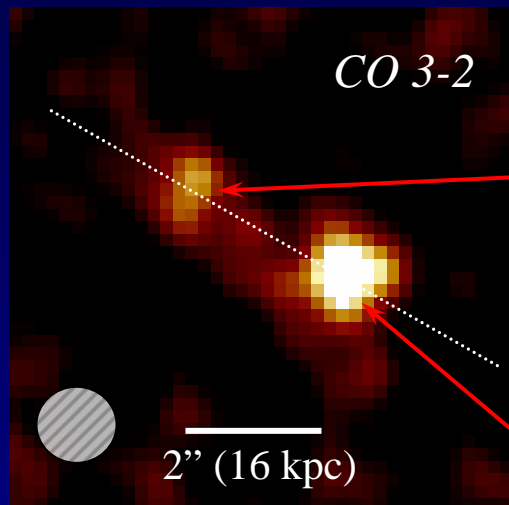
HDF 242: An Early Stage Merger?

SMMJ123707+6214 (HDF 242) $z=2.49$



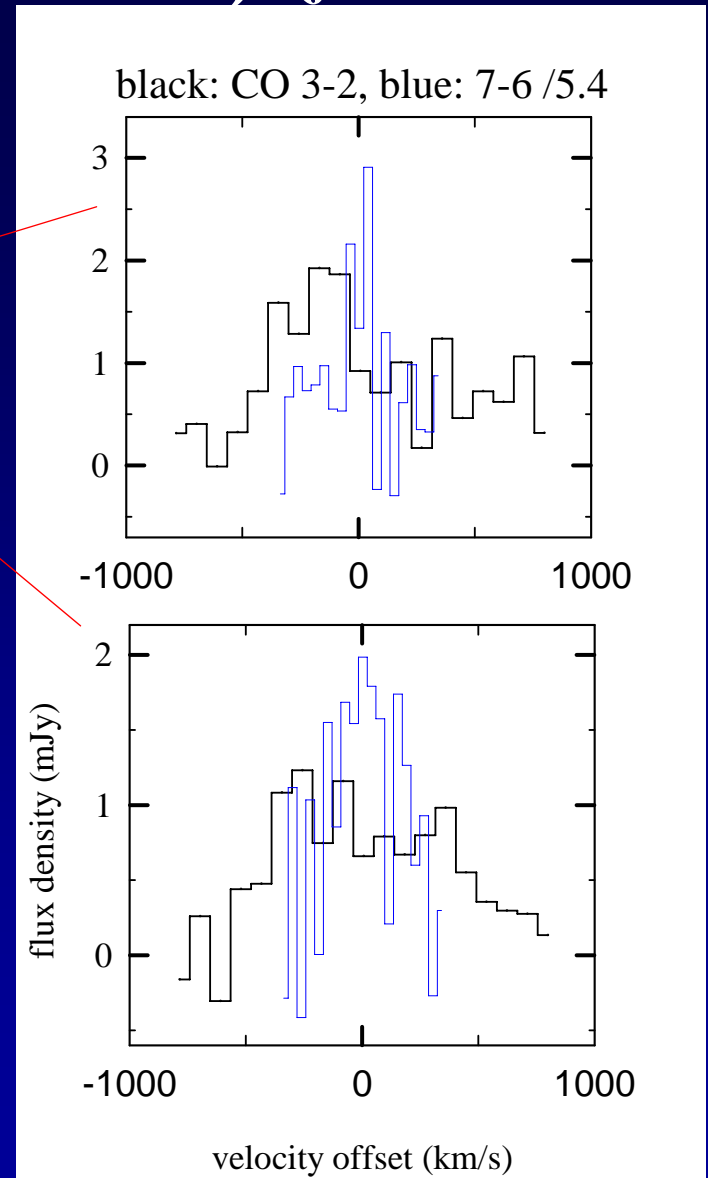
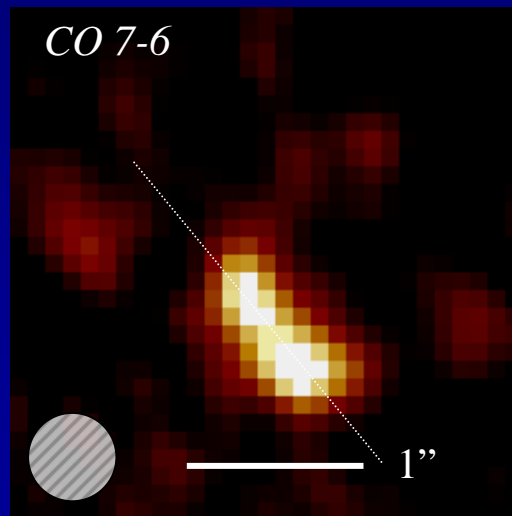
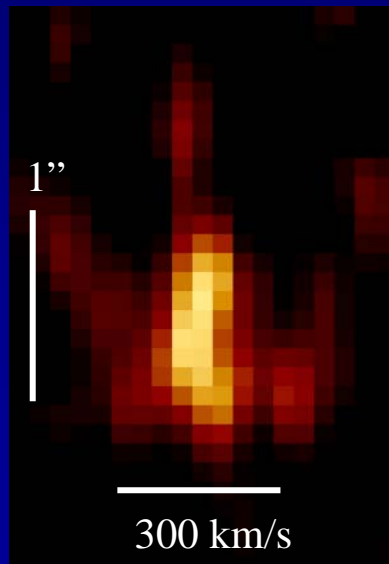
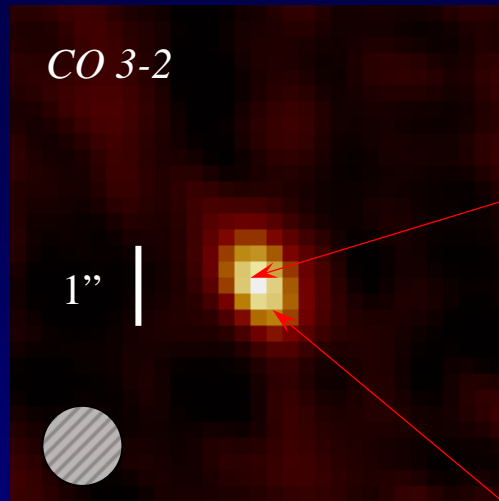
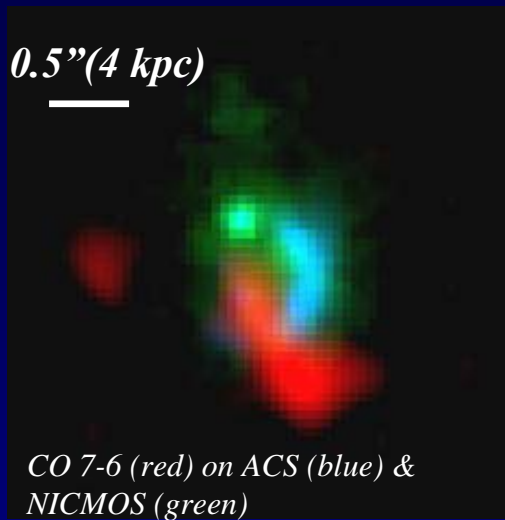
CO components:

- projected separation ~ 16 kpc
- velocity difference 100-150 km/s

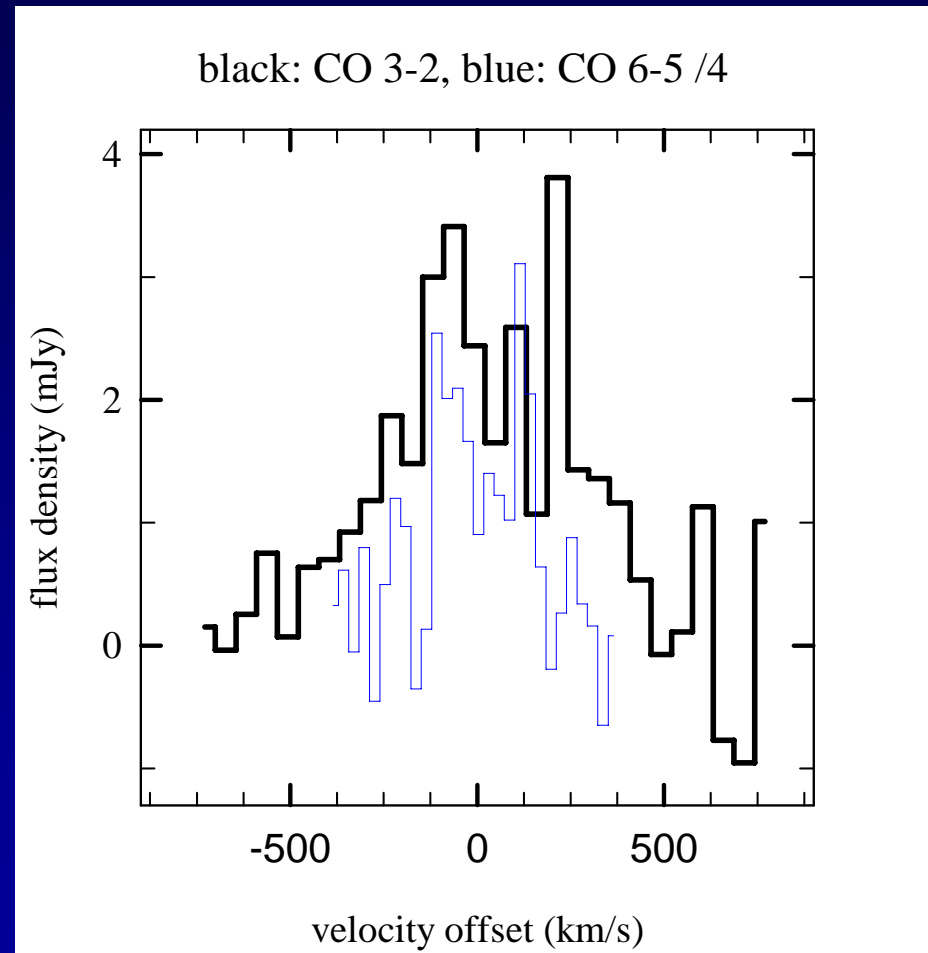
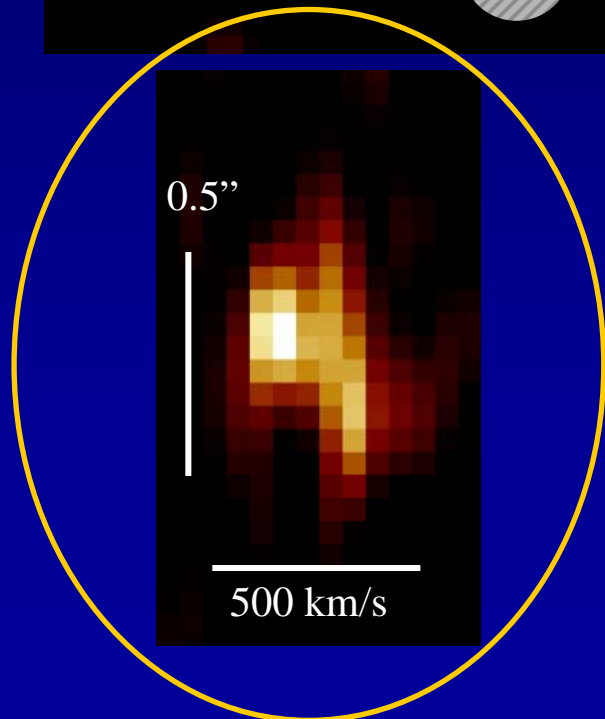
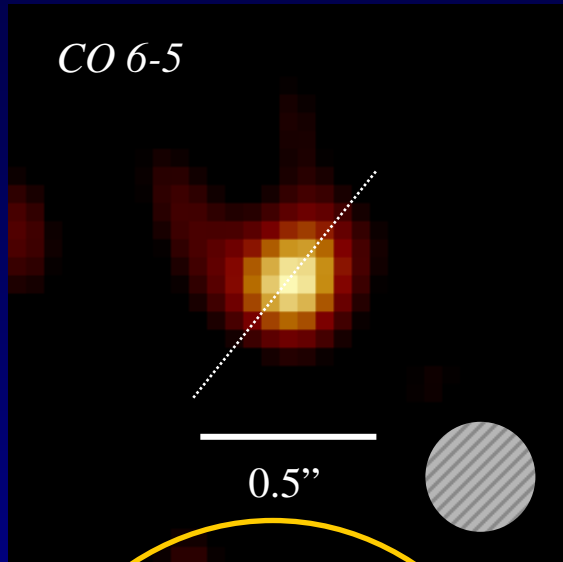


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SMMJ163650+4057 (N2 850.4) $z=2.39$



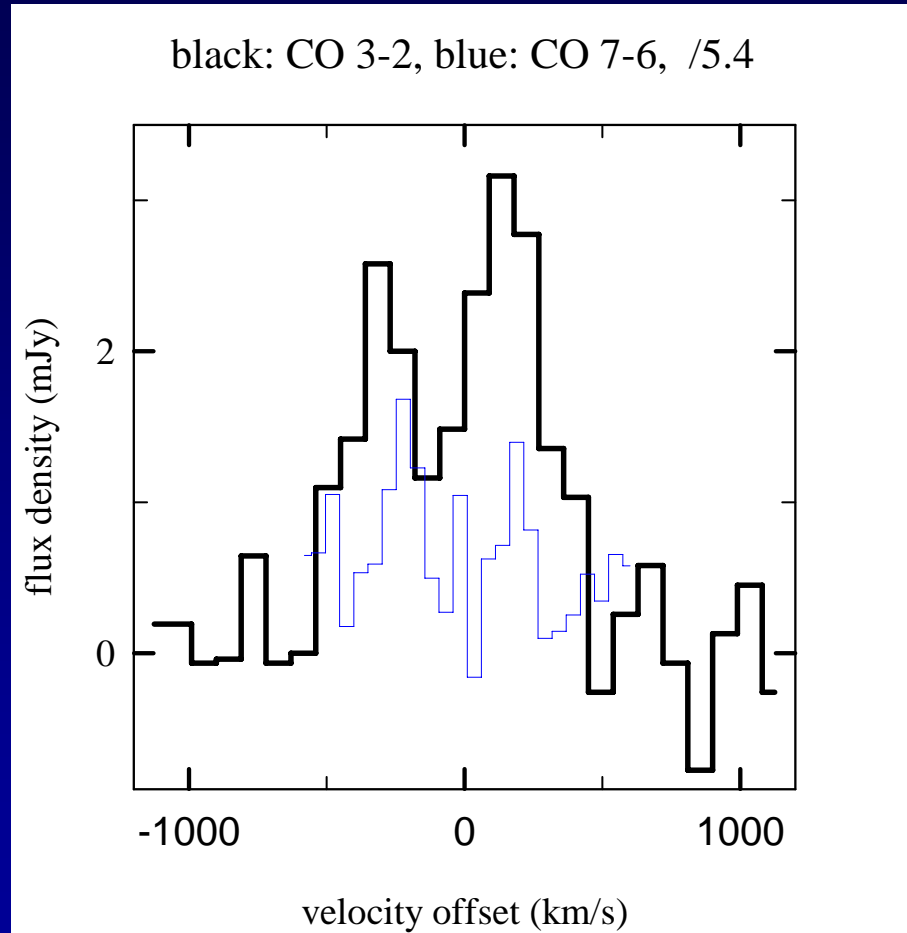
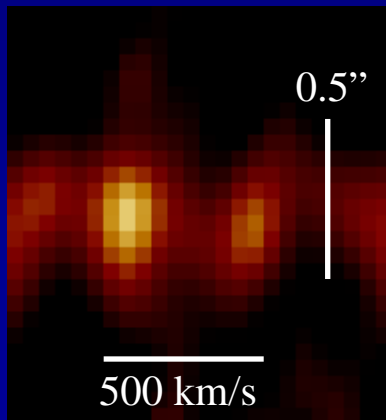
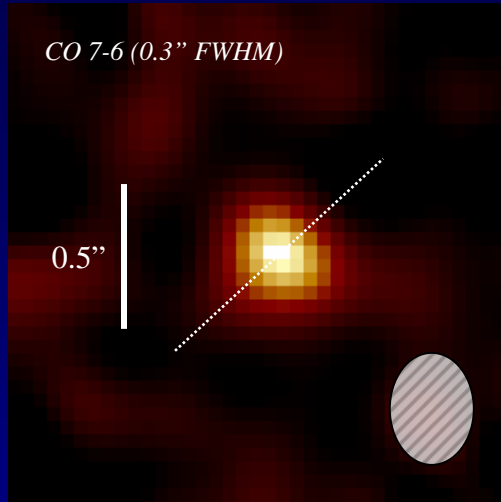
SMMJ123549+6215 (HDF76) $z=2.20$



IRAM Plateau de Bure
resolution = 0.4''x0.3'' FWHM

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SMMJ16358+4105 (N2850.2) $z=2.45$



*IRAM Plateau de Bure
resolution = 0.3" FWHM*

*CO Size $\sim 0.25''$ FWHM (1.6 kpc)
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SMGs As ‘Maximum Starbursts’

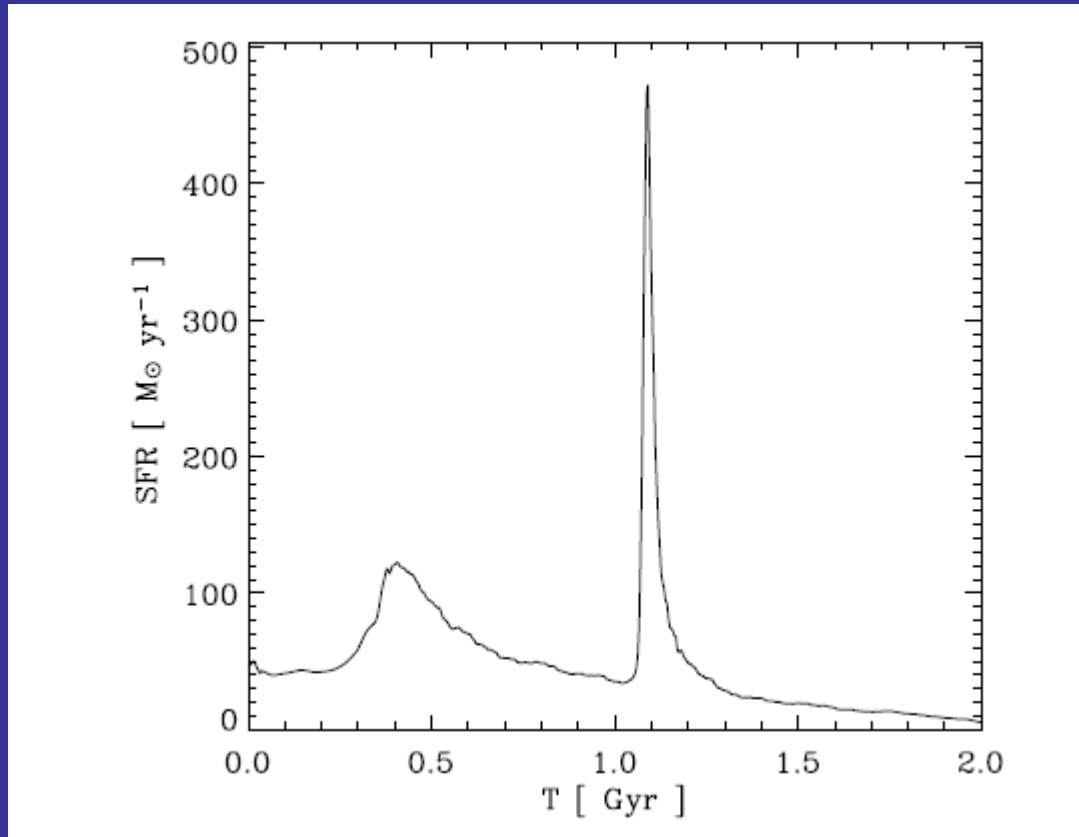
globally unstability to collapse ($Q \leq 1$)

$$\Sigma_{gas,crit} \geq 2.9 \times 10^3 \frac{\sigma_{100} v_{400}}{R_{1.6}} \quad [M_{\odot} pc^{-2}]$$

star formation at maximum rate

$$SFR_{max} = \frac{\varepsilon f_g M_t}{t_{dyn}} = 620 \varepsilon_{0.1} f_{0.4} v_{400}^4 \quad [M_{\odot} yr^{-1}]$$


Lifetime of the SMG Phase



Springel et al. 2005, Mihos and Hernquist 1996

Lifetime of the SMG Phase

<i>galaxy sample</i>	Φ ($h_{70}^{-3} \text{ Mpc}^{-3}$)
<i>SMGs: $S_{850\mu\text{m}} \geq 5 \text{ mJy}$, $z=1-3.4$</i> <i>OFRGs: $z=1-3.4$</i>	$1.1 \pm 0.1 \times 10^{-5}$ $\sim 1 \times 10^{-5}$
<i>quiescent (passive) $K \leq 20$ $B_z K$ $z=1.4-2$</i>	$1.5 \pm 0.4 \times 10^{-4}$
<i>quiescent (passive) $K \leq 21.7$ DRG $z=2.0-2.6$</i>	$6.5 \pm 2 \times 10^{-4}$

 ***SMG Duty Cycle ~ 0.1 , or ~ 100 Myrs***
from: 1) SMG/red sequence volume densities
2) ratio of gas exhaustion timescale to
merger time/ stellar pop age (~ 1 Gyr)

Chapman et al 2005a,b, Reddy et al. 2005, Daddi et al. 2004, 2005,
Kong et al. 2006, Grazian et al. 2007, Zirm et al. 2006, Toft et al. 2007

Summary

- *SMGs are compact & massive with 20-50% gas fractions*
- *SMGs are dissipative major mergers*
- *SMGs are very gas rich, 'maximum' starbursts that can convert a large fraction of their original gas mass to stars in a few hundred Myrs*
- *Comparison with compact red sequence objects implies SMGs rapidly form compact M^* spheroids at $z \sim 2-3$*
- *SMG phase must be short-lived ~ 100 Myrs*