EXPLORING THE MULTI-PHASE STRUCTURE OF OUTFLOWS IN LOW-Z U/LIRGS

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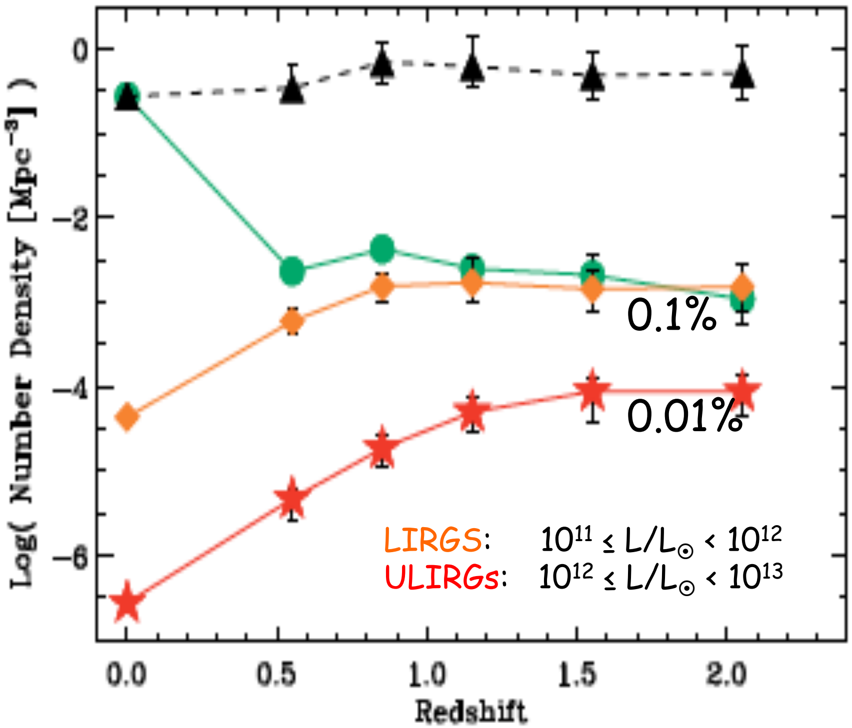
U/LIRGS. BASICS

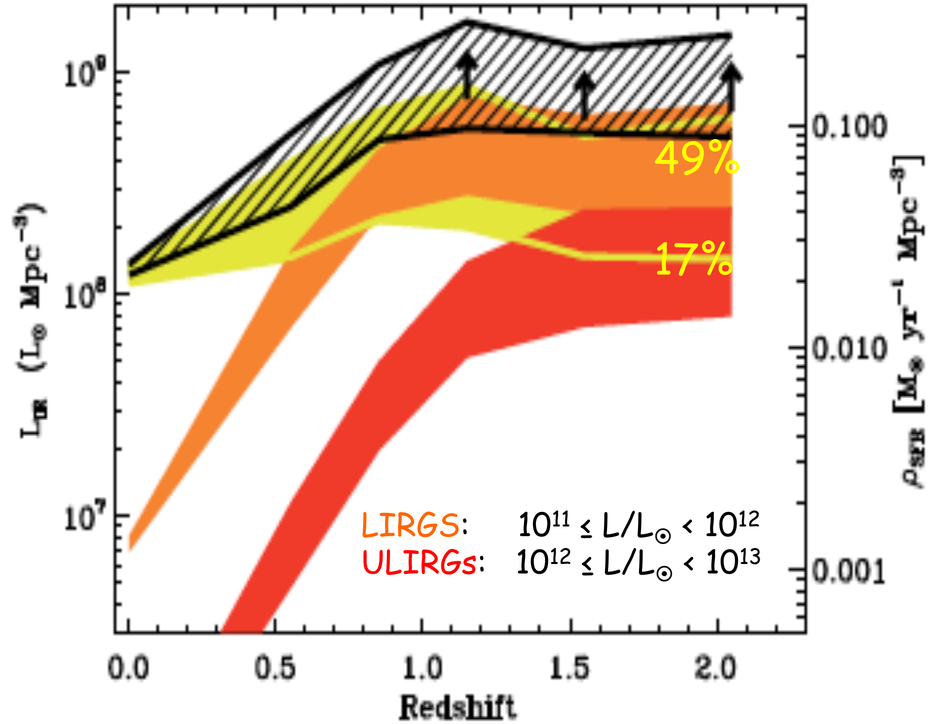
U/I

- m
- fr
  m
- si
- e:
- si

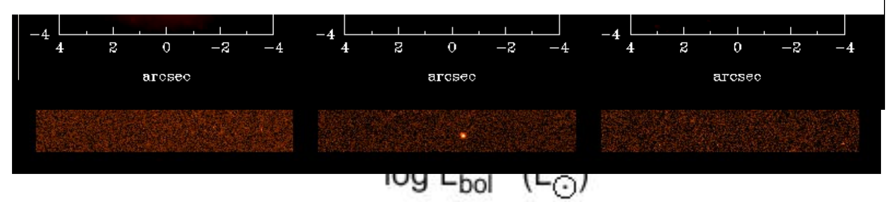
NUMBER DENSITY



LUMINOSITY CONTRIBUTION



- More numerous @ high-z (dusty IR phase)
- SFR (local U/LIRGs) ~ SFR (MS-SFGs @ z~2)



U/LIRGs: UNIQUE LABORATORIES TO INVESTIGATE IMPACT OF MOST EXTREME & LUMINOUS STARBURSTS (+ AGNS) IN THEIR AMBIENT ISM & OUTFLOWS ON SCALES OF HUNDRED OF PARSECS

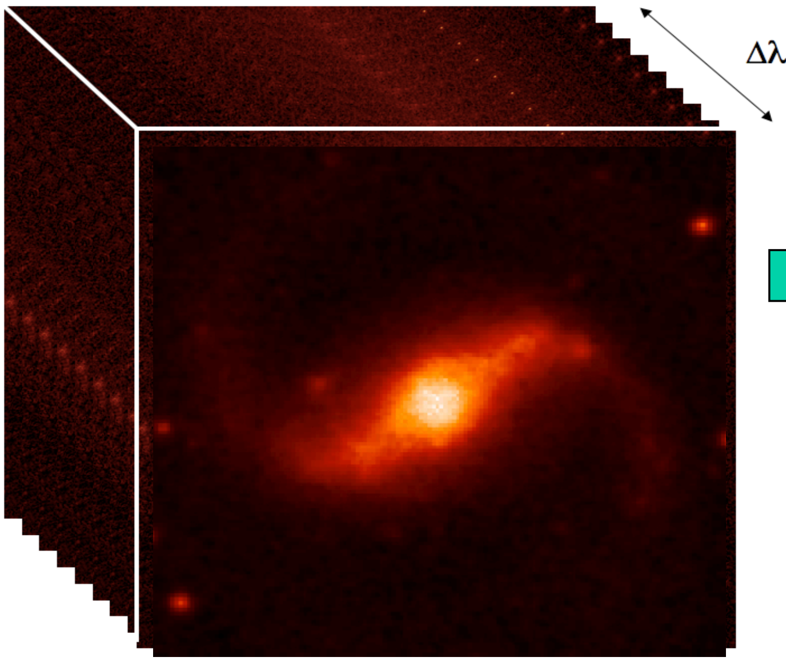
THE MULTI-λ IFS SURVEY OF LOW-Z U/LIRGS

- ~ 75 LIRGs + ULIRGs @ z < 0.2 (i.e. ~ 0.2-3 kpc/")
- Different dynamical status (isolated, interacting, mergers)
- 30% AGNs

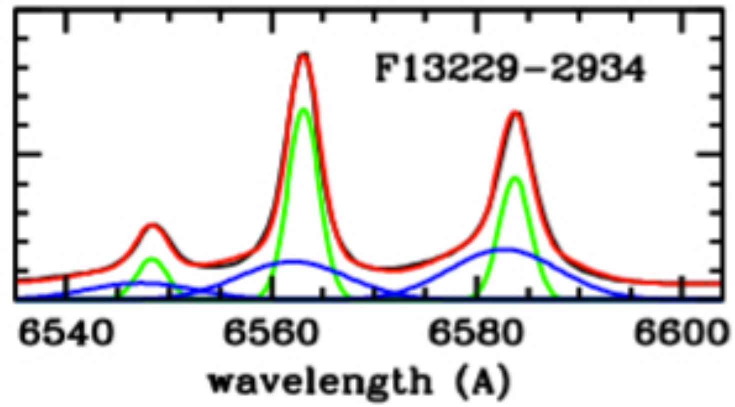
TELESCOPE	IFS	FoV (arcsec)	Sampling. (´´/spaxel)	λ Range (μm)	Spectral Resolution (R)	Number of Targets
4.2m/WHT	INTEGRAL	12x16	0.90	0.49-0.82	1400	22
3.5m/CAHA	PMAS	16x16	1.00	0.36-0.70	1200	14
8.0m/VLT	VIMOS	27x27	0.67	0.52-0.74	2650	42
8.0m/VLT	SINFONI	8x8	0.25	H, K	3000-4000	22
ALMA			0.33	CO(2-1)		4

IONIZED GAS. INTEGRATED GAS KINEMATICS

IFS data cube



Integrated spectrum

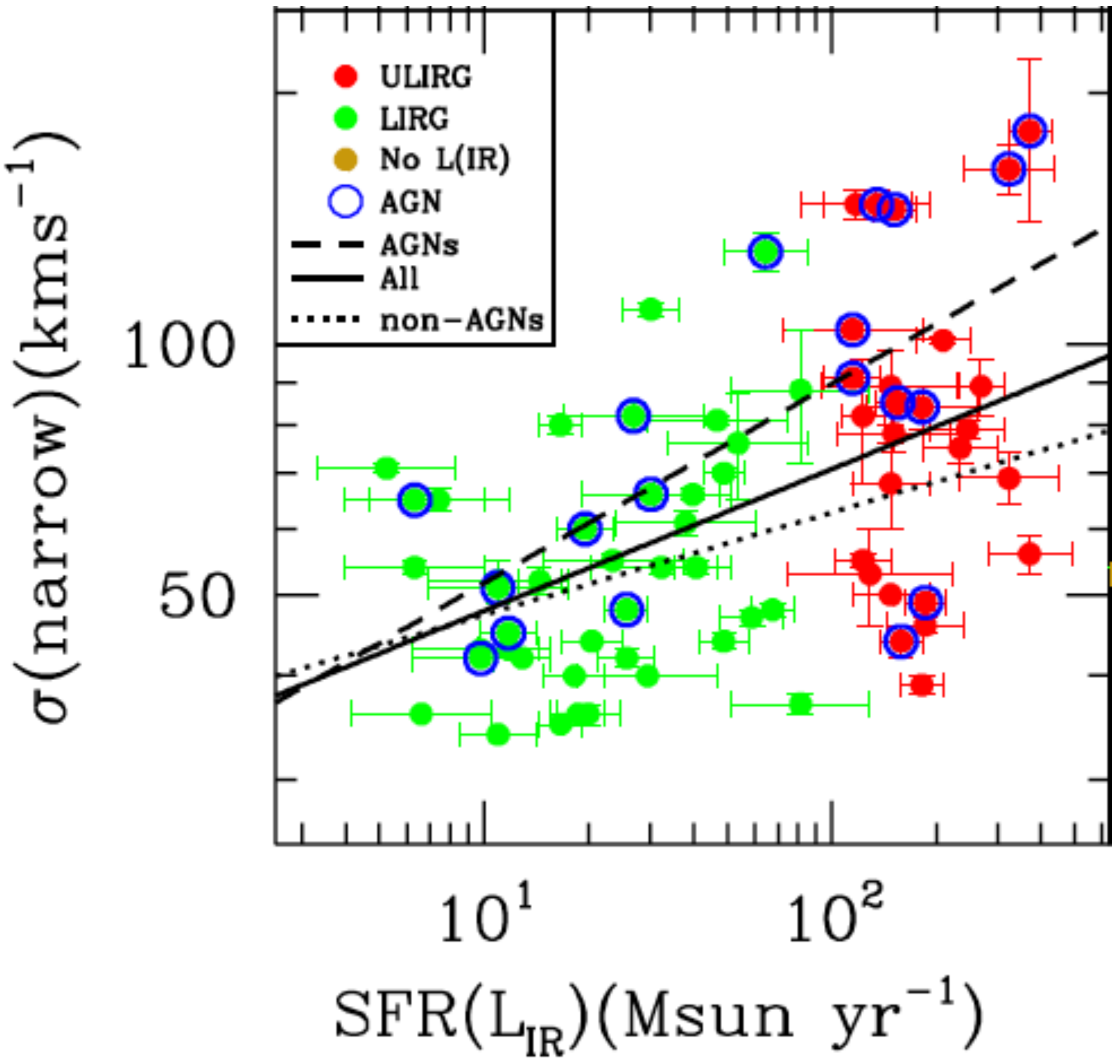


2 Components (Ha –[NII]):
Narrow: Ambient systemic ISM
Broad: Outflow Vmax = Δv + FWHM/2

- Velocity field removed + S/N optimization => well constrained fits
- Optimization for detection of faint broad outflows
- Similar methodology as high-z (Shapiro+09, Newman+12)
  Then: same tracer (Ha) , integrated spectra, 2 Gaussian fitting

Arribas+14

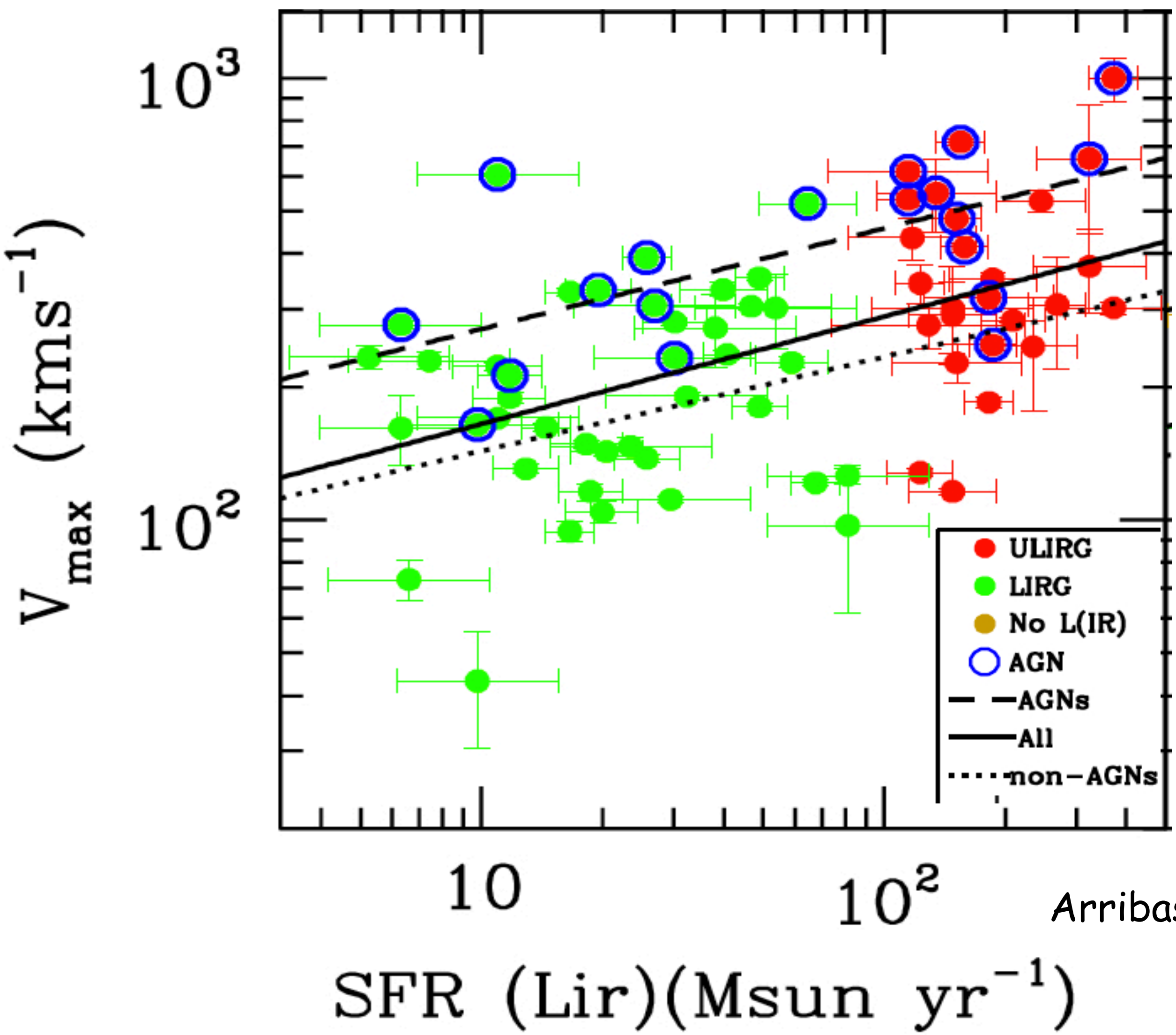
AMBIENT IONIZED GAS. AGN & STAR FORMATION IMPACT



- Gas more turbulent than spirals: σ ~1.5-4 x $\sigma_{spirals}$ (~25 kms^{-1};Epinat+09)
- Weak dependence with increased SF: $\sigma \sim SFR^{0.12\pm0.03}$
- σ range similar to z~2 SFGs (Forster-Schreiber+09)

Arribas+14

IONIZED GAS OUTFLOWS. AGN & STAR FORMATION IMPACT ON V_{max}



Arribas+14

Outflows universal

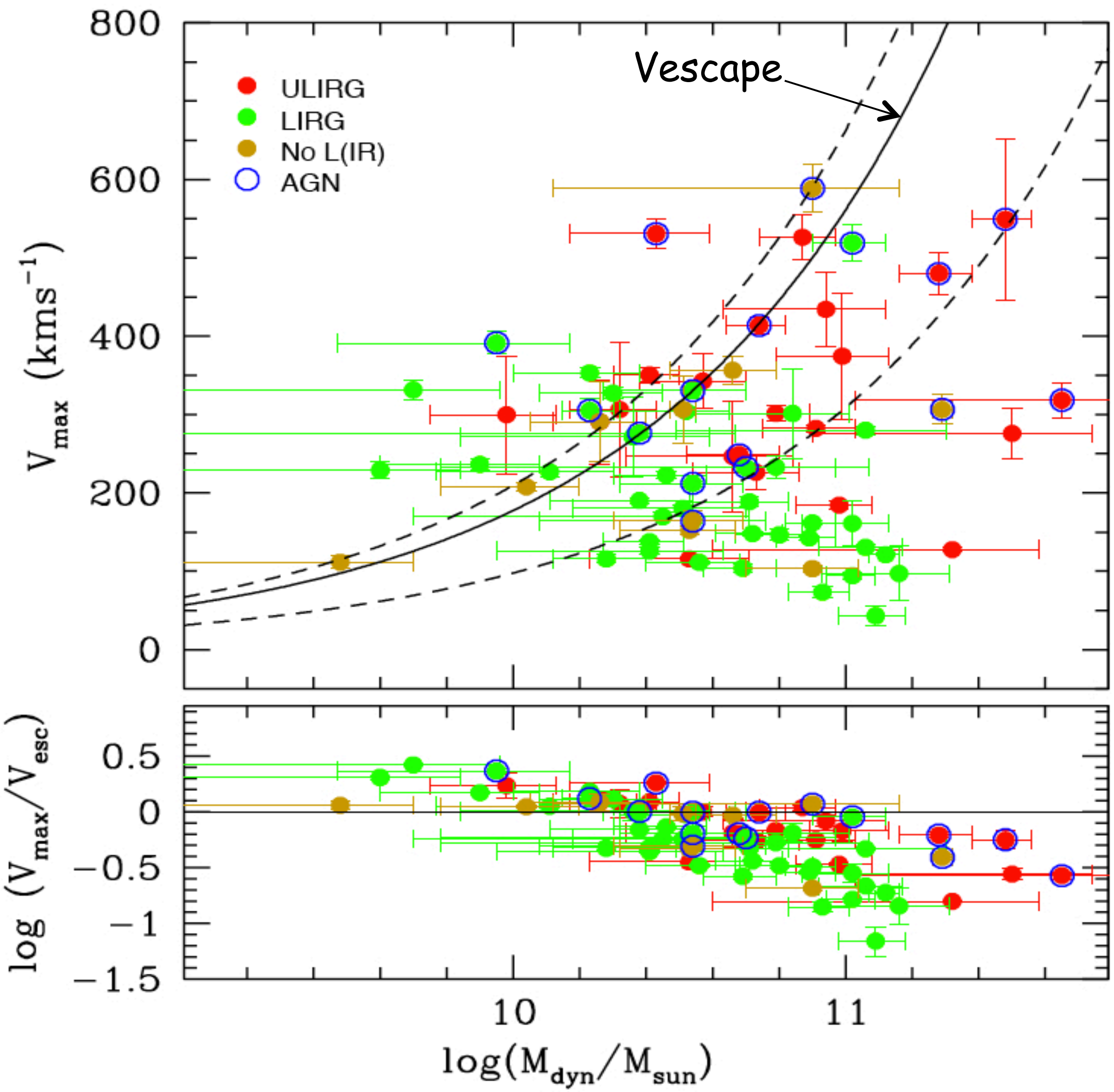
Vmax(non-AGN) ~ $SFR^{0.24\pm0.05}$

Vmax (AGN) ~ 2x (non-AGN)

Mass(AGN) ~ 1.4x (non-AGN)

AGNs do not dominate Lbol but dominate the ionized outflows

IONIZED GAS OUTFLOWS. DOES IT ESCAPES?



NO!

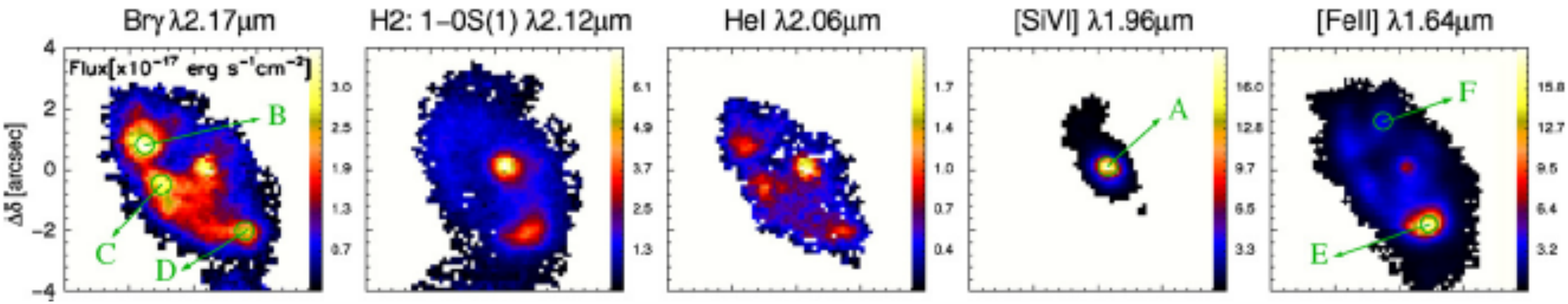
Only galaxies with $M_{dyn} < 2.5\times10^{10}\ M_\odot$ are able to expel gas i.e. Vmax > Vesc

Arribas+14

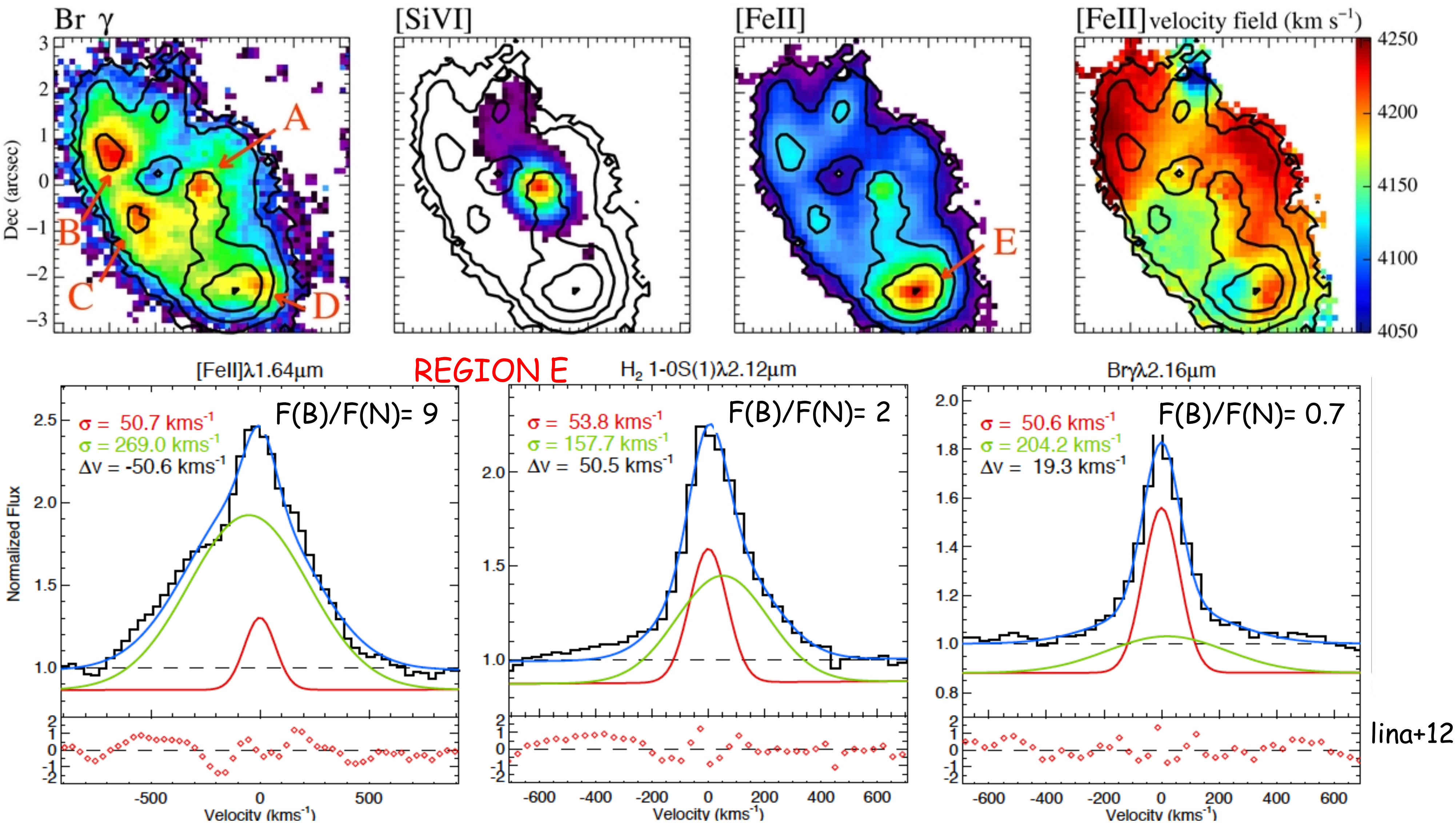
M_{dyn} from Bellocchi+13

MAPPING THE 2D MULTI-PHASE STRUCTURE OF THE ISM

ionized	molecular	highly ionized	coronal	shocks
Young SC	dense gas	Young SC	AGN	SNe

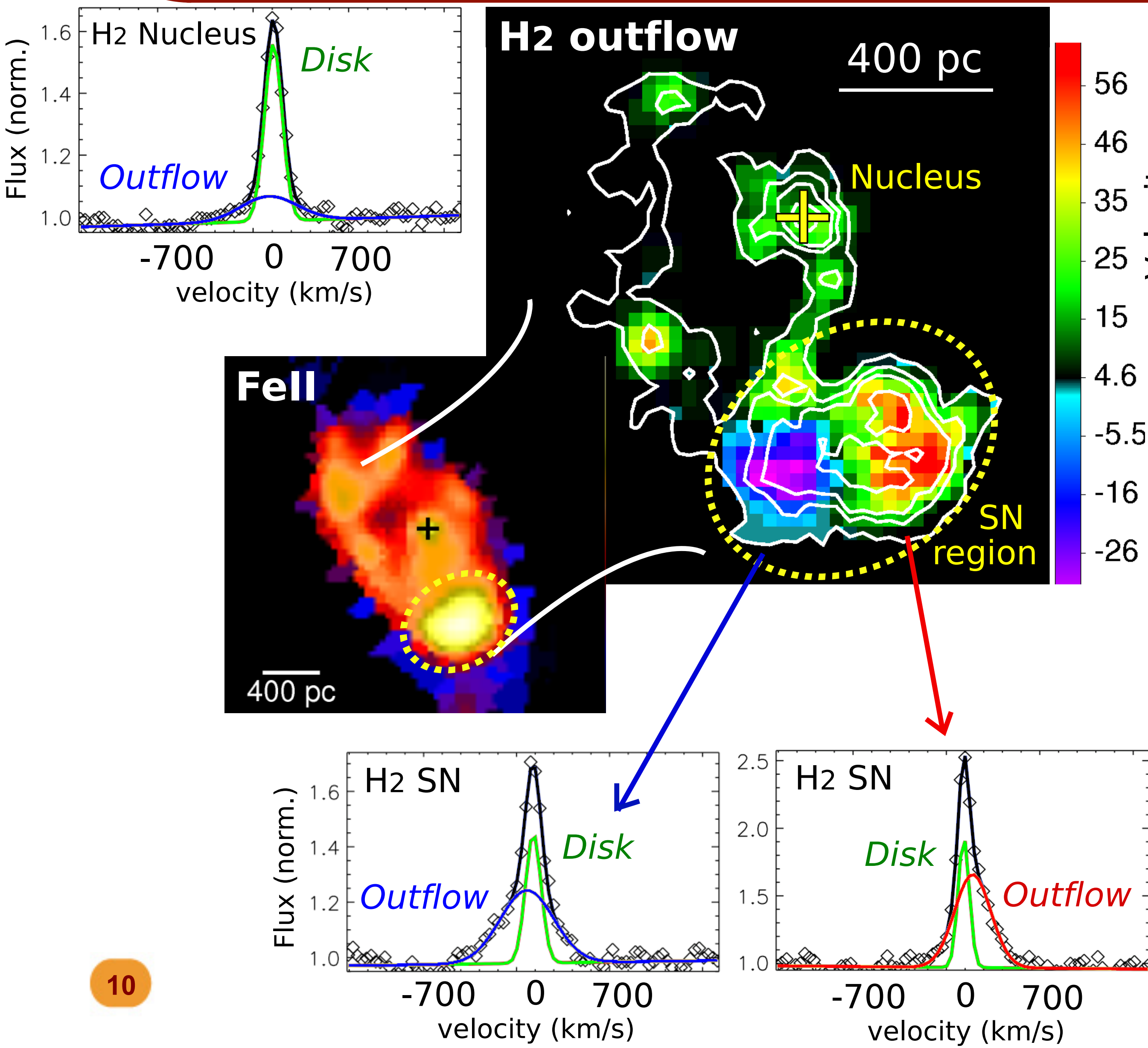


NGC 5135. SNE-INDUCED OUTFLOWS IN STAR FORMING CLUMP



[FeII]: V_{max} ~ 370 km s^{-1} / FWZI ~ 1400 km s^{-1} / Mass ~5.5×10^4 $M_\odot$! (preliminary)

NGC 5135. SNE-INDUCED OUTFLOWS IN SF CLUMP. HOT MOLECULAR GAS



HOT H2-OUTFLOW
(preliminary)

$M_{(hot\text{-}H2)} \sim 440\ M_\odot$

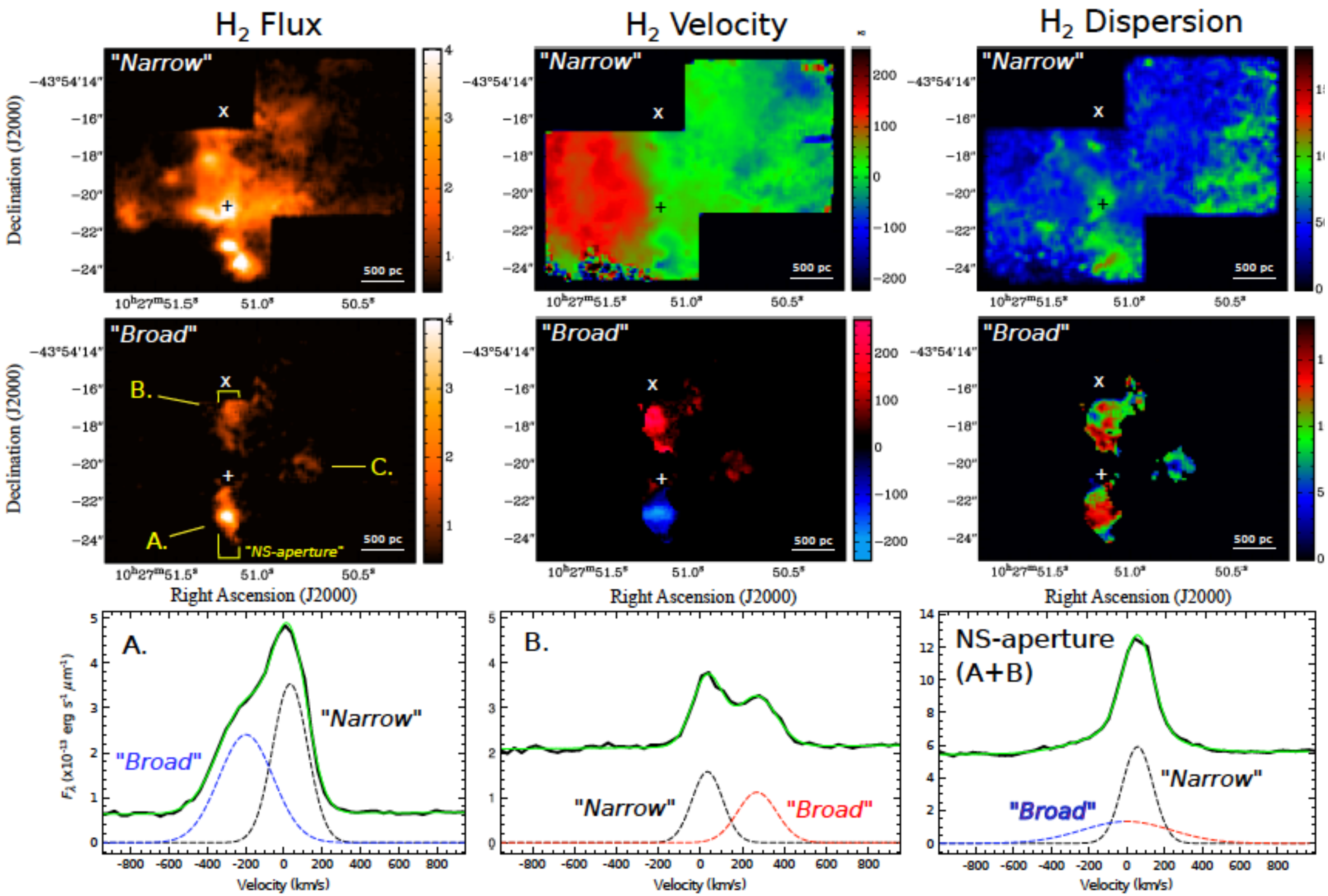
SIZE ~ 400 pc

$V_{max} \sim 240$ km s^{-1}

FWZI ~ 1000 km s^{-1}

ALMA CYCLE 2 FOR COLD GAS

NGC 3256.
2D STRUCTURE OF THE HOT H2 OUTFLOW



HOT-H2 OUTFLOW

M_A ~ 630 $M_\odot$
M_B ~ 570 $M_\odot$
M_{A+B} ~ 1200 $M_\odot$

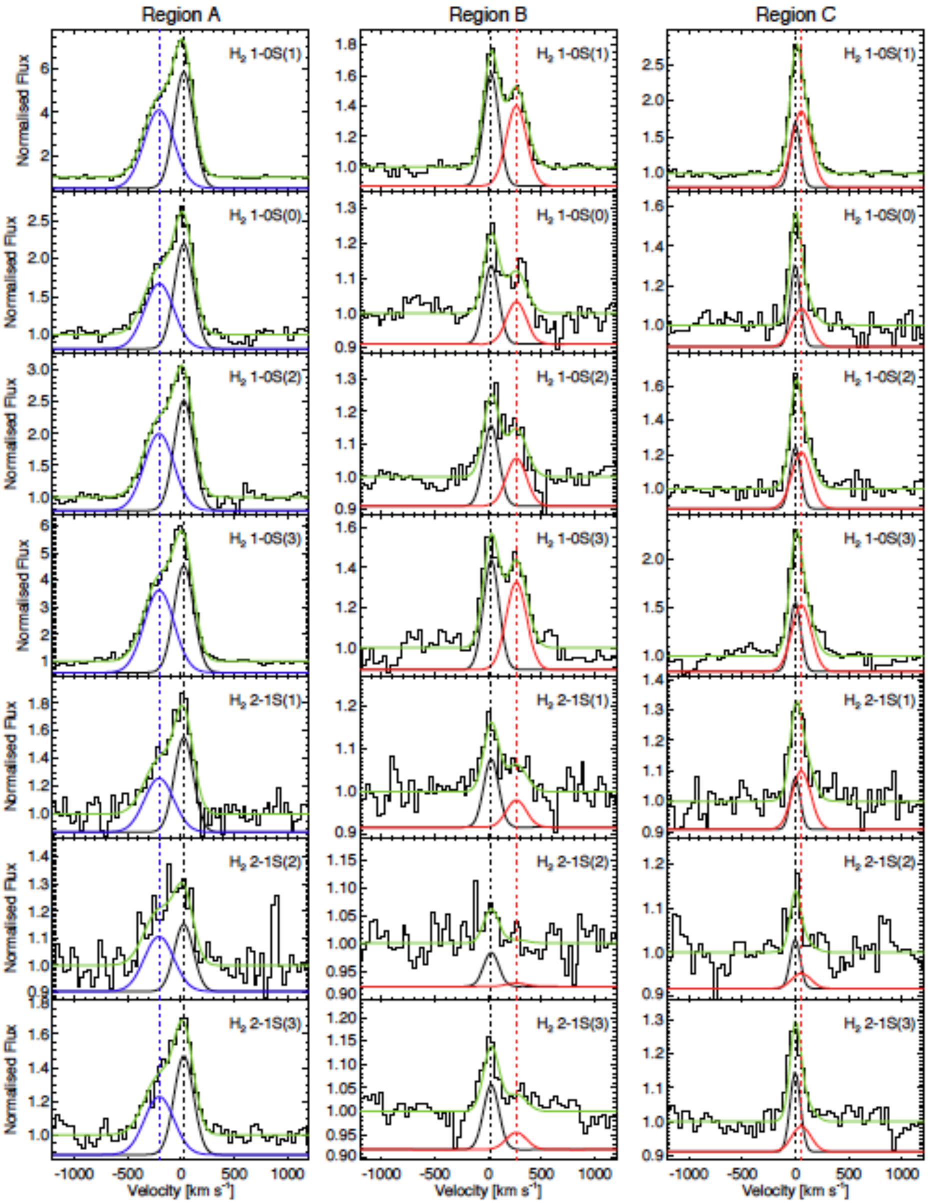
Size ~ 1.3 kpc
Opening A.: 40deg

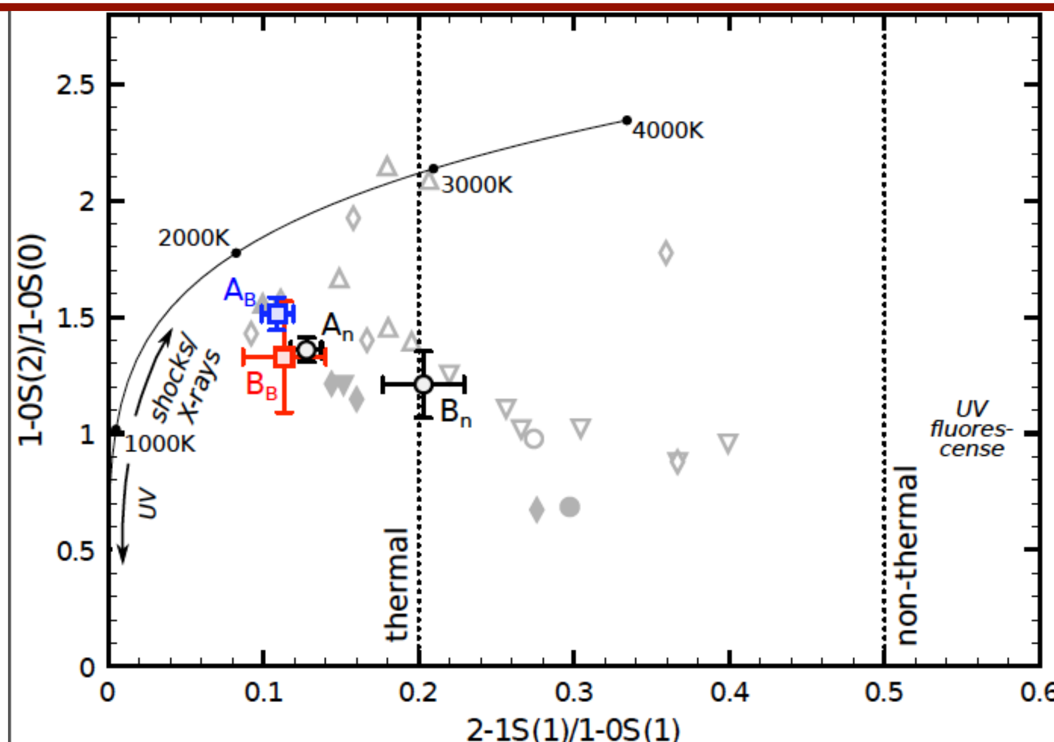
V_{max} ~ 450 km s^{-1}

FWZI ~ 1200 km s^{-1}

Emonts+14, submitted

NGC 3256.
EXCITATION STRUCTURE OF THE HOT H2 OUTFLOW





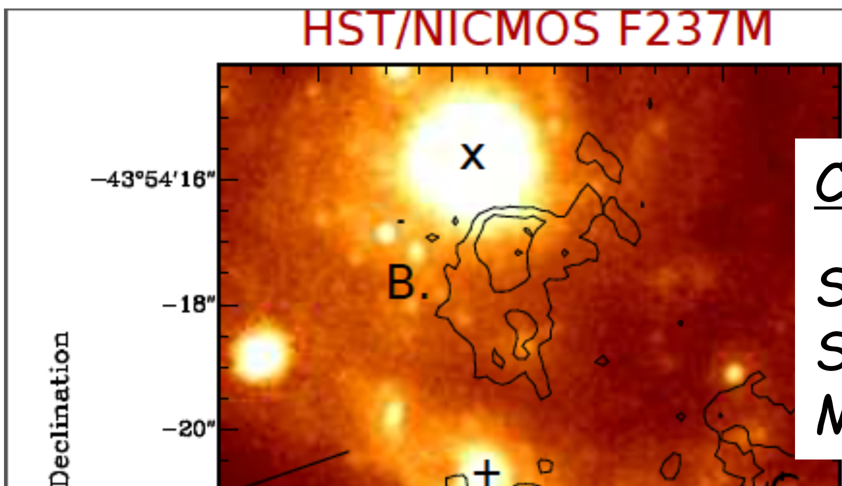
Compatible with thermal processes
Close to LTE with T ~2000 K
More complex than LTE

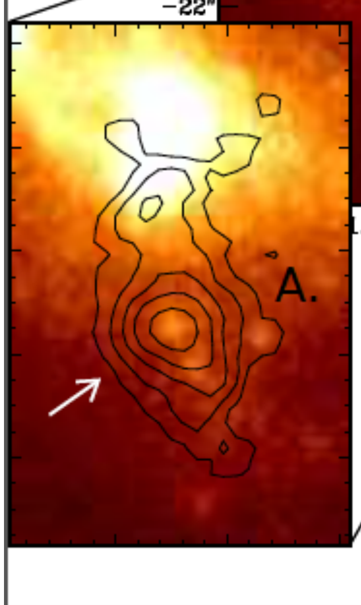
No/minor differences between broad & narrow

Emonts+14, submitted

NGC 3256.
THE HOT & COLD MOLECULAR OUTFLOW

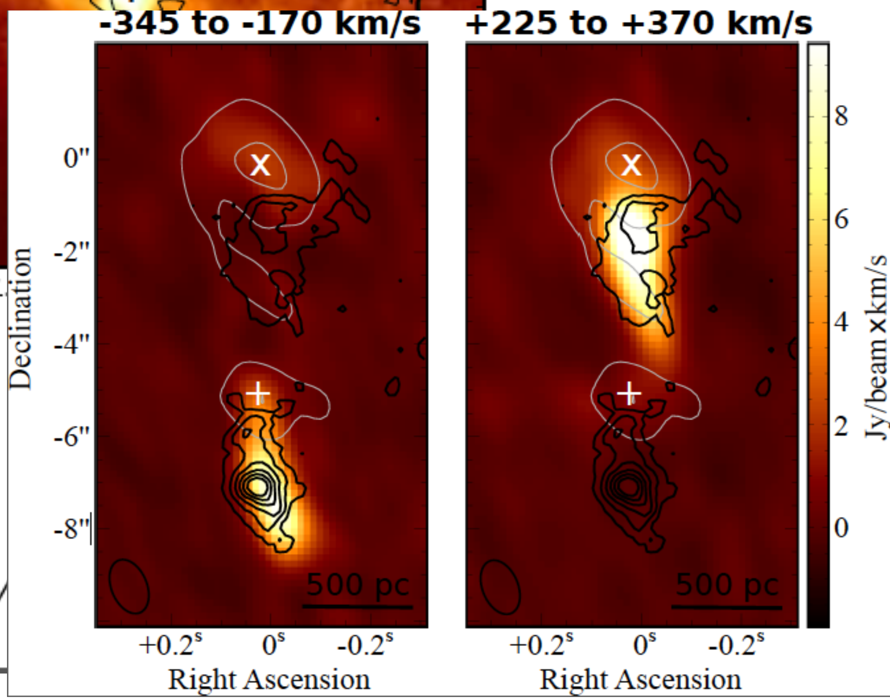
Emonts+14, submitted
Sakamoto+14

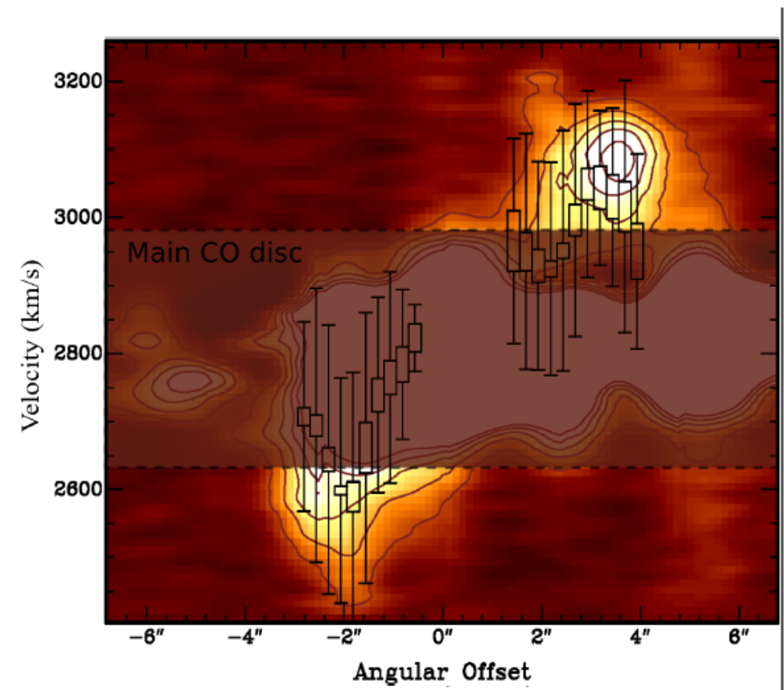




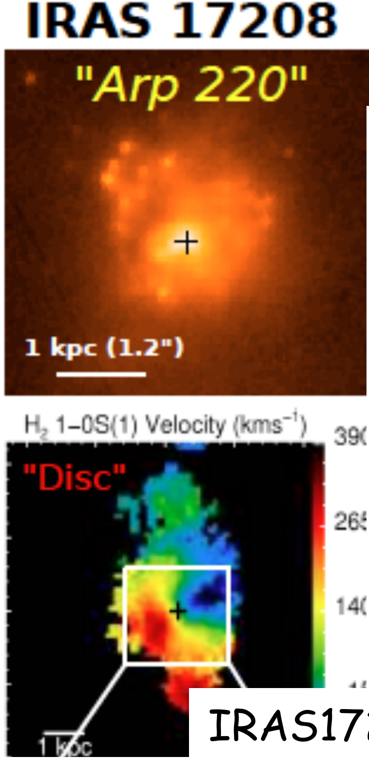
COLD & HOT H2 OUTFLOW

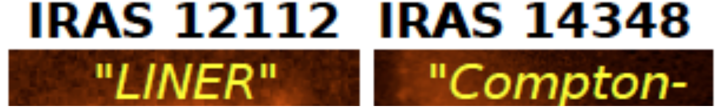
Same spatial structure (collimated, narrow, size)
Same kinematics (amplitude, blue- & redshifted)
Mass ratio of ~6x 10^{-5} (hot-to-cold)

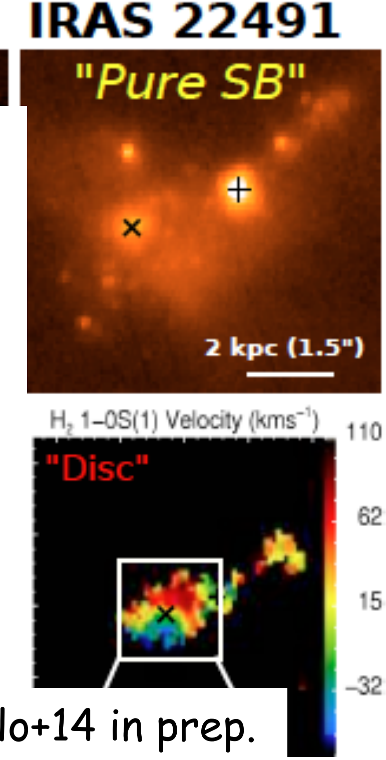




MA … VS





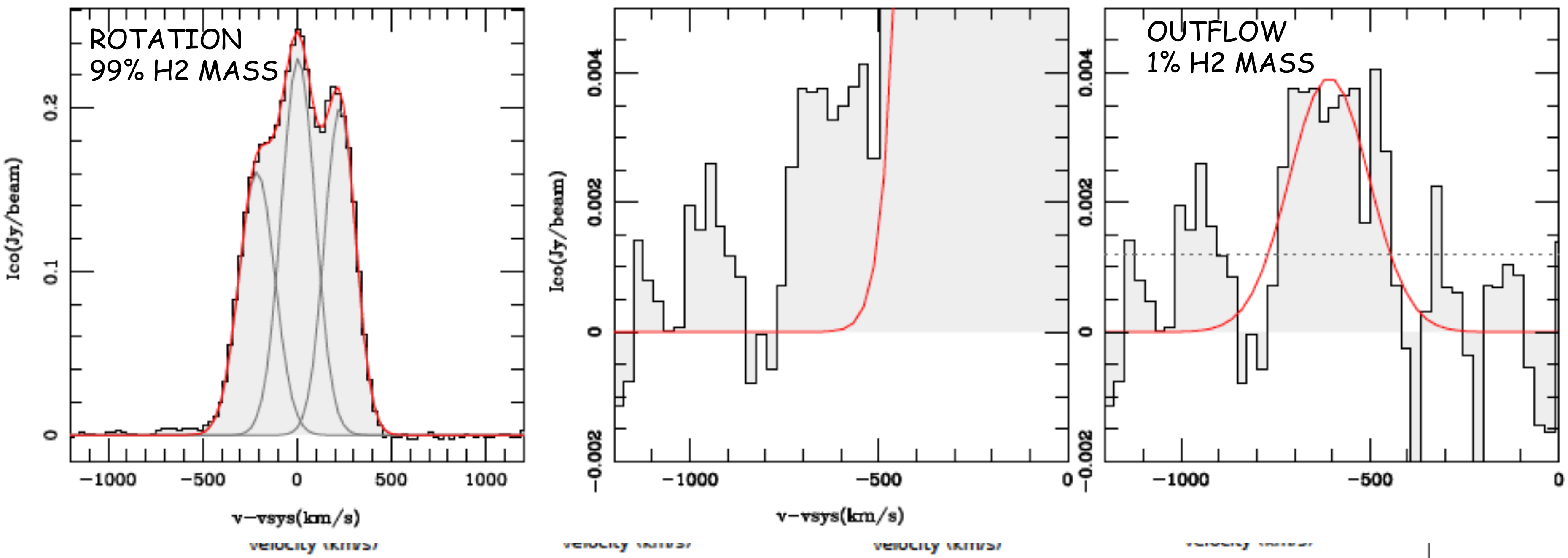


HOT-H2 OUTFLOWS ULIRGs
(preliminary)

Common: 4 out of 4
Size ~2-3 kpc
FWZI ~ 1000 km s^{-1}

M_{hot} ~ few thousand $M_{\odot}$
M_{hot} ~10^{-4} to 10^{-5} M_{cold}

IRAS17208, COLD CO /PDBI / Garcia-Burillo+14 in prep.



SUMMARY

Multi-wavelength IFS survey of local U/LIRGs underway: study the kinematic properties of the different phases of ISM and outflows.

1.Ambient ionized ISM (more results in Arribas+14)

- Ambient ISM x2-4 more turbulent than in spirals
- Weak dependence on SFR ($\sigma \sim SFR^{0.12\pm0.03}$)

2.outflows in U/LIRGs (more results in Arribas+14)

- Outflows are universal based on the detection of a broad, usually blueshifted, Ha
- AGNs generate faster (x2) and more massive (x1.4) outflows than pure starbursts
- Average outflow properties in U/LIRGs are similar to z~2 SFGs of comparable SFR

3.Multi-phase outflows (Emonts+14; Garcia-Burillo+14; Colina+12; work in progress)

- NGC 5135: SNe induced outflows in SF clump with velocities up to 1400 km/s (FWZI), and different mass/velocity distribution in different gas phases.
- NGC 3256 & IRAS 17208: Hot and cold molecular gas trace similar kinematics on kpc scales
- ULIRGs with different activity: hot H2 outflows: common, sizes ~2-3 kpc, masses ~few x 10^3 $M_\odot$