AS7004: Observational Astrophysics II – HT 2014
Observational Projects

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1 Galaxy Dynamics

Since the 1930s we have known that a large (usually dominant) fraction of the mass in a galaxy does not produce light; clinching evidence for this came from the rotation curves of spiral galaxies. Here we will attempt to do this[1]. The science outcome from the spectroscopy would be to derive the rotation curve (de-projected velocity as a function of radial distance), fit a light+dark mass profile ("maximum disk"...), and determine the stellar/dark matter mass components.

1.1 Target Considerations

- The galaxy should be sufficiently large (angularly) that you get a decent baseline in the spatial direction to measure the rotation. Too compact galaxies are no good.
- The galaxy should be sufficiently small (angularly) that the ALFOSC slit length reaches large enough radii that you can actually sample the outer rotation curve. Recall for both points that the surface brightness will decrease with radius, so the more rapidly moving material will also be fainter. The fact that the signal you are most interested in is the faintest is a recurring problem!
- You need an inclination angle. Since you will measure $V_{\mathrm{rot}} \times \cos i$ and not V_{rot} directly you need to de-project. This is easily done from the images (assuming an infinitely thin disk), but if the inclination is small you will not measure the V_{rot} at all!
- You need a spectroscopic feature to trace. For the stellar rotation field you would need a stellar absorption line. Seeing absorption against the continuum, your exposure time will be set by the time needed to reach SRN=X in the continuum, which depends upon the stellar surface brightness. Alternatively one could use an emission line, of which Hα would be by far the strongest. If you work with an

[1] One could also consider spatially mapping the dispersion velocity of an elliptical galaxy, or attempting to map the 1D velocity field of a starburst, although the considerations would be rather different.

emission line you are measuring the flux *above the continuum* so the continuum level itself is close to irrelevant. This will be observationally faster, but carries the penalty that you are not measuring the stars directly but the gas that they ionize. However, the penalty is probably well worth accepting (the assumption that nebulae follow stars is quite reasonable...) and observationally it is much much easier.

You may pick any galaxy you want. However one may consider: NGC 4605, NGC 1035, NGC 4062, NGC 701, NGC 2608, NGC 3495, NGC 1087, UGC 3691, NGC 4682, NGC 3672, NGC 1421, NGC 2715, NGC 4321, IC 467, NGC 7541, NGC 7664, NGC 2998, NGC 753, NGC 801, UGC 2885

1.2 Observational Considerations

The goal is to measure rotational velocity. The Milky Way rotate at what kind of velocity? ALFOSC can deliver resolving powers of up to $\sim$ 150 km/s, so you may be able to measure velocities down to a few tens of km/s. ALFOSC grism #8 looks like a good bet to get the Hα line at this kind of R. Other grisms (e.g. #5) can capture Hα but perhaps the resolution is too low.

2 Resolved Galaxy Metallicities

Here at Stockholm University we are undertaking one of the largest Hubble Space Telescope programmes ever awarded to Europeans: the (extended) Lyman alpha Reference Sample [(e)LARS]. Over several years we will image 42 nearby Starburst galaxies in with 8 HST filters; unfortunately we have almost no resolved spectroscopy. This is particularly useful since we need to know how the the [N II]/Hα ratio changes across the galaxy and how the metallicity evolves spatially from the central regions (where the starburst is young) to the outer regions where the stars are older. This metallicity gradient includes information about what fraction of the metals are produced in the current episode of star-formation and what is remnant from previous generations of stars (a currently open question) and potentially if metallicity is decreased by either enriched galaxy outflows or inflows of unpolluted gas. The same spectra would enable maps of the dust content (Hα/Hβ), the excitation parameter (hardness of the ionizing flux, [O III]/[O II]), and possibly also gas kinematics (see for example the Galaxy Dynamics project).

2.1 Target Galaxies and Considerations

LARS galaxies are listed in Table 1.

Considerations are very much the same as for the galaxy dynamics project. You'd want to select one of the larger targets, although none are too large to fit in the ALFOSC chip. This is exclusively an emission line project – stellar absorption features are likely too hot to see. Be sure to pick a big galaxy!

First paper on the sample: Hayes et al (2013, ApJ, 765, 27).

LARS ID#	SDSS ID	R.A.	Dec.	z
01	SDSS J1328+4355	202.18340	43.930530	0.0280
02	SDSS J0907+5326	136.77063	53.449046	0.0298
03	SDSS J1315+6207	198.89642	62.124249	0.0307
04	SDSS J1307+5426	196.86765	54.447443	0.0326
06	SDSS J1545+4415	236.43578	44.263876	0.0341
07	SDSS J1316+2922	199.01628	29.381746	0.0378
08	SDSS J1250+0734	192.55742	7.5789468	0.0382
09	SDSS J0823+2806	125.97884	28.106336	0.0472
10	SDSS J1301+2922	195.42321	29.381453	0.0574
11	SDSS J1403+0628	210.94658	6.4708537	0.0843
12	SDSS J0938+5428	144.55634	54.473719	0.1021
13	SDSS J0150+1308	27.618398	13.149793	0.1467
14	SDSS J0926+4427	141.50160	44.460023	0.1806

Table 1: LARS galaxies: ID, coordinates, and redshifts. Note the absence of LARS 05!

2.2 Observational Considerations

Ideally we would obtain a complete spectrum between the [O II] emission line at $\lambda = 3727$Å, and the [S II] doublet at $\lambda\lambda 6717,6731$Å. With a complete spectrum over this range we can measure metallicities using all the common diagnostics: N2 index, R_{23} index, O3N2 (which are all "strong line calibrations"). We should also anchor the metallicity measurement with a direct measure using some electron temperature (T_e)-sensitive emission line ([O III]λ4363Å). Some of the grisms can do this in one shot, but your wavelength resolution will be low. You may want to consider a blue setting to capture [O II]λ3727 to [O III]λ5007Å, and a red setting to get Hα to [S II]. That way you will resolve fast velocity components if they are there (and the should be) and have higher sensitivity to the T_e-sensitive [O III] line.