# Ionized Gas Velocities from Multi-Slit Spectroscopy for Nearby, Edge-on Galaxies

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## Introduction

Several galaxies show extraplanar (EP) gas with decreasing rotational velocities as height above the disk increases (e.g. Rand 1992, Heald et al. 2007). This is often referred to as a "lagging halo." Models that reproduce these velocity gradients require that ~15% of the EP gas is from infalling IGM or satellite accretion, while the remainder is from galactic fountain flows (Fraternali & Binney 2008). Accreted material is also necessary to maintain observed star formation rates without galaxies using up their gas supplies on timescales shorter than their lifetimes (Larson at al. 1980). Additionally, models of SFR densities and molecular gas depletion rates indicate that ionized gas is the primary source for refueling star formation (Bauermeister et al. 2010).

We have optical observations for several edge-on targets from a multi-slit (MS) spectroscopic setup on the ARC 3.5m telescope at Apache Point Observatory, NM. Our setup allows us to measure velocities of Hα-emitting gas as a function of height above the midplane in 11 radial distance bins in a single exposure. The goal of our project is to study the kinematics of ionized EP gas.

We present results from Hα observations and modeling for a subset of our sample. Several of our targets overlap with those from HALOGAS (Hydrogen Accretion in LOcal GAlaxieS), which is a WSRT deep HI survey studying cold gas accretion in the local universe. Our observations provide an optical complement to the HALOGAS survey.

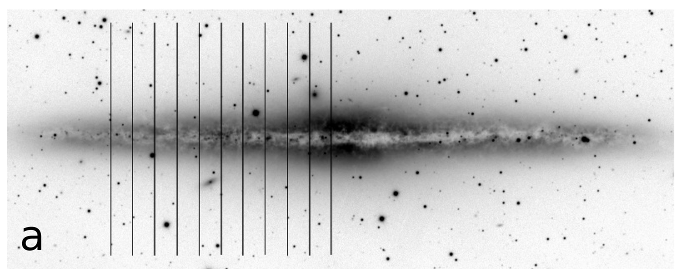
## Multi-slit Spectroscopy

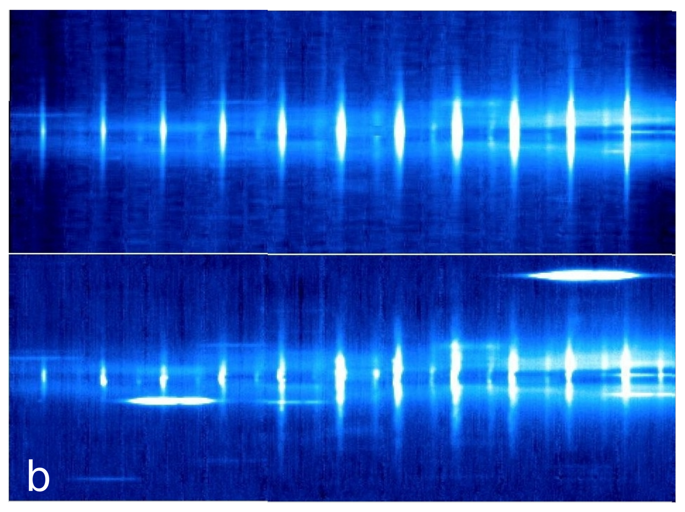
- 11 parallel slits, 1.5" wide, spaced 22.5" apart
- narrowband filter prevents neighboring spectra from overlapping
- 0.58 A/pix → 65 km/s resolution
- field of view: 4' x 4'

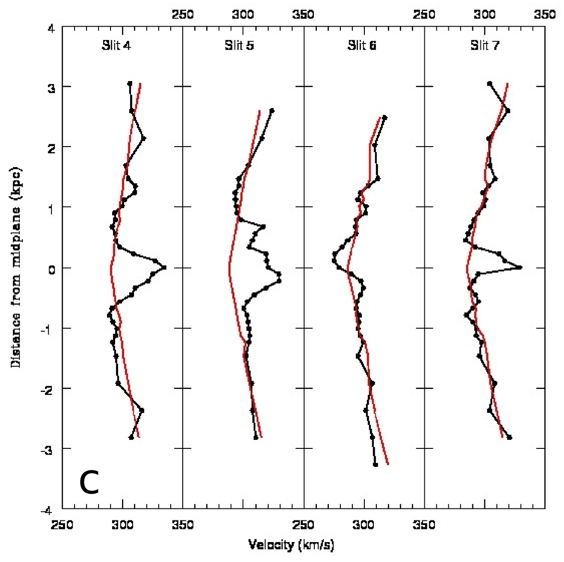
## Modeling

- each galaxy is modeled specifically for the MS setup
- emission profiles are based on LOS velocity and gas density
- scale height and length are measured from the data and input to the models
- various lags are tested to see which best matches the data

## NGC 891



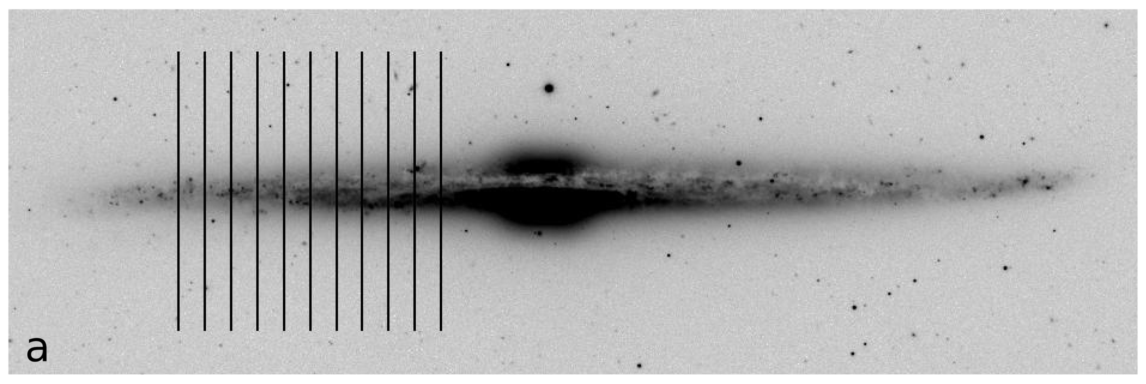



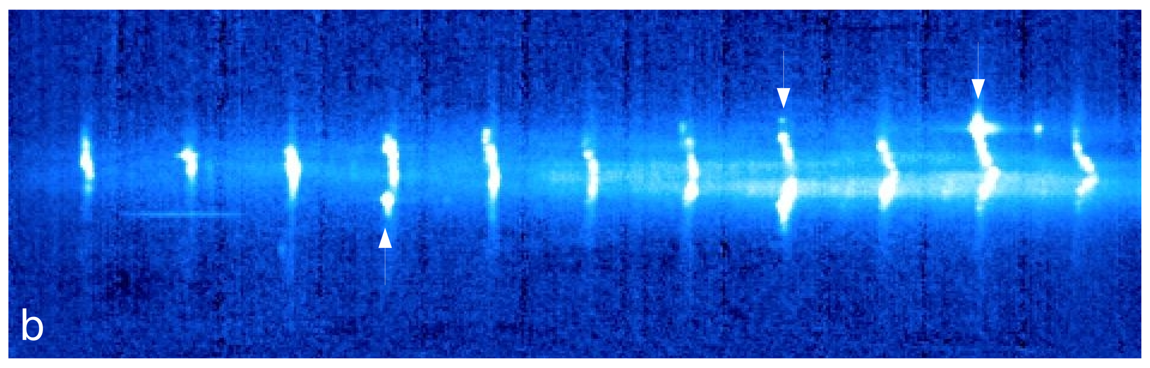

***a)*** *Slit positions overlaid on an Hα image, courtesy of M. Patterson (327.02D).*

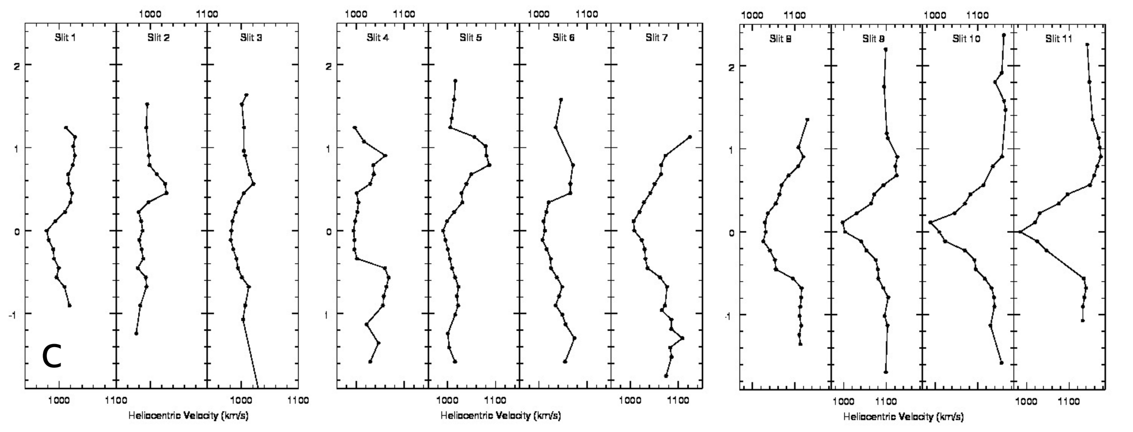
***b)*** *Model (top) and observations (bottom). MS data are a series of spectra, side by side, with wavelength on the x-axis and spatial direction along the y-axis.*

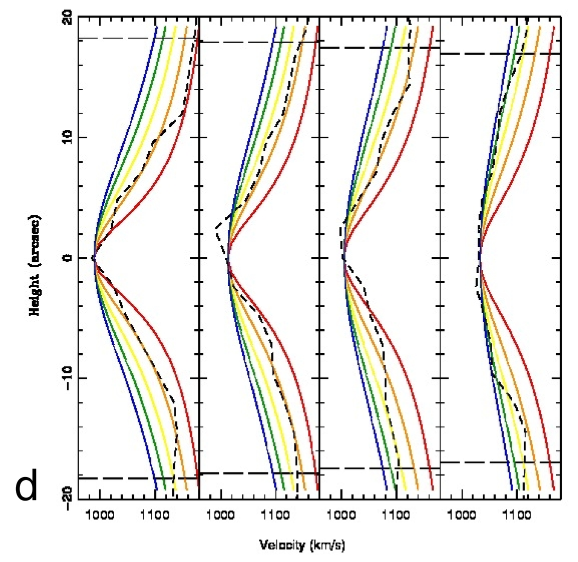
***c)*** *Velocities from data (black) and model with a lag of 14 km/s/kpc (red) for slits that show a lagging component.*

## NGC 4565



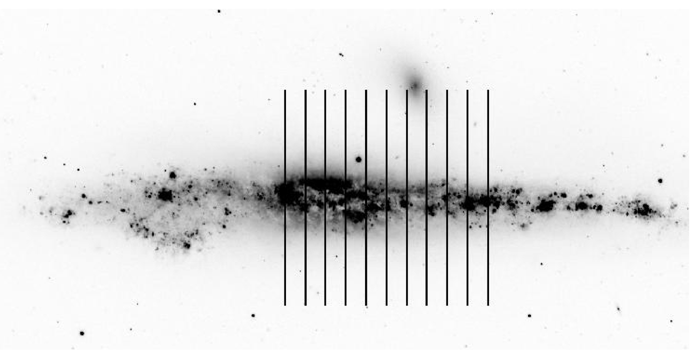

***a)*** *Slit positions overlaid on an Hα image, courtesy of M. Patterson (327.02D).*

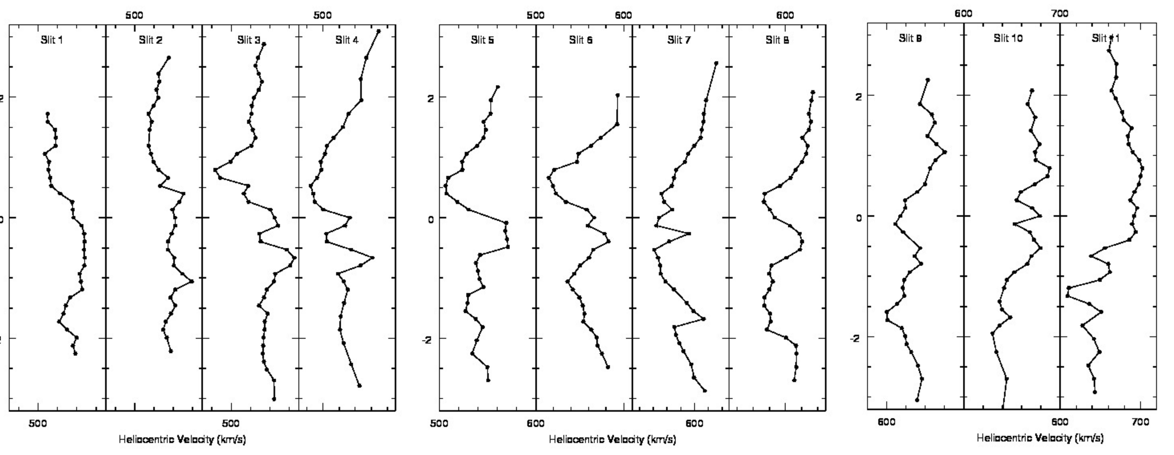
***b)*** *Observations show a very thin disk, which is slightly inclined, and a thicker disk with more diffuse emission. Bright Hα-emitting regions are indicated with arrows.*

***c)*** *The data appear to have a steep velocity gradient in the inner disk and a smaller gradient in the outer disk. This can be caused by viewing geometry when the disk is thin and has an inclination close to (but less than) 90˚.*

***d)*** *Models of the inner thin disk are shown for inclinations of 88˚ (red) through 84˚ (blue) in 1-degree increments for the inner 4 slits. An inclination of 87˚ matches the data (black). Horizontal dashed lines show the projected extent of the thin disk assuming an optical radius of 6' and an inclination of 87˚. At this size and inclination, the bright regions indicated in (b) lie at the edge of the disk. Observed emission outside the thin disk was modeled as a thick, diffuse disk that is also inclined at 87˚. It does not appear to have a vertical velocity gradient.*

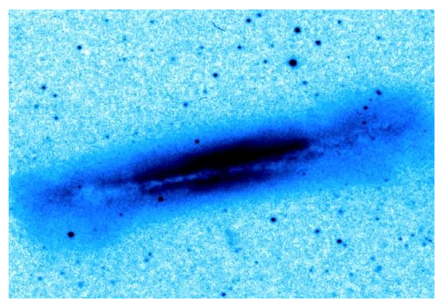
## NGC 4631

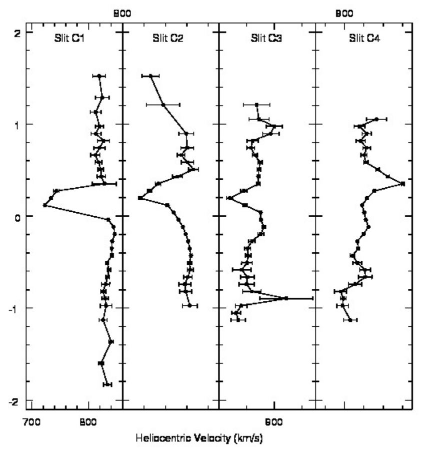


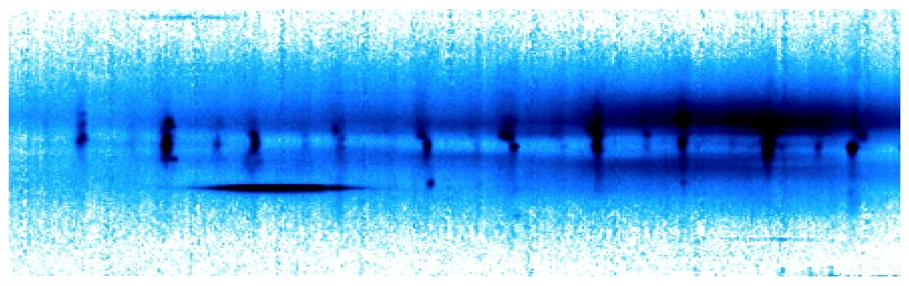


*This galaxy shows a curved pattern in its velocity profiles, which is the typical signature of a lagging component. Preliminary models indicate that a lag of ~30 km/s/kpc best matches the data.*

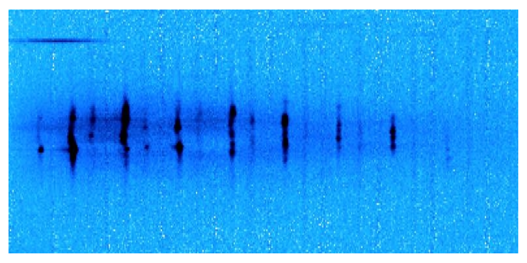
## NGC 3628

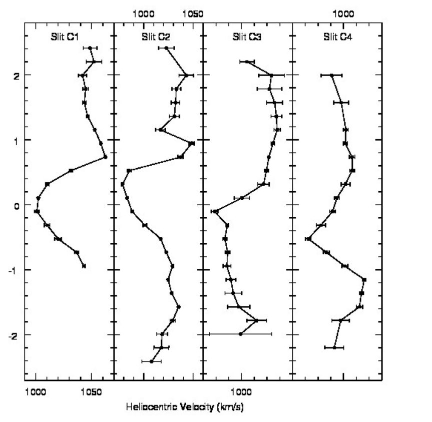






## NGC 4517





*NGC 3628 and NGC 4517 show thick, extended Hα emission and prominent dust lanes. Both also show signs of interaction. However, neither shows any lagging component.*

## References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