NORDIC OPTICAL TELESCOPE

Proposal 48-

APPLICATION FOR OBSERVING TIME

OBSERVING PERIOD 48

October 1, 2013 - April 1, 2014

1. Title of proposal:

Measuring the Rotation Curve of the Elusive NGC 5963: The Adventure.

2. Abstract:

We propose to use the NOT telescope to obtain deep surface spectroscopy and photometry for the low surface brightness galaxy NGC 5963. We will measure the Hα line emission from the ionized gas around stars to unfold its rotation curve. A light+dark mass profile fit to the measured spectroscopic data will be done to determine the galaxys stellar/dark matter components. We intend to use the photometric data to investigate the targets underluminous nature

3. Principal Investigator: (**NB:** The P.I. has full responsibility for the content of this proposal!)

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4. Co-investigators and affiliations:

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5. If this is a PhD thesis project at a Nordic institute, please give name of student, supervisor and expected time of completion:

6. Observing period(s) requested and preferred scheduling:

Run	Instrument	Time	Month(s)/Date(s)	Moon	Seeing	Sky
A	ALFOSC	7 H	May	B	1.5	P

7. Number of nights already awarded to project: 0

8. Number of nights needed to complete project: 1

9. If your project can not be done in service mode, please justify:

Yes

10. Any other special constraints on the scheduling?

No

11. Scientific justification for the proposal:

Dark matter was first termed in a paper from 1933 by Fritz Zwicky. He used the virial theorem to calculate the gravitational mass of the galaxies in the Coma cluster and found a discrepancy between the measured mass and their expected luminosity. He referred to this "missing mass" as "dunkle materie". Today scientists have accumulated convincing evidence of dark matter from many independent theoretical and observational studies, such as galaxy rotation curves (Rubin, V. C et al. 1980 ApJ 238 , 471) , velocity dispersions (Faber, S. M.; Jackson, R. E. 1976 ApJ 204, 668) , gravitational lensing (Refregier, Alexandre 2003 ARAA 41, 645) , measurements of the cosmic microwave background (Hinshaw, G et al. 2009 ApJS 180, 225) , baryon acoustic oscillations (Percival, Will J et al. 2007 MNRAS 381, 1053) , supernovae distance measurements (Komatsu, E et al. 2009 ApJS 180, 330) , Lyman-alpha forest measurements (Viel, Matteo et al. 2009 MNRAS 399L , 39) of distant galaxies and in structure formation scenarios (Springel, Volker et al. 2005 Natur 435, 629).
According to the successful Planck mission (Planck Collaboration 2013 arXiv 1303, 5062), the dark matter part of the total energy in the universe is a staggering 26.8% compared with the 4.9% of ordinary matter. Even though the consensus among scientist today is that dark matter consists of Weakly Interacting Massive Particles (WIMPs), no official detections of these elusive particles have been made and the hunt for these particles is one of the major undertakings of modern physics. In what better way to make aspiring astronomy students more comfortable with observational techniques, than to let them discover for themselves the existence of dark matter? The reproducibility of science is after all one of the fundamental pillars of science itself. By the guidance of past and present mentors we therefore propose to use the NOT telescope to measure the rotation curve of NGC 5963, fit a light+dark mass profile to the acquired data and determine the stellar/dark matter mass components of this galaxy. The rotation curve will not be derived by direct measurements of the velocity of the stars in the galaxy but will be inferred by measurements of the Hα line emitted from the ionized gas around stars.

The need for a new observation and its selection: The target in consideration, NGC 5963 is of the type Low Surface Brightness (LSB) galaxy (Romanishin, Strom & Strom 1982 ApJ 252, 77) which are usual targets for dark matter studies due to their peculiar mass to light ratio. NGC 5963 is no exception to such studies (e.g. Bosma et al. 1988, A& A 198, 100). However, the latest direct observations of NGC 5963 we could find in the literature were taken over a decade ago (Simon et al. 2004 ASPC, 327, 18), which speaks for the acquisition of newer observations.
Another virtue of the selected target is that if photometric images of good enough quality of the galaxy is provided, they might give insight to its anomaly underluminous nature (Zackrisson et al. in preparation). NGC 5963 strongly deviates from the expected Tully-Fisher (TF) relation (Springob et al. 2007 ApJS, 172, 599) by being underluminous and/or having far greater non-baryonic mass than expected. Newer observations with the NOT may aid in uncovering why this is so.

13. Technical description of the observations. (Please provide a self-contained case.)

Because the target NGC 5963 is of low surface brightness nature, we aim for fairly deep spectra (1.5-2h) in order to obtain reducible data from the outer skirts of the galaxy. We used spectral data from the *Sloand Digital Sky Survey* (SDSS) in order to calculate the flux of the Hα line which we will also look at. The flux was calculated from the equivalent width and continuum of the line and then converted into magnitude using Vega as a reference star. A somewhat average of the known flux from Vega at similar wavelengths as the 6565Åwe are interested in was used in the conversion and we get a magnitude for our line of interest as $m_{H\alpha} = 19.3$. Given an integration time of 2h we would achieve a *Signal to Noise ratio* (S/N) of ≈ 8.5 according to the *Nordic Optical Telescope*'s own calculator using the #8 grism. In case that seeing is bad due to high air mass we would instead use the #7 grism in order to boost our S/N very slightly, sacrificing a bit of a resolution. We assume that we may need up to 30 min of overhead time and thus need 2.5h in total for the spectroscopy.

Although dark conditions would have been optimal for our photometric observations due to the target's faint surface brightness, we can make due with a bright full moon as well. Just as with the spectroscopy we aim for very deep imaging in order to reach the very faintest outskirts of the galaxy and enable a closer study of the outer morphology. Using the SDSS photometric data of NGC 5963 and calculating the surface brightness for different sizes of apertures we get a central surface brightness of $Sb_c = 20.35$ and on average $Sb_{avg} = 22.1$. Again using the NOT exposure time calculator tool we require an exposure time of at least 20 min, which would provide us with a $S/N > 3$ in all bands $UBVRI$ without risk of saturation. Given 20 minutes on average for each of the 5 bands and including 10 min of overhead we would require a total time of 2.5h for our photometry observations.

As we only have 1 target but 5 bands + spectroscopy, the total time needed would be 5h including overhead for our observations. Our target NGC 5963 possess the fortunate position in the sky during the designated days for observations that it is visible during the entire nights. Thus, we do not demand 5 consecutive hours of observations but are capable of splitting it up into several segments.

Should opportunity present itself for more time at the telescope we would use this time for photometric and spectrophotometric calibrations. If time would allow it we would also try to obtain even deeper photometry.

14. Requested instrument setup(s):

Run	Instrument	Mode	Setup
	ALFOSC	Standard imaging-filters	UBVRi
	ALFOSC	Spectro-long-slit	1.0, 1.3
	ALFOSC	Spectro-long-slit	Grism #7, #8

15. Target list with coordinates, or intervals in R.A. and Decl. of (sample of) objects:

Run	Name	α_{2000}	δ_{2000}	Magnitude	Diam($'$)	Additional Info.
A	NGC 5963	15 33 27.8	+56 33 35	B=12.70	1.52	

Remarks: Target coordinates refer to EquJ2000.

16. Backup programme (or justification why none is needed).

(**NB:** The backup programme should also take unfavourable wind conditions into account)

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17. List of observing periods, and publications from NOT observations, within the last three years.

No former observations have been made at the NOT by the PI nor Co-investigator.

18. Additional remarks not covered by the items above, if any:

This proposal is part of the Observational Technique II course at Stockholm University.