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MORPHO-KINEMATICS ANALYSIS OF GALAXY AT Z∼0.6

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Abstract. We present a first morpho-kinematics analysis of the Intermediate MAss Galaxy Evolution Sequence (IMAGES) sample. This sample is the largest two-dimensional kinematics sample representative of intermediate mass galaxies at z∼0.6. A robust classification scheme has been developed to divide the sample into three distinct classes based on dynamical characteristics : (i) the rotating disk galaxies ; (ii) the perturbed rotators ; (iii) the complex kinematics. We find that 43% of the galaxies have complex kinematics, 25% have perturbed rotation and 32% are consistent with pure rotation. A morphological analysis was also carried out and compared with the kinematical one. We find a good agreement between morphology and kinematics as almost all the spirals have relaxed dynamics and complex kinematics can generally be explain by disturbed morphological features. As in the local universe, a correlation between morphology and kinematics of distant object can be derived.

1 Introduction

In the local universe, both the physical and kinematical properties of galaxies vary systematically with the Hubble type (Roberts & Haynes, 1994). In this scheme, rotating disk galaxies constitute the majority of the galaxy population. They represent 70% of the intermediate mass galaxy population, which themselves include at least 2/3 of the present day stellar mass (Hammer et al. 2005).
In the distant universe, morphological investigations based on HST imaging has brought observational evidence that a large fraction of galaxies have peculiar morphologies that do not fit into the elliptical-spiral Hubble sequence (e.g. Brinchmann et al., 1998; van den Bergh et al., 2001; Zheng et al., 2005). Moreover, first kinematical studies at intermediate redshift (e.g. Flores et al., 2006), also conclude that a large fraction of these galaxies were not dynamically relaxed.
It is yet unclear what are the links between these galaxy populations and their local counterpart and what are the physical process driving this evolution. The main supposed processes at work for galaxy evolution are (i) the secular evolution with slow and continuous matter accretion through the inter galactic medium (e.g., Semelin & Combes, 2005, Birnboim et al., 2007) ; (ii) minor mergers and accretion of small satellites (Somerville et al., 2001) ; (iii) more violent evolution through hierarchical merging (e.g., Hammer et al., 2005). To disentangle the relative importance of each process, both high resolution imaging and integral field spectroscopy are required. Indeed, morphological studies can bring substantial clues about the merger rate (Conselice et al., 2005, Bell et al., 2006, Lotz et al., 2006) but kinematics studies using 3D spectroscopy appear to be a unique tool to directly distinguish between interacting and non-interacting galaxies, and probe the evolutionary state of distant galaxies.
In this context, we are involved in a Large Program using the integral field capability of GIRAFFE (LP : IMAGES) to gather a complete and representative sample of velocity fields and dispersion maps of intermediate mass galaxies at intermediate redshift. Galaxies are selected in different fields by their absolute J band magnitude (M_J(AB) < -20.3, see Ravikumar et al. 2007 for more details). We have developed a robust classification scheme to divide the sample into distinct dynamical and morphological classes. The kinematical classification is described in Sect. 2 the morphological one in Sect. 3. Finally, we compare both classifications in Sect. 4.

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2 Kinematical Classification

A first part of the sample (28 objects) was observed during the FLAMES/GIRAFFE guaranteed time (ESO runs 071.B-0322(A), 072.A-0169(A) and 75.B-0109(A)). The other part (35 objects) was observed in the frame of the large program IMAGES (ESO run 174.B-0328 - PI : F. Hammer). The [OII]$\lambda\lambda$3726,3729 doublet is used to derived both velocity fields and velocity dispersion maps (more details on the method used to extract kinematic fields from 3D spectroscopy data can be found in Flores et al. 2006 and Yang et al. 2007). These maps, completed with a full set of simulations, are used to divide the sample into three dynamical classes :

- Rotating Disks (RD) : When the velocity field shows a rotation pattern that follows the optical major axis and the dispersion map show a peak near the dynamical center.
- Perturbed Rotators (PR) : When the velocity field shows a rotation pattern but the dispersion map shows a peak not located at the dynamical center, or does not show any peak.
- Complex Kinematics (CK) : When the velocity field and the dispersion map show discrepancies compared to regular rotation.

In Fig. 1, we show a representative example of each kinematical class.

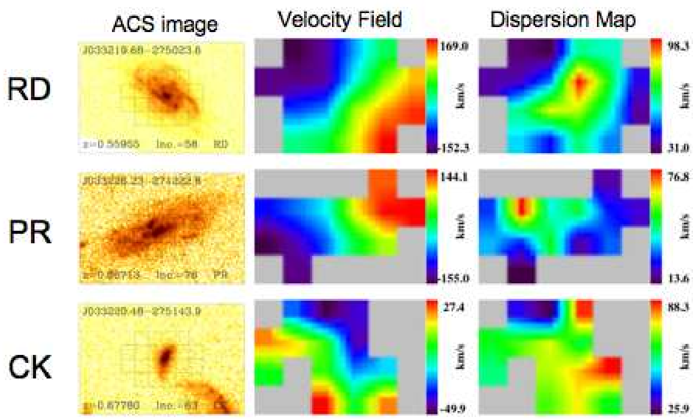

Fig. 1. Form left to right : ACS I-band image, Velocity field and sigma map of three galaxies representative of the three kinematical classes. From top to Bottom : Rotation disk, Perturbed Rotation, Complex kinematics.

3 Morphological Classification

The morphological analysis is performed in three steps : (i) a surface brightness profile analysis is carried out to quantify structural parameters; (ii) we construct a set of color maps for the whole sample; (iii) a morphological label is assigned to each object based on visual inspection of the images and detailed analysis of the structural parameters and physical properties derived from the first two steps. The method adopted for the visual classification was to sort all the galaxies from the more regular/symetric ones to the more irregular/asymetric ones. Once this exercise done, we defined different morphological classes gathering objects with similar properties. We find that the galaxy sample can be divided into 4 morphological classes : (i) : the passively evolved spirals, i.e., objects comparable with local universe spiral. These objects show regular structures (arms), a highly symmetric disk surrounding a redder bulge; (ii) : the peculiar galaxies, i.e., objects with asymmetric features in the image or in the color map. Peculiar galaxies can be : Tadpole like (Pec/T), that is objects showing a knot at one end plus an extended tail ; Suspected mergers (Pec/M), that is peculiar object for which the irregularities could be associated with merger/interaction events and Irregulars (Pec/Irr) for objects similar to local irregulars. (iii) the compact galaxies, i.e., all objects barely resolved and too concentrated to be decomposed. (iv) : the obvious merging/interacting systems, i.e., objects showing tidal tails, multiple cores or two components.

In Fig. 2 we show, for each morphological class, a three color image of a representative galaxy.

Fig. 2. B-V-z color images of galaxies representative of the six morphological classes used in this study. From left to right : passively evolved spirals, peculiar/irregulars, peculiar/tadpoles, peculiar/mergers, compact galaxies and obvious mergers.

4 Comparison between kinematics and morphology

We find a good agreement between morphological and kinematical classifications. More than 64% of rotating disks are classified as Spirals and more than 60% of complex rotators are peculiar galaxies or mergers. Among the galaxies classified as spirals, only one has a Complex Kinematics and three have perturbed rotation. The spiral classified as complex rotator is a galaxy for which the velocity field is not aligned with the optical axis. Over the three perturbed rotators, one spiral shows an interacting companion at ∼7kpc (and same z) and its σ map shows a distortion oriented towards this companion, one shows a sigma peak shifted from the dynamical center but located on a possibly minor merger event (Puech et al. 2007) and the last one shows an elongated σ peak possibly due to a giant bar.
Peculiar galaxies are mainly distributed between PR and CK. Interestingly, galaxies identified as possible mergers or tadpoles like are mainly CK (9/12), whereas irregulars are mainly PR/RD (10/12).
Compact galaxies are mostly CK (5/8) and only one is RD. This last object is morphologically ambiguous as it possibly shows spiral arms, but a very complex color distribution. Not surprisingly, all the galaxies identified as major merger are CK.
Table 1 gives the statistics of each kinematical class versus the morphological one.

	Spirals	Peculiar			Compact	Merger
		Pec/Irr	Pec/T	Pec/M		
RD	19%	6%	2%	0%	2%	0%
PR	6%	13%	2%	2%	4%	0%
CK	2%	6%	6%	12%	10%	10%

Table 1. Comparison between morphological and kinematical classifications.

5 Conclusion

We have presented a morphological analysis of a representative sample of intermediate mass galaxies at z∼0.6. To derive our morphological classification, both structural parameters and color maps have been used, complemented with a visual inspection of each object. This method has been tested against an independent kinematical classification and we find a good agreement between the morphological and the dynamical state of galaxies. Rotation dominated galaxies are generally disks, and very rarely peculiar or compact. On the contrary, galaxies showing complex kinematics are completely dominated by disturbed morphologies. The major overlap between the different kinematical classes are for irregular galaxies which are known to span a large range of kinematical properties.
These results show that, when derive properly, the morphological information can be representative of the underlying kinematical properties, even at z∼0.6. As in the local universe, a correlation between morphology and kinematics of distant object can be derived. This correlation represents a powerful tool to understand the

mechanisms of formation and evolution of galaxies.

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