“2D kinematic characterization of a representative sample of local (U)LIRGs. A `kinemetry’ analysis based on VIMOS/VLT with integral field spectroscopy”.

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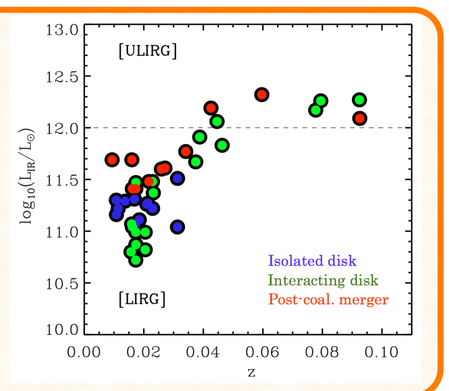
Introduction

The 2D kinematic characterization of a sample of 38 (Ultra) Luminous Infrared Galaxies [(U)LIRGs] systems (51 individual galaxies) at low redshift (<z>=0.022) is carried out with the VIMOS/VLT. The sample encompass a wide variety of morphological types (from isolated disks for low-luminosity LIRGs to a majority of merger remnants for ULIRGs) and nuclear excitations (HII, Seyfert and LINER). Studying the characteristics of (U)LIRGs at low-z allow us a better understanding of the interrelated physical processes involved, and the implications for high-z objects.

We present the 2D kinematic properties of the ionized gas phase (Hα) for the whole sample, for which relatively high linear resolution and signal-to-noise (S/N) ratio can be achieved (Bellocchi+2013). Then, we discussed the results obtained when applying the "kinemetry" method (Krajnovic+2006), along with the kinematic criteria used by Shapiro+2008 (“unweighted”) and Bellocchi+2012 (“weighted”) to distinguish between “rotation-dominated disks” and “major mergers”, considering the asymmetries in both the velocity field (v) and velocity dispersion (σ) maps (Bellocchi+2016).



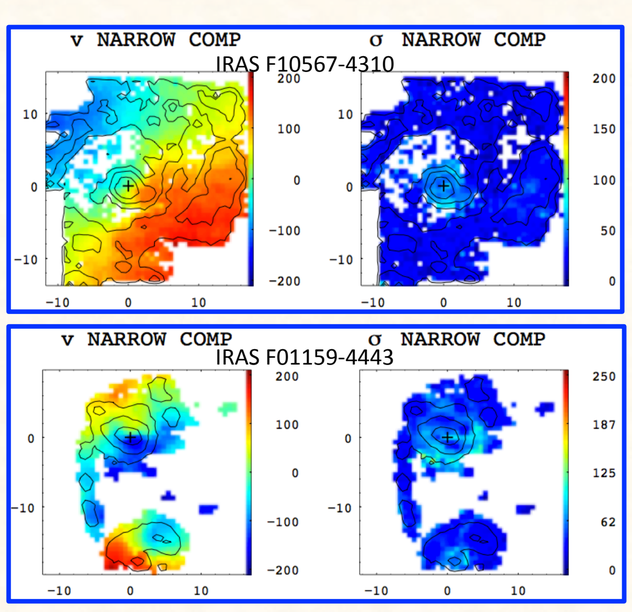
`Kinemetryc’ analysis

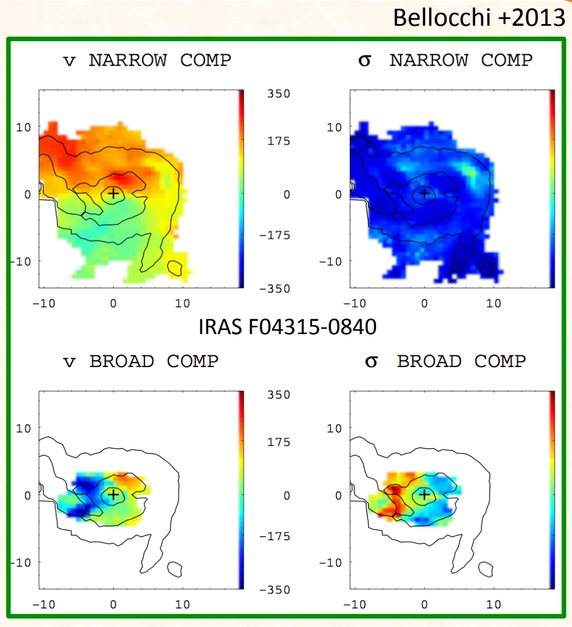
- LINE FITTING and MAP GENERATION: spatially resolved kinematic maps of the narrow (systemic) and broad components
- DERIVATION OF KINEMATIC PARAMETERS: v_{shear}, σ, v/σ, M_{dyn} (Bellocchi+2013)

- KINEMETRY: Harmonic Fourier expansion of 2D maps of observed moments (velocity field /velocity dispersion)
- The kinematic asymmetries σ_{asym}, v_{asym} (i.e., deviations with respect to the ideal rotating disk case) derived according to the “unweighted” and “weighted” criteria for the whole sample (Bellocchi +2016)
- Definition of TOTAL KINEMATIC ASYMMETRY K_{tot} :

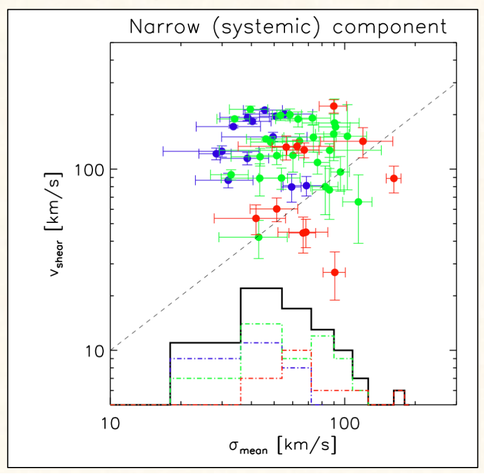
$$K_{tot} = (v_{asym}^2 + \sigma_{asym}^2)^{½}$$

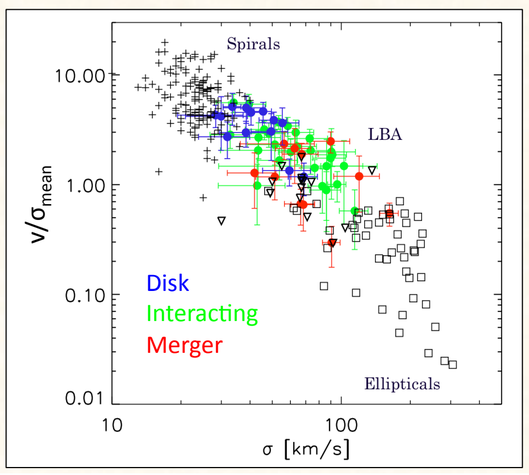
Bellocchi +2013



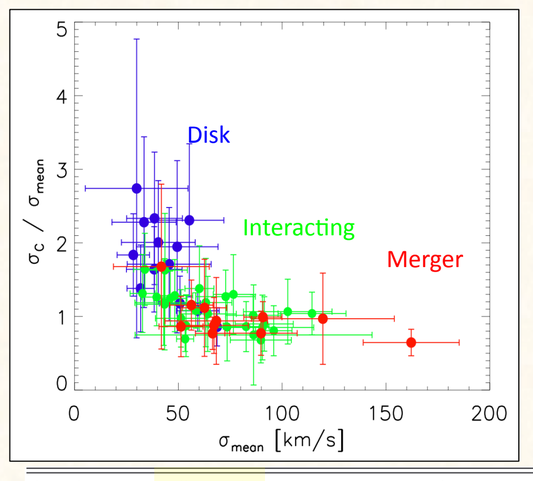


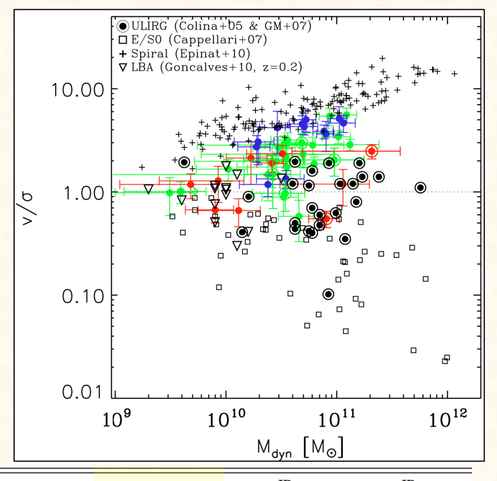
2D kinematic properties in local (U)LIRGs





Sample	*SFR* [$M_\odot$ yr^{-1}]	*v* (km s^{-1})	*σ* (km s^{-1})	*v/σ*	R_{eff} (kpc)	M_{dyn} (10^{10} $M_\odot$)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Spiral	1.8 ± 0.4 (0.7)	162 ± 7 (143)	24 ± 0.5 (24)	7.0 ± 0.3 (6.3)	5.5 ± 0.3 (4.8)	11.5 ± 1.5 (4.9)
E/S0	0.12 ± 0.04 (0.08)	47 ± 4 (44)	162 ± 9 (163)	0.34 ± 0.03 (0.34)	2.9 ± 0.3 (2.4)	13.8 ± 3.2 (6.9)
LBA	26.7 ± 7.1 (17.0)	67 ± 11 (63)	71 ± 6 (67)	0.95 ± 0.11(1.1)	1.4 ± 0.1 (1.5)	1.0 ± 0.2 (1.0)



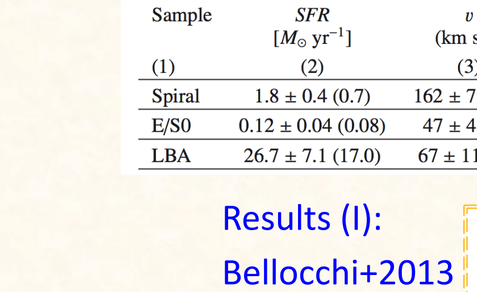


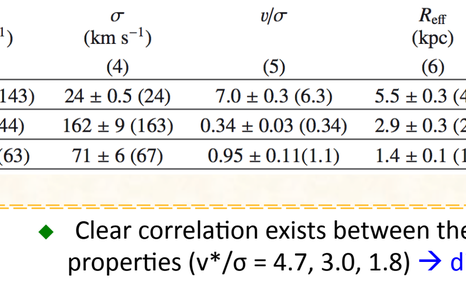
Sample	⟨log L_{IR}⟩ ($L_\odot$)	*SFR* ($M_\odot$ yr^{-1})	v^*_{shear} (km s^{-1})	σ_{mean} (km s^{-1})	$v^*_{shear}/\sigma_{mean}$	R^{IR}_{eff} (kpc)	M^{IR}_{dyn} (10^{10} $M_\odot$)
(1)	(2)	(3)	(5)	(6)	(7)	(8)	(9)
ALL	11.4 ± 0.4	88 ± 15 (45)	171 ± 9 (177)	63 ± 4 (58)	3.2 ± 0.3 (2.6)	2.5 ± 0.2 (2.4)	4.9 ± 0.6 (3.5)
LIRG	11.3 ± 0.3	44 ± 6 (34)	170 ± 9 (167)	59 ± 3 (54)	3.4 ± 0.5 (3.3)	2.5 ± 0.2 (2.4)	4.5 ± 0.5 (3.5)
ULIRG	12.2 ± 0.1	278 ± 20 (272)	178 ± 24 (190)	95 ± 12 (90)	2.0 ± 0.4 (1.9)	2.8 ± 0.6 (2.4)	7.1 ± 2.6 (4.8)
(U)LIRG disk	11.3 ± 0.3	48 ± 18 (32)	195 ± 17 (182)	44 ± 4 (46)	4.7 ± 0.5 (4.3)	2.7 ± 0.3 (3.0)	5.1 ± 1.0 (4.9)
(U)LIRG Inter	11.4 ± 0.5	91 ± 25 (41)	174 ± 8 (190)	67 ± 3 (63)	3.0 ± 0.3 (2.5)	2.6 ± 0.2 (2.4)	4.8 ± 0.5 (3.5)
(U)LIRG merger	11.7 ± 0.3	129 ± 32 (86)	134 ± 21 (157)	80 ± 11 (67)	2.0 ± 0.3 (1.5)	2.6 ± 0.5 (2.0)	4.7 ± 1.9 (1.7)

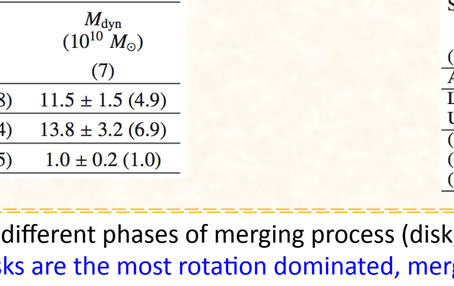
Results (I): Bellocchi+2013

- Clear correlation exists between the different phases of merging process (disk, interacting and merger) and the mean kinematic properties (v*/σ = 4.7, 3.0, 1.8) → disks are the most rotation dominated, mergers are the most dispersion dominated
- The sample covers the gap between local spirals and Ellipticals/S0s: LIRGs classified as disks partially overlap with local spirals with similar v_{shear} but larger σ_{mean} → thicker disks in LIRGs than in spirals; interacting and mergers (U)LIRGs have v^*/σ_{mean} closer to E/S0
- σ_c/σ_{mean} excellent discriminator between disks and mergers
- Rotation anti-correlates with the infrared luminosity L_{IR}: higher fraction of objects with complex kinematics (v*/σ <1) among ULIRGs than LIRGs
- Dynamical mass ranges from 0.04 to 1.4 m* (m* = 1.4 x $10^{11}M_\odot$) with ULIRGs more massive than LIRGs by a factor of 2 → (U)LIRG mergers involve sub-m* galaxies of similar mass
- The subclass of (U)LIRGs classified as mergers share similar kinematics with LBAs, although LBAs show M_{dyn} a factor of 5 smaller.

Relationship between the ‘kinemetry’ asymmetry K_{tot} and morpho-kinematic parameters: L_{IR} , interaction phase and dynamical ratio







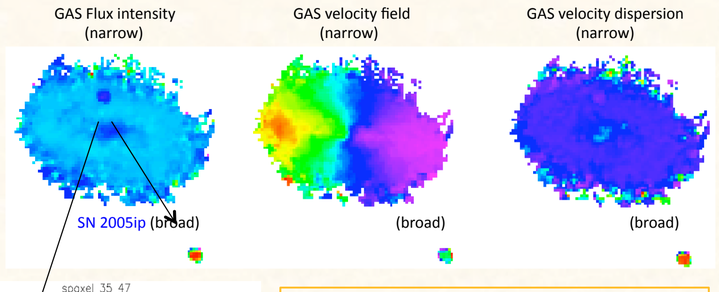
Results (II): Bellocchi+2016

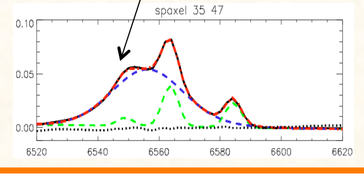
- K_{tot} - L_{IR} : the most luminous objects (ULIRGs) show high kinematic asymmetry K_{tot}
- K_{tot} – proj. nucl. sep:
  - kinematic asymmetries increase during the early stages of the interaction
  - asymmetries reach their maximum during the “ongoing merger phase”
  - they decrease during the post-coalescence mergers phase (some dispersion)
- K_{tot} – dynamical ratio v*/σ: an inverse trend is derived between the K_{tot} and the intrinsic dynamical ratio v*/σ: morphologically classified disks show higher dynamical ratio (v*/σ > 2) and lower total kinematic asymmetry K_{tot} (< 0.14).

Our results support the ‘kinematic downsizing’ scenario proposed by Kassin+2012.

Ongoing work

(CALIFA PMAS/PPAk)





Kinematic GAS parameters:

v* = 222 km/s
σ_{mean} = 116 km/s
$M_{dyn} \approx 4.6 \times 10^{10}\ M_\odot$
σ_c = 130 km/s
v^*/σ_{mean} = 1.9

- Derivation of KINEMATIC PARAMETERS for both the STELLAR and GAS components in local galaxies using PMAS/PPpak as part of the CALIFA survey (Sanchez +2014) and MUSE data (Galbany+2016) → v_{shear}, σ, v*/σ, M_{dyn}
- Development of automatic (python) scripts based on Bayesian approach to derive the best fit parameter (i.e., wavelength, FWHM, flux) for each spaxel (Bellocchi in prep.)
- Application of “BaTMAn” to our data

→ “BaTMAn: Bayesian Technique for Multi-image Analiysis”. It is a new technique to perform adaptive binning based on Bayesian statistics. It merges together pixels/spaxels/regions that contain the same information ‘within their own errors’ (Casado et al. in prep.).

REFERENCES: Arribas et al. 2008, A&A 479, 687; Krajnovic et al. 2006, Astron.Soc. 366, 787; Shapiro et al. 2008, ApJ 682, 231; Bellocchi et al. 2012, A&A 542, 54; Sanchez et al. 2012, A&A 538,8; Bellocchi et al. 2013, A&A 557, 59; Bellocchi et al 2016, A&A; Galbany et al. 2016, MNRAS, 455, 4087