Integral Field Spectroscopy of Submillimeter Galaxies (SMGs) with OSIRIS LGS-AO

Karín Menéndez-Delmestre

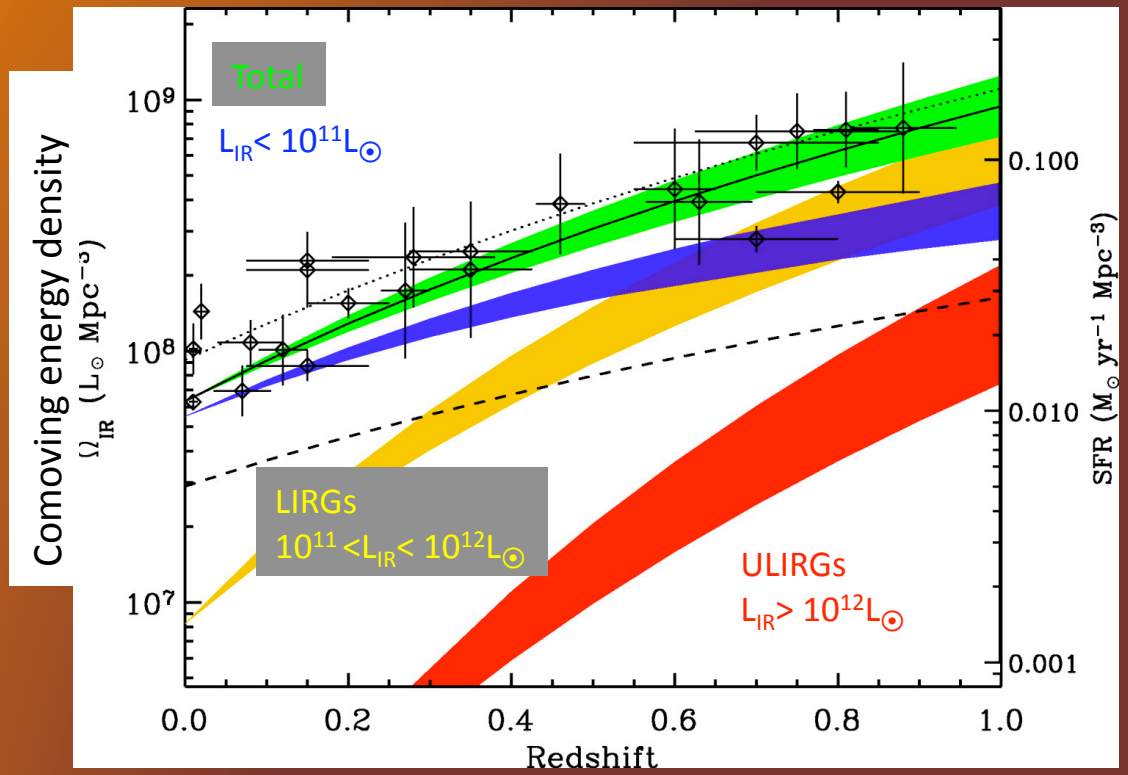
NSF Fellow

Carnegie Observatories,
Pasadena, USA

Work in progress…
Menéndez-Delmestre in prep.

Andrew Blain, Mark Swinbank, Ian Smail,
Scott Chapman, Dave Alexander, Rob Ivison

IR-luminous galaxies



IR-bright sources are quite rare locally, but dominate the comoving energy density at high z

Shift an IR-luminous galaxy to higher redshift
→ boost in observed submm flux!

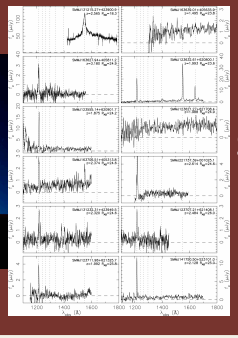
SMGs in the "big picture"

- Observationally-defined population of strong submm emitters
- ~100s detections abound with SCUBA, MAMBO, Bolocam, AzTEC
- Challenge to identify redshifts
  - ~70% are μJy radio sources ➔ a **radio-identified** sample
- M_* ~$10^{11} M_\odot$, SFRs~10^2 - 10^3 $M_\odot$/yr
- Progenitors of today's L >~ L* galaxies (e.g. Lilly+99)

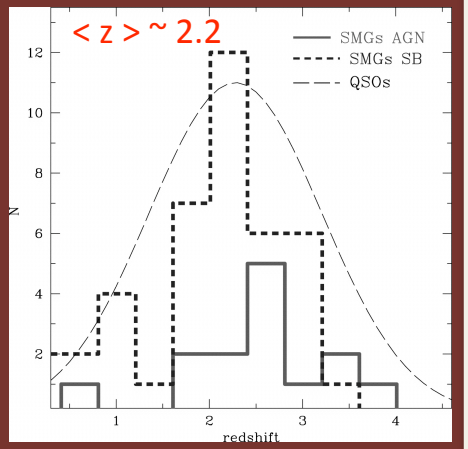
Building the radio-identified sample of SMGs:

SCUBA detection:
~13" spatial resolution

VLA radio counterparts (Ivison+98+02)



UV-based spectroscopic-z (LRIS-B, Keck)



Chapman+05

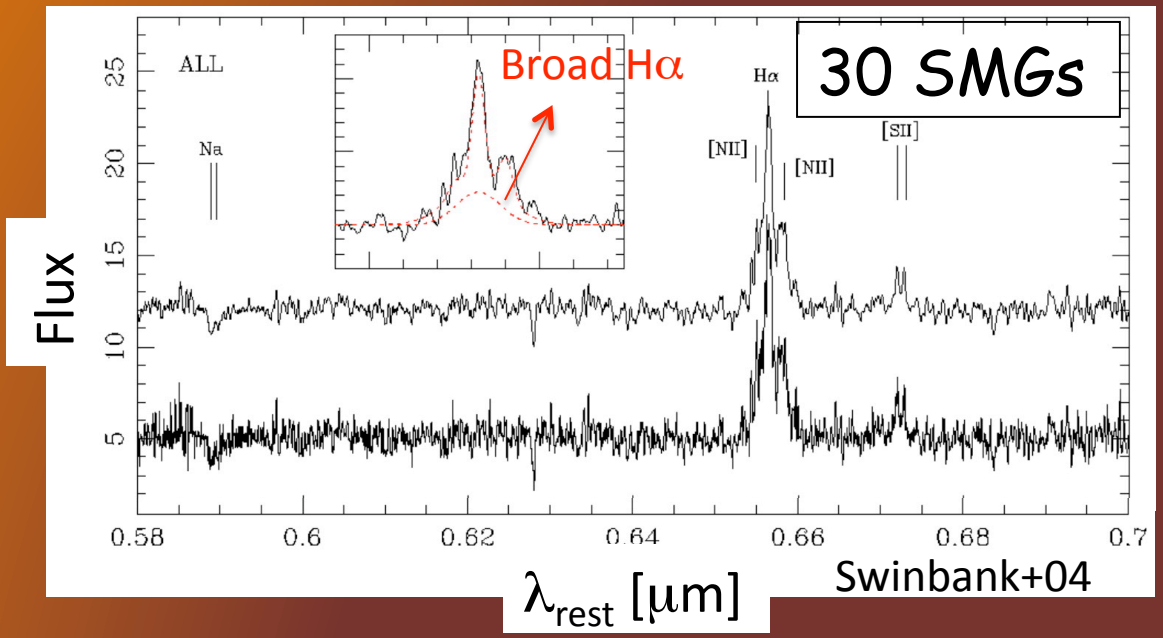
AGN signatures in SMGs

- Many SMGs display AGN signatures:
  - X-rays (Alexander+05)
  - optical (Chapman+05)
  - Near-IR (Swinbank+04)
  - mid-IR (Menéndez-Delmestre+07+09, Valiante+07, Pope+08)
- Begs the questions:
  - How much does AGN activity contribute to the SMG luminosities?
  - Can we disentangle the AGN contribution when determining SFRs?

This work

Near-IR AGN signatures in SMGs

- At *z*~2, near-IR traces the rest-frame optical emission



- The width of Hα can be used to derive dynamical masses and SFRs
- But the Hα line can be enhanced by the high-velocity gas in the broad-line region close to the central AGN
- Attempts have been made to disentangle the AGN contribution by including a broad component… difficult

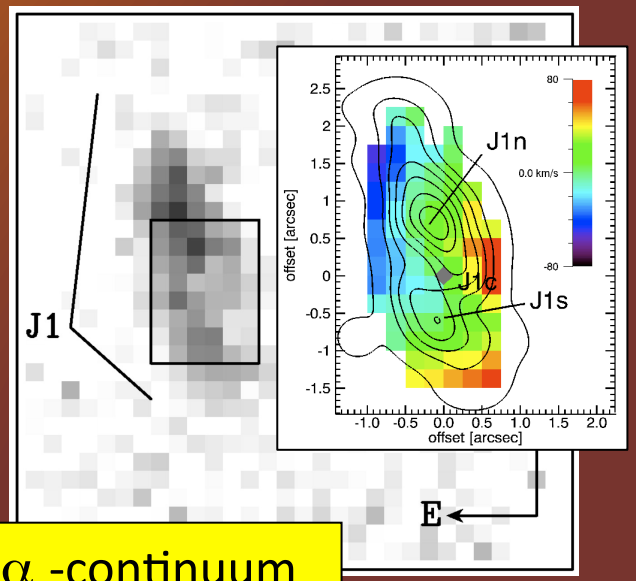
With no spatially-resolved information, it is difficult to disentangle AGN-contribution.

IFU view of SMGs

(seeing-limited, unaided by Adaptive Optics)

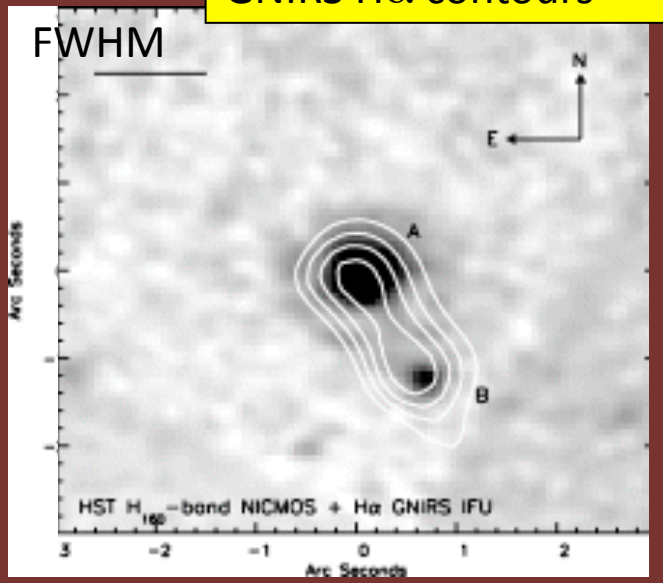
SPIFFI Hα view of SMM J14011 @ z=2.565 (Tecza+04)

Inset: Hα Velocity map (Nesvabda+07)



Hα -continuum

NICMOS H-band, GNIRS Hα contours



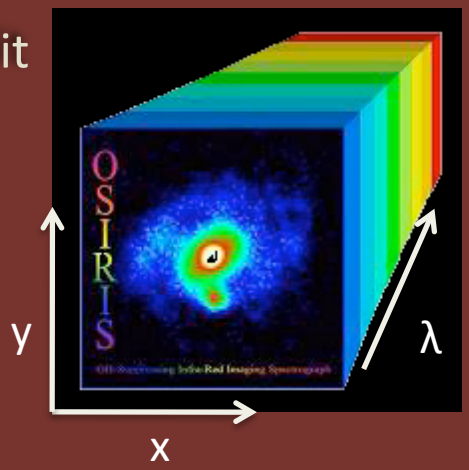
GNIRS observations of SMM J030227 @ z=1.407 (Swinbank+06)

- A handful of SMGs have been observed with IFU instruments
- Although with modest resolution, these observations already reveal Hα sub-structure

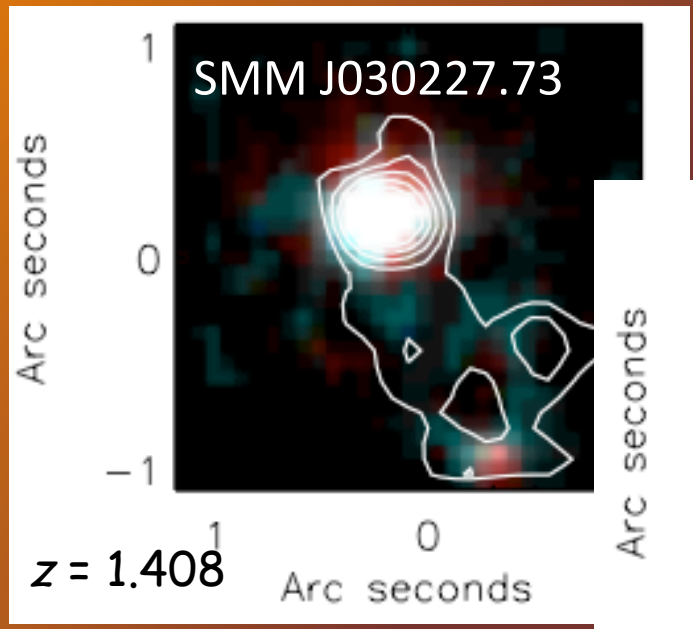
also Bouché+07

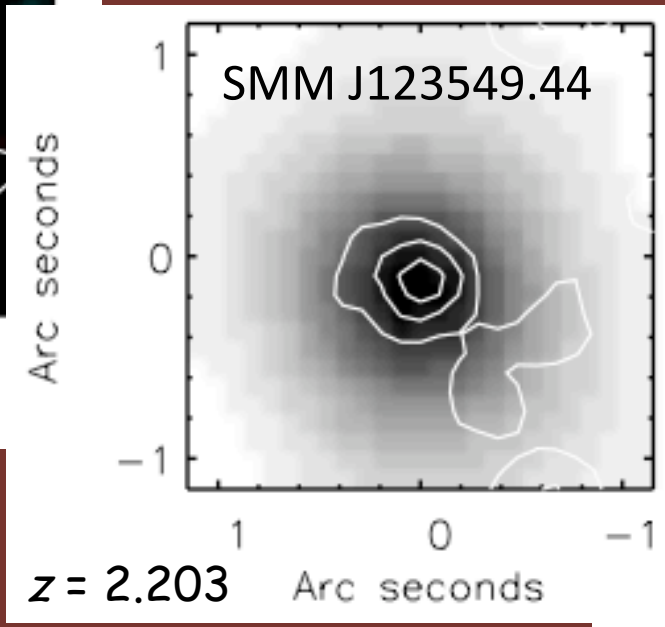
AO-aided Integral Field Spectroscopy with Keck/OSIRIS

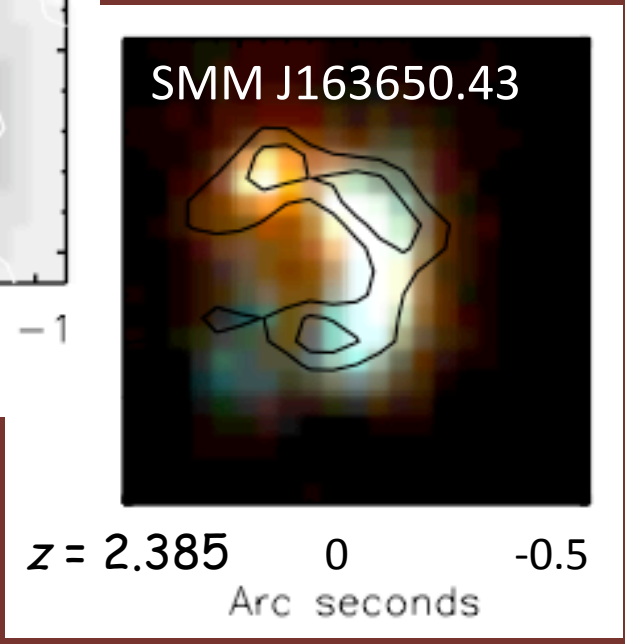
- OSIRIS = "OH-Suppressing IR Imaging Spectrograph"
  - lenslet-based
  - designed to be used with Laser Guide Star Adaptive Optics (LGS-AO)
  - sub-arcsec resolution → ~10x the non-AO resolution → down to kpc-scale!!
  - FOV = 4.8 x 6.4", 2.4 x 3.2" (0.1", 0.05"/lenslet)
  - R~3400 (~6 Å @ 2 μm)
- Our sample: SMGs with bright Hα (from longslit spectroscopy) to optimize detection
  - 3 SMGs within 1.4 <z < 2.4
  - ~3 hours of integration time / source



OSIRIS view of SMGs





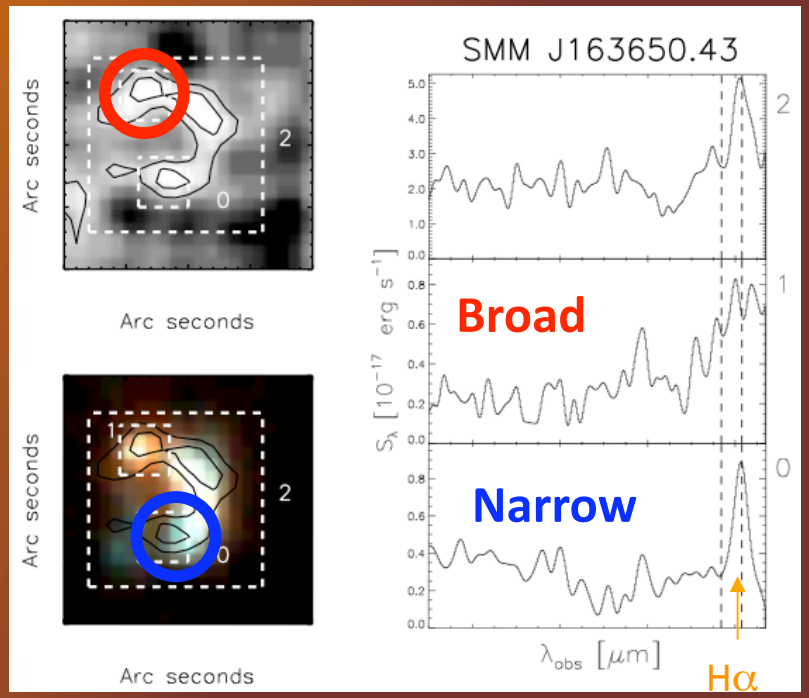


OSIRIS Hα contours overlaid on continuum images

- Hα emission spreads over ≳1-2" (≳ 8-16 kpc at z~2)

Multiple galactic-scale sub-components in SMGs

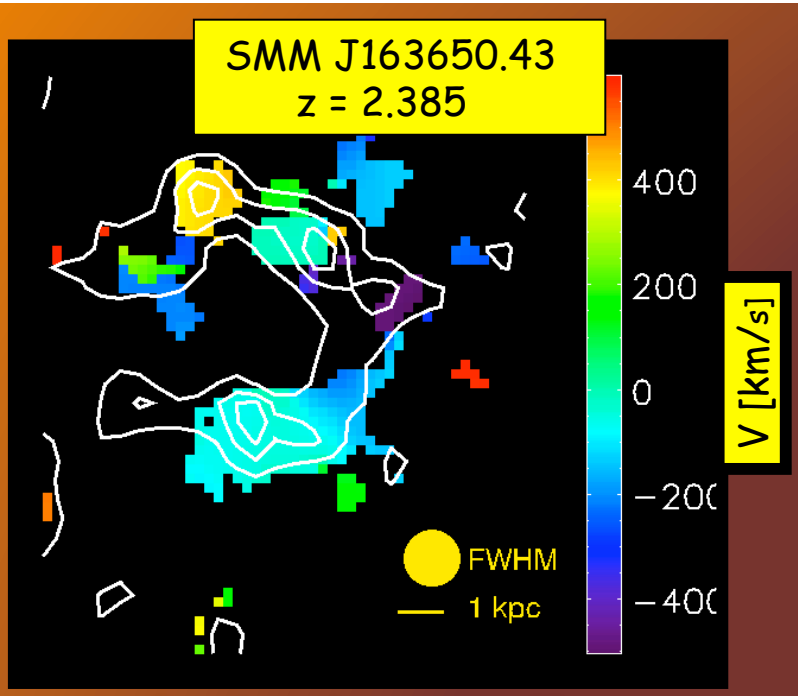
Spatial distinction between AGN and Extended SF



- Separation between spatial and spectral info:
  - Broad Hα -- AGN (FWHM~2400 km/s)
  - Narrow Hα (FWHM~475 km/s) -- Star-formation

With OSIRIS, we can spatially distinguish between AGN and star-forming regions

Dynamics of SMGs

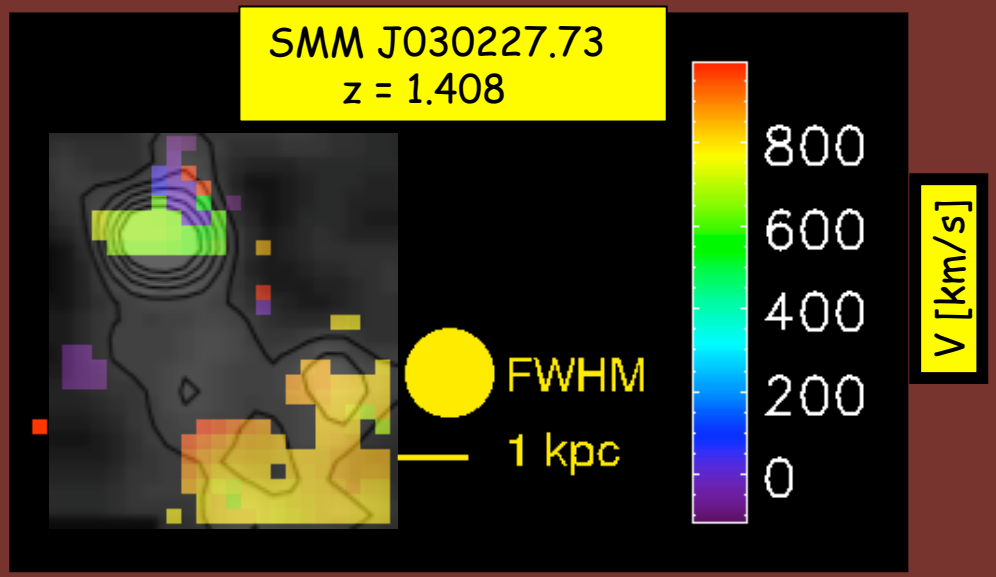


- We find no evidence for ordered rotation, as would be associated to a disk and such as are found in:
  - Select massive LBGs (Law+07, Förster-Schreiber+07)
  - MASSIV galaxies at z~1-2

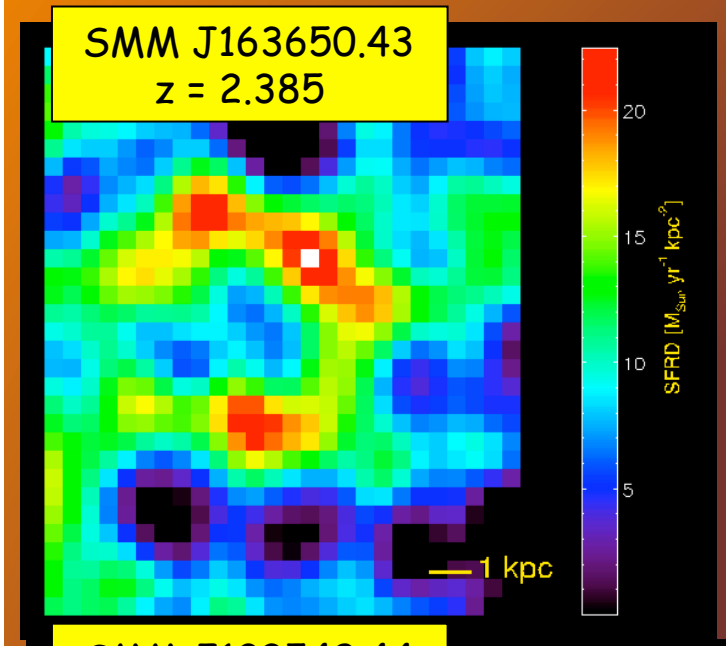
- We find velocity offsets between different sub-components (~ few x 100 km/s)

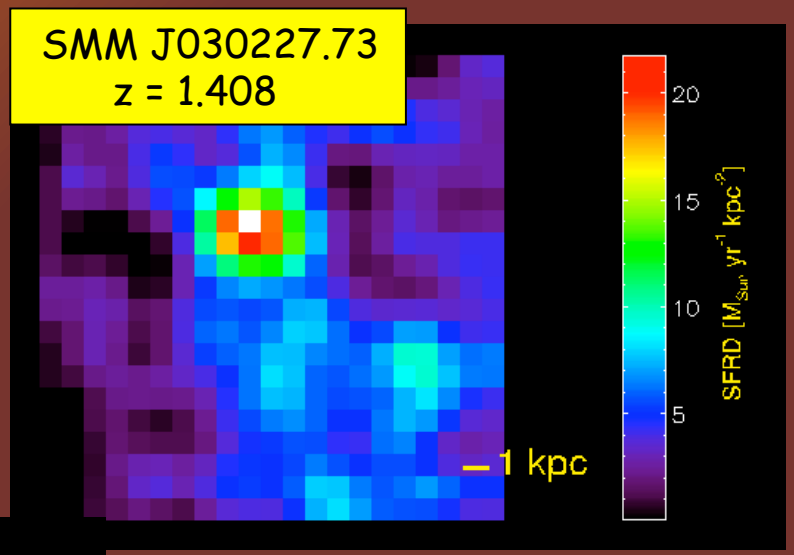
Merger?

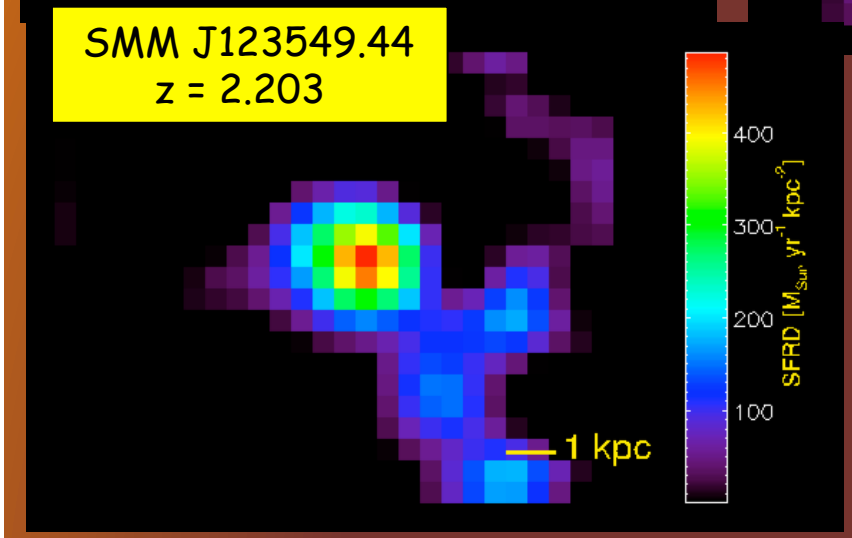
- Merger scenario in agreement with SMGs' disturbed morphologies



Σ_{SFR} from Hα maps







Star-formation in multiple ~1 kpc "clumps"

- Σ_{SFR} ~ 10-100 $M_{\odot} yr^{-1} kpc^{-2}$

(extinction-corrected based on SMG mean Balmer decrement; Takata+06)

- Compare to: (Kennicutt+98)
  - Normal spirals: $<\Sigma_{SFR}>$~0-0.1
  - Local SBs: $<\Sigma_{SFR}>$~1-1000
  - LBGs: $<\Sigma_{SFR}>$~2.9 (Erb+06); $(\Sigma_{SFR})_{peak}$ ~10-25 (Law+07)

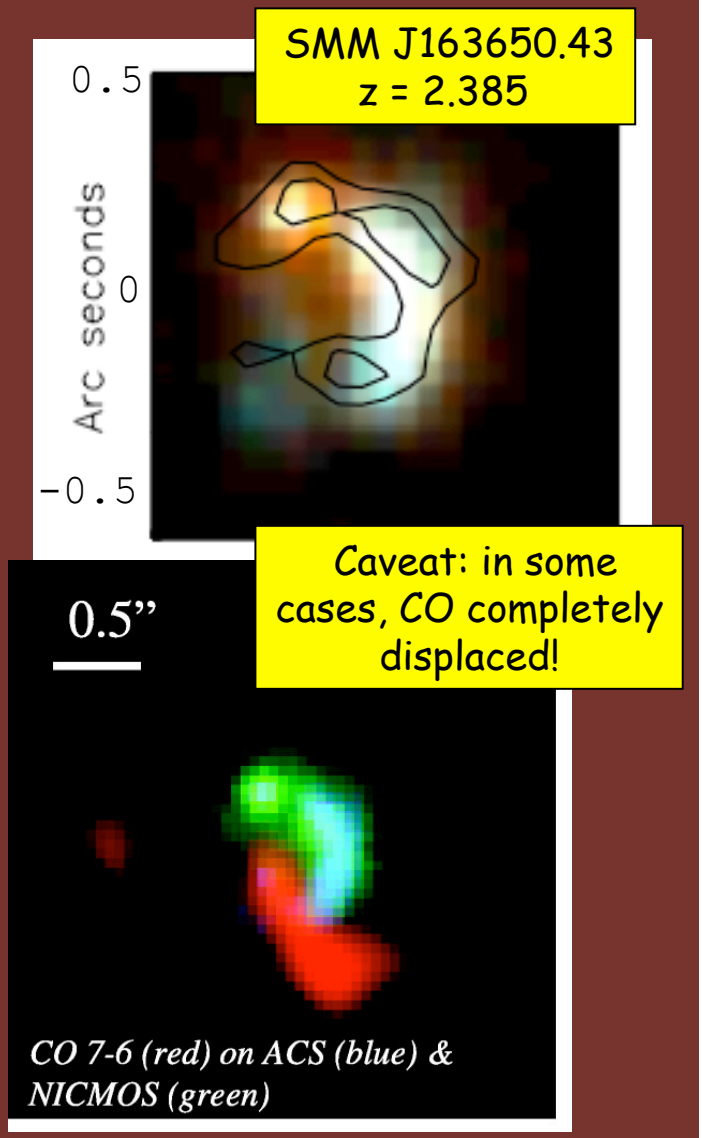
SMGs harbor SF activity similar to local starbursts, but on larger spatial scales, reflecting their large luminosities and total SFRs.

Gas masses

- Assume that ionized gas is mixed with molecular gas
- Rely on local Schmidt-Kennicutt relation to get Σ_{gas} from Σ_{SFR}
- Σ_{gas} ~ 10^3-10^4 $M_\odot/pc^2$
  - Similar to CO-based measurements by Greve+05, Tacconi+06+08
- Considering Hα-sizes, find similar estimates to CO-derived total masses

IFU view of ionized gas: a viable venue to study distribution of molecular gas at much reduced integration times

But caveats…



Neri+03
Greve+05
Tacconi+06+08

Main Results

From the first observations of SMGs aided by Laser Guide Star Adaptive Optics: (Menéndez-Delmestre in prep)

- We find that SMGs display galactic-scale sub-units (1-2 kpc) and Hα spatial extensions $\gtrsim$1-2”
  - Evidence for extended spatial sizes, as opposed to compact sizes
- We spatially distinguish between two distinct emission regions: a compact, broad- Hα AGN and more extended narrow-Hα stellar emission coming from kpc-scale clumps.
- We find no evidence for ordered rotation, but velocity offsets (~ *few* x 100 km/s) could indicate ongoing merger activity between sub-components.
- Agreement with CO-derived gas masses suggests that ionized gas kinematics are a viable venue to explore the distribution and abundance of the molecular gas fueling SMGs.