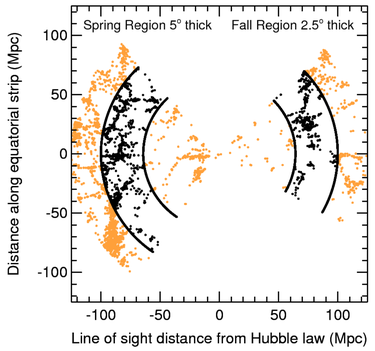
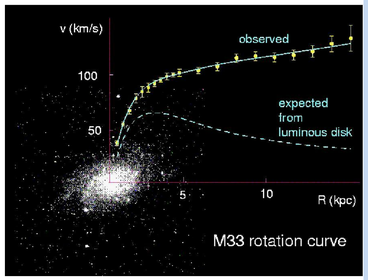
Extracting Galaxy Rotation Curves for a Dark Matter Census and Exploring Kinematic Anomalies

Kirsten Hall, Sheila Kannappan, Kathleen Eckert, David Stark and The RESOLVE team

Background and Motivation

- The RESOLVE (REsolved Spectroscopy Of a Local VolumE) survey is a volume-limited census of stellar, gas and dynamical mass in a 53,000 cubic Mpc region of the nearby universe.
- The RESOLVE team aims to study star formation and merger activity for all galaxies (black dots at right) contained in the volume.
- The extraction of velocity fields and creation of galaxy rotation curves allows for a determination of the amount of mass contained within a galaxy. This is done with a rotation curve – plot of velocity vs. radius – and the Motions Find Mass equation.
- This total mass is compared to the mass determined to be in the galaxy based on the light coming from it. The difference between the two mass calculations is the amount of dark matter in that galaxy.
- The velocity fields are extracted from optical data, and will be compared to velocity measurements from radio data. This to obtain accurate velocity measurements, and it allows for the identification of galaxies with anomalous kinematics , or internal motions that do not orbit the galactic center, such as inflows and outflows of ionized hydrogen gas.





Motions Find Mass

- The MFM equation allows astrophysicists to determine the amount of mass contained within a radius of a galaxy.
- Consider the centripetal force and the gravitational force that attracts a satellite toward a central body:

$$Fnet = \frac{Msat \times v^2}{R}$$

$$Fnet = \frac{G \times Msat \times Menclosed}{R^2}$$

- Equating the two and solving for Menclosed:

$$Menclosed = \frac{v^2 \times R}{G}$$

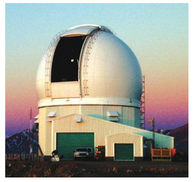
Acknowledgements: Thank you to National Space Grant College and Fellowship Program, and NC Space Grant Consortium for supporting and funding this research. Thank you to NSF for support of the CAP REU Site Program and the RESOLVE Survey under grants OCI-1156614 and AST-0955368.

References

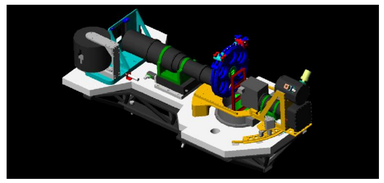
- Beauvais, Charles, and G. Bothun. "Precision Velocity Fields in Spiral Galaxies. I. Noncircular Motions and RMS Noise in Disks." *Astronomical Journal*. 125.1 (1999): 99-121. Web. 4 Jun. 2012.
- Kannappan, Sheila J., and Elizabeth J. Barton. "Tools for Identifying Spurious Luminosity Offsets in Tully-Fisher Studies: Application at Low Redshift and Implications for High Redshift." *Astronomical Journal*. 127.5 (2004): 2694-2710. Web. 4 Jun. 2012.
- *Kannappan, S.J., D.G. Fabricant, and M. Franx. "Physical Sources of Scatter in the Tully-Fisher Relation." Astronomical Journal. 123.5 (2002): 2358-2386. Web. 4 Jun. 2012.*
- Teuben, P.J. "Velocity Fields of Disk Galaxies." *Disks of Galaxies: Kinematics, Dynamics and Peturbations, ASP Conference Proceedings*. 275. (2002): 217-228. Web. 4 Jun. 2012.

Analyzing Galaxies' Spectra

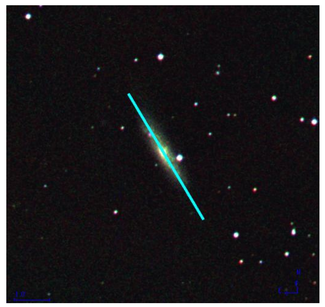
Spectroscopy



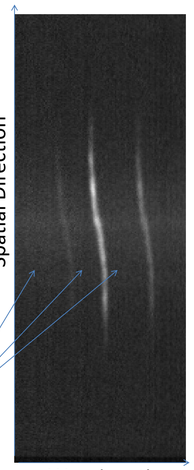
SOAR optical telescope, Chile



GOODMAN spectrograph

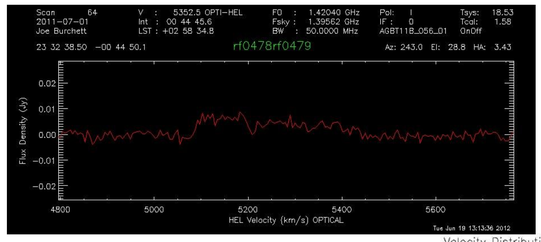


- A slit is placed across the galaxy for collecting light
- Gas emission lines on a Spectral Image

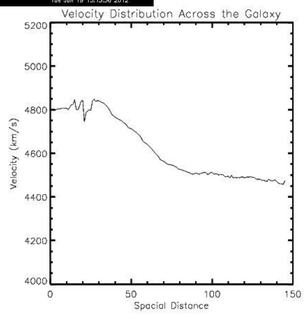


Data Comparisons

- In radio astronomy there is poor resolution, so when observing one galaxy, it is possible to obtain a profile that contains information for two galaxies. These are confused sources and need to be separated with use of the optical data.

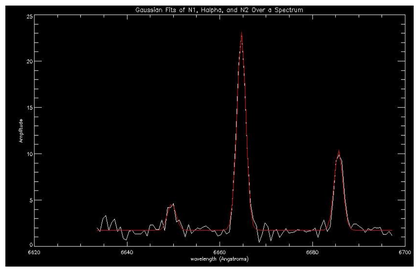


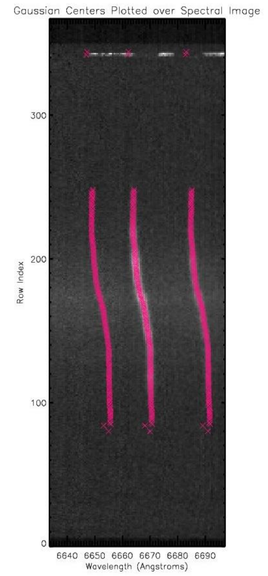
- Optical data traces ionized hydrogen which often concentrates near the galactic center, and may be moving in directions outside of the usual orbit.
- Velocity components in directions other than around the center cannot be considered in the mass calculation, so we look for asymmetry and turbulence in the rotation curves



Extracting Velocities

- Velocities are extracted from the spectra by fitting Gaussian functions to the emission lines from gases at well-known wavelengths. In particular, ionized hydrogen produces a very strong line on the spectrum, so it is ideal for velocity determination.

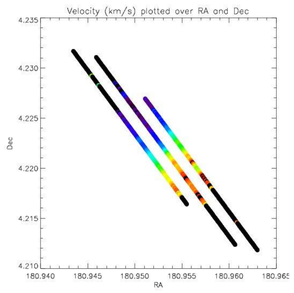




- The velocities are determined radially across the galaxies with use of the redshift formula:

$$\lambda observed = \lambda emitted \left(1 + \frac{v}{c}\right)$$

- This formula accounts for the Doppler shift due to the galaxies' rotations. When the Gaussian is fit over the emission line, the center of the fit gives the redshifted wavelength of light. Thus, by knowing the rest wavelength, one can use the redshift formula to calculate velocity.
- The GOODMAN slicer has 3 slits receiving light from the galaxies giving 3 sets of spectra across a galaxy and allowing for the creation of a 3D velocity field.



Future Work

- Compare velocity information obtained from optical and radio data, sorting out any discrepancies to determine the most accurate velocity fields and rotation curves to apply to the Dark Matter census
  - Includes fitting velocity field models and assessing kinematic anomalies
- Separate galaxies with kinematic anomalies for future exploration
  - Identify asymmetries and turbulence in rotation curves
  - Explore possible reasons for anomalies such as star formation and active galactic nuclei