The Galaxy Velocity Function Since $z=1.5$ in DEEP2

Susan Kassin (Oxford), Ben Weiner (Steward), Christopher Willmer (Steward), S.M. Faber (Lick), David Koo (Lick), Marc Davis (Berkeley), Jeff Newman (Pittsburg), Joel Primack (Santa Cruz), & DEEP2 Team
What is a Galaxy Velocity Function?

In analogy with the galaxy luminosity function, or the galaxy stellar mass function...

the galaxy velocity function is the number density of galaxies as a function of their internal velocities.

Major goals = study galaxy assembly and trace dark halos.

(Also a probe of cosmology, e.g., Newman & Davis 00,02).
Why Study the Galaxy Velocity Function?

It’s not straightforward to relate galaxy L’s or even M∗’s to the dark halos in which they reside.

- Significant errors in M∗’s (at least factor of 2-3)
  - The galaxy property a dark halo velocity most directly compares to is galaxy velocity (Navarro & Steinmetz 97; Klypin et al. 02).
  - Dark halo masses most directly traced by V_c
Data for the Galaxy Velocity Function

- Need a large redshift survey with high enough spectral resolution to measure internal kinematics
  => DEEP2 Survey

- ~50,000 spectra

- ~30,000 spectra with successful measurements of emission linewidths or absorption line velocity dispersions
Galaxy $\sigma$ Measurements

- **Absorption line $\sigma$'s** measure the velocity dispersion of early type galaxies within the effective radius (Gebhardt et al. 2003)
- **Emission line $\sigma$'s**
  - For rotation dominated systems, they measure $0.6V_{\text{rot}}$ (Rix et al. 1997, Weiner et al. 2006a)
  - For disturbed systems, they sum all disordered motions beneath the seeing limit (Weiner et al. 2006a)
- **Automated programs:**
  - FITDISP performs least squares fits to absorption line spectra with a linear combination of broadened stellar templates, fits for broadening
  - LINEFIT performs a least-squares fit to the emission lines, fits for linewidth
Example FITDISP output:
Fitting to Ca HK lines for a Galaxy at $z=0.8$

Chi squared as a function of broadening

$log$ rest wavelength

Least squares fit to spectrum with a linear combination of broadened stellar templates from MILES.

For each spectrum, 50 Monte Carlo realizations are simulated and re-fit to get error on sigma.
What normal disk kinematics would look like at $z=1$

intensity

velocity

Seeing blurs velocity into "dispersion" - model this when fitting the data.

dispersion

H-alpha vel field of NGC 7171, from Rutgers Fabry-Perot at CTIO

(Ben Weiner, SAK et al 2006)
Incompleteness in the Velocity Function

Given a Tully-Fisher Relation, Make Luminosity Selection

\[ \log V_{\text{rot}} \text{ (km/s)} \]

luminosity
Incompleteness in the Velocity Function

Given a Tully-Fisher Relation, Make

Magnitude Selection:

\[ \log V_{\text{rot}} (\text{km/s}) \]

This is what happens to the Luminosity Function…

Luminosity Selection in a Luminosity Function

\[ \log \phi \]

Luminosity

true

selected
Incompleteness in the Velocity Function

A given magnitude cut will result in an artificial fall-off in the faint end of the velocity function. This is due to the scatter in the magnitude-velocity relation.
Velocity Function for *Emission Line* Galaxies

Emission line widths sum rotation and random motions beneath seeing limit (Weiner et al. 2006a)

Increase in $\sigma$ over $0.2<z<1.5$ by a factor of $\sim 1.5-2$, perhaps also some $\sigma^*$ evolution
Absorption line widths measure velocity dispersion within the effective radius (Gebhardt et al. 2003)

Evolution in $\sigma^*$, magnitude of which TBD
Velocity Function for *Emission and Absorption Line* Galaxies

![Graph showing velocity function for emission and absorption line galaxies with incompleteness indicated.]
Velocity Function for *Emission and Absorption Line* Galaxies

**Need SAMS** (and cosmological hydro simulations)

V\text{vir} for dark matter halos from N-body simulation plotted as solid lines (Project Horizon, Julien Devriendt)

Much less evolution found for simulated halos, and in opposite sense
Velocity Function for *Emission and Absorption Line* Galaxies and Groups

Note change in velocity scale from previous plot

Group measurements in DEEP2 from Brian Gerke
The lines plotted are the 1:1 line and $V=0.6\sigma$ (Rix et al. 1997).

Sigma captures the velocity scale for rotation and dispersion dominated galaxies, while $V_{\text{rot}}$ only works for rotation dominated galaxies.

From Weiner, SAK et al. 2006a