The DESI peculiar velocity survey



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The Dark Energy Spectroscopic Instrument

- 4-meter Mayall Telescope at Kitt Peak National Observatory
- 5000 robotic fibres in 10 petals with 500 each





Photometric and spectroscopic survey

- DESI Legacy Imaging Survey DR9
 - grz photometry for target selections (supplemented with WISE data)

DESI survey

- 3 arms (360 980 nm, R: 2k-5k)
- Main target classes for BAO
 BGS, LRG, ELG, QSO
- Milky Way science targets
- Spare fibres for secondary targeting programmes



Peculiar velocities and how to measure them

- Proper motions of galaxies relative to the Hubble flow
- Contain information about the mass distribution in the universe

- redshifts and a redshift-independent distance indicator
 - Standard candles: Cepheids and SNIa
 - Tip of red giant branch, surface brightness fluctuations, standard sirens
 - Galaxy scaling relations: fundamental plane and Tully-Fisher relation

• Fei Qin's talk for more details on peculiar motion science

Fundamental plane of early-type galaxies

Empirical relation:

 $\log(R_0) = a \log(\sigma_0) + b \mu_0 + c$

- Scatter ~20%
- Requires good quality spectroscopy to obtain the central velocity dispersion





by DESI Legacy Imaging Survey DR9

by ChangHoon Hahn

Tully-Fisher relation of late-type galaxies

- $L=\alpha v_{max}^{\beta}$ with a Scatter ~20%
- Measurements of maximal rotational velocity v_{max}
- Off-centre fibres \rightarrow redshifts relative to the centre





Understanding the DESI fibre assignment

- Fibres can move in patrol radius, many competing targets
- Multiple passes (up to 7), observations in dark time and bright time



Using the spare fibres

- Main targets (BGS, LRG, ELG, QSO, MWS) have always priority
- Spare fibres:
 - Bright galaxies are masked for dark time targets (ELG, LRG, QSO): If no other target within patrol radius of fibre positioner
 - After multiple passes: all main targets within patrol radius observed
 - Some big galaxies (from SGA) cover several patrol radii
 - no other targets by chance (very rare)
- Spare fibres are used for several secondary targeting programmes

- Allow for additional observations in dark time with high SNR (FP)
- Over time: additional measurements of off-centre redshifts (TF)

Target selection

- Had to be done before start of spectroscopic observations
- Using DESI Legacy Imaging Survey DR9
- ETGs for FP and LTGs for TF-relation
- Truth catalogues from the Siena Galaxy Atlas and GalaxyZoo
- Colour cuts, inclination, photo-z, and profile fits (Sersic index)





Target selection

- Using the science verification data (observation before the main survey) to test our criteria and refine them further
- Using fastspec data to further clean the sample (~75% remain)





DESI vs other surveys

- DESI will have the largest sample of fundamental plane observation ever done so far (expecting up to 300 000 galaxies)
- 14 000 square degree **DESI ETG** SDSS DR16 6dFGSv SDSS DR7 DESI 8000 SDSS ורח 75° 6dFGSv 7000 60° 6000 -45° s 5000 -4000 -30° 15° 18h Oh 6h 2h 1.6 12h10h 22h 4h z 0° 3000 -15° 2000 --30 1000 --45° 0 -60°

-75°

0.08

Ζ

0.06

0.00

by Cullan Howlett

0.02

0.04

0.10

0.12

0.14

Current status of the observations

- 29 983 of our photometrically selected ETGs targets (22 519, if spectroscopic selection is considered as well) have already been observed by DESI before summer (Everest/Fuji releases)
- 15 981 have spectra with a SNR>7.5 (despite many in bright time ... dark time observation in the future after a bug fix)
- Already a larger sample than the 6dFGS FP catalogue
- Fitting is work in progress, but data already agrees well with previous fundamental plane calibrations (Said+ 2020)
- Paper and public release next year!



Current status of the observations

- Tully-Fisher relation targets are slower going
- At least two observations on the same galaxy required
- Currently one pass for most of the DESI so far
 - \rightarrow need multiple passes to get spare fibres for all our target
- Mostly tests with MANGA
- Fibres get enough light to get redshifts

Maybe paper next year





Improving cosmological measurements

• Growth rate: $f\sigma_8$, improving constraints from DESI BGS for the evolution and scale-dependence



Conclusions and Outlook

- Tully-Fisher relation and fundamental plane distances collected with the same survey
- All proofs of concept successful and first data collected
- Success rate measured \rightarrow important for mocks

- At least two papers (target selection and fundamental plane) early next year with the first public DESI data release
- 300 000 fundamental plane distances and up to 125 000 Tully-Fisher relation distances by the end of the DESI survey
- Notable improvements in the measurements of $f\sigma_8$ at low redshifts

Questions?