Fundamental problems in galaxy evolution

Karl Glazebrook

Biases: observational problems, high-redshift





Fundamental problems: 10 yrs ago

- I. True abundance of red/elliptical galaxies at z>1?
- 2. Morphological distribution at z>1 in massselected samples
- 3. Dependence of M vs SFR vs Z vs redshift?
- 4. Can we measure circular velocities of z>I galaxies?
- 5. Can we detect the BAO feature in the galaxy distribution?



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VAN DOKKUM ET AL.

Build-up of Milky Way ancestors.





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- I. What are the *kinematic* morphology fractions at z>0.5?
- 2. What is the galaxy merger rate?
- 3. What drives turbulence in high-z disks?
- 4. How do 'clumps' drive galaxy evolution?
- 5. How does the Tully-Fisher relation evolve?
- 6. Is the IMF and SFL Universal in space and time?

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NMFS et al. (2009); Mancini et al. (2011); and SINS+zCOSMOS (in prep.) Kinemetry: Shapiro et al. (2008); Kinematic modeling: Genzel et al. (2008,2011); Cresci et al. (2009)





What is the kinematic disk fraction?

- Surveys find ~30–50% disks (albeit turbulent/high dispersion) in hetereogenous samples. (See my Dawes review arXiv:1305.2469)
- Fractions in clean mass selected samples? Dependence on mass, SFR, z, environment?
- What about quiescent galaxies?



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Different approaches to merger rate

- Close pairs
- Close pairs near in redshift space (spec-z or photo-z)
- Irregular morphology
- Irregular kinematics







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What we don't know about the merger rate

- Inconsistencies between kinematic and close pair methods? Homogenous samples?
- What are the time scales of the various methods?
- What is the dependency on galaxy mass ratio/ colour?
- Can we develop 3D non-parametric measures of kinematic disturbance?



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Turbulence is high

Green et al. (2013)

BUR



What drives turbulence?

- Source not specified by Q~I Toomre disk model
- Cosmic accretion?
- Gravitation instability (clump formation, clumpclump interactions) ?
- SFR feedback?









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Do clumps build bulges?



Elmegreen & Bournard (2008)

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Tully-Fisher disagreement





Evolution of the zeropoint?



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| IMF variations? |
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| Low mass SFGs may have steeper IMF (Hoversten & Glazebrook 2008, Meurer et al. 2009) |
| High mass ellipticals may be 'bottom heavy' (van Dokkum & Conroy 2010, Cappellari et al. 2012) |
| IMF may vary with redshift (van Dokkum 2008, Davé 2008) |
| IMF cutoff scales with Jean's mass? (Narayanan & Davé 2012) |
| |



<u>ALMA</u>

- High redshift:
- Molecular gas & dust, resolved, in NORMAL objects.
- Detections, structures, kinematics, star-formation laws
- Star-free molecular disks at z>2?





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Bournaud et al. (2013) z~2 sim

neutral gas





z=0.13 SFR=32 M $_{\odot}$ yr⁻¹ σ =50 km/s

