The Local Group Census[1]

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Proposal Summary:
The **Local Group Census (LGC)** will provide a unique deep narrow band image resource of all Local Group (LG) galaxies in the northern hemisphere (M_V brighter than −14). This will enable both old and new emission line populations (e.g. PN, LBVs) to be cataloged to unprecedented levels. The LGC will be enhanced with complementary broad band data to probe the linkages between stellar populations (e.g. AGB→PN) in the range of LG galaxies. Analysis of the population samples across the wide range of galaxy types seen in the LG will aid in the understanding of the LG evolutionary processes, and the role of the stellar populations in e.g. chemical enrichment of the LG. The LGC object catalogues will be an invaluable resource for further spectroscopic and kinematical studies with 8-m telescopes.

Name	RA (2000)	Dec (2000)	Type	D (kpc)	Size[a] (′)	M_V	m_V[c] (OB)	m_{5007}[d] (PN)	WFC Fields	Bands[f]
WLM	00 01 58	−15 27.8	IrrIV-V	940	5	−14.0			1	n, b
IC 10	00 20 25	+59 17.5	dIrr	820	5[e]	−17.6	18.5		1	n, b
NGC 147	00 33 12	+48 30.5	dSph/dE5	589	20	−14.8			2	n, b
NGC 185	00 38 58	+48 20.2	dSph/dE3p	620	16	−15.3			2	n, b
NGC 205	00 40 22	+41 41.4	E5p/dSph-N	725	6	−16.3			1	n, b
M 32	00 42 42	+40 51.9	E2	725	9	−16.4			1	n, b
M 31	00 42 44	+41 16.1	SbI-II	725	> 150	−21.1	16.3	20.3	∼100	n, b
LGS 3	01 03 53	+21 53.1	dIrr/dSph	810	15	−10.5			2	n, b
IC 1613	01 04 54	+02 08.0	IrrV	765	11	−14.9	16.5		1	n, b
M 33	01 33 51	+30 39.6	ScII-III	795	∼60	−18.9	16.0	20.7	16	n, b
Fornax	02 39 59	−34 27.0	dSph	131	71	−13.0	18.8		4	n, b
EGB0427+63	04 32 01	+63 36 24	BCD/dE			−10.9			1	b
Leo A	09 59 24	+30 44.7	dIrr	270	4	−11.7	18.7		1	n, b
Sextans B[b]	10 00 00	+05 19.7	dIrr	1300	4	−14.3			1	n, b
NGC 3109[b]	10 03 07	−26 09.5	dIrrIV-V	1260	13	−15.8			1	n, b
Leo I	10 08 27	+12 18.5	dSph	250	13	−11.9			1	n, b
Sextans A[b]	10 11 06	−04 42.5	dIrr	1450	4	−14.4	18.5		1	n, b
Leo II	11 13 29	+22 09.2	dSph	205	9	−9.6			1	b
GR 8	12 58 40	+14 13.0	dIrr	2200	1	−11.6	18.5		1	n, b
Ursa Minor	15 09 11	+67 12 52	dSph	65	50	−8.9			4	b
Draco	17 19 58	+57 50 05	dSph	72	28	−8.6			2	b
Sagittarius	18 55 03	−30 28.7	dSph-N	24	> 600	−14.0		∼14	∼30[g]	n, b
NGC 6822	19 44 56	−14 48.1	IrrIV-V	540	40	−16.4	16.5		4	n, b
DDO 210	20 46 51	−12 50 51	dIrr	950	2	−10.9			1	n, b
Pegasus	23 28 34	+14 44.8	dIrr/dSph	759	4	−12.7	18.5		1	n, b

Table 1: Notes: [a]tidal radius in arcmin, [b]van den Bergh (1999) indicates that these are members of a small group of galaxies just external to the Local Group, [c]brightest OB star mag, [d]brightest PN mag., [e]> 60 arcmin H I envelope, [f] 'n': narrow band filters: [O III], He II, Hα, [S II], StrY, 'b': broad band filters, g′, r′, i′, [g]because of confusion with the Galactic Bulge only regions of Sagittarius will be observed. (Compilation mainly from Mateo (1998).)

Target Galaxies and Exposure Request: The following galaxies will be observed, most in the the narrow and broad band filters listed in Bands[f]. Exposures are 60 minutes/narrow filter and 30 mins/broad filter. The total time request is for **840 hours ≡ ∼12 weeks** over three years.

[1]A proposal in response to the 2nd announcement of opportunity for: Large Scale Imaging Surveys with the INT Wide Field Camera

Scientific Justification — The Local Group Census:

All galaxies within ∼1.25 Mpc of the Local Group (LG) barycenter (Corteau & van den Bergh, 1999) are probably LG members. The LG is composed of two giant spirals, the Galaxy and M 31, each dominating their related subcluster of mainly dwarf spheroidal galaxies. The dwarf irregular galaxies are found to be more randomly distributed through the LG (van den Bergh, 1999).

The LG provides a unique sample of galaxies covering a range of luminosities and metallicities, the study of which provides key linkages to issues of star formation histories, galaxy evolution and formation and chemical enrichment processes occurring at higher redshifts. Much observational data has been obtained on the LG galaxies, e.g. recent reviews by Mateo (1998) & van den Bergh (1999, 2000). However, only with the recent advent of wide field cameras is it possible to attempt a systematic census of all LG galaxies.

Our proposed Local Group Census (LGC) will target all populations exhibiting strong emission lines, e.g. planetary nebulae, H II regions, symbiotic stars, supernova remnants, luminous blue variables, Wolf-Rayet's. The LGC will focus on a deep narrow band survey of all the LG galaxies (to M_V −14, with a few fainter) visible from La Palma, thus excluding the LMC & SMC. The Milky Way will not be targeted, although observations of the Sagittarius Dwarf will include portions of the Galactic Bulge.

In addition, the broad band r′ data (the off-band for Hα, [S II]) will be supplemented with g′ & i′ to study the resolved stellar populations, to compare and contrast with the emission line populations (e.g. OB→LBV→WR, RGB→AGB→PN). Spectroscopic follow-up for these projects will be particularly suited to the AUTOFIB2 multifibre spectrograph at the WHT, and to the GMOS multislit system on Gemini.

The potential of the LGC as a resource in studying galaxy & stellar evolution is illustrated by some examples:

Planetary Nebulae: **Bands:** [O III], He II, Hα, StrY, r′

Four planetary nebulae (PN) are known in the dwarf spheroidal companions of the Milky Way; three in Sagittarius (Walsh et al, 1997; Walsh et al. 2000) and one in Fornax (Danziger et al. 1978); one in the dwarf irregular (NGC 6822) and many in M 31 and its dwarf spheroidals (Ciardullo et al. 1989; Jacoby & Ford 1986) and in M 33 (Magrini et al. 1999). However there has never been a systematic deep survey for PN in LG galaxies. Since PN arise from the common low mass (1-7$M_\odot$) stars they are excellent probes of the old stellar population. Their strong emission lines make them ideal test particles for the galaxian gravitational potential with implications for dark halos (e.g. Hui et al. 1995); their numbers provide a probe of the star formation history through the specific frequency and, for large galaxies, a distance indicator through the PN luminosity function; their alpha-element abundances (O, Ne, Ar, S, etc, but not C) remain almost unchanged through the stars lifetimes, and so the nebular abundances can provide the abundances for the PN progenitor stars (e.g. the chemical content of the host galaxies some Gyrs ago).

A deep survey on the brightest PN emission line ([O III] 5007Å) will provide a well defined catalogue (positions and fluxes) of PN within 1 Mpc (m_{5007} up to 25 mag, with a completeness limit ∼3 mag below the PNLF peak luminosity). An off-emission image (Str y, c.f. Magrini et al. 1999) allows distinction of the PN from emission line stars. An Hα image will then will allow us to estimate the excitation class of the candidate PNe, and to distinguish them (in a statistical sense) from high-excitation, compact H II regions.

Symbiotics: **Bands:** [O III], Hα, StrY, g′, r′, i′

Symbiotic binary systems show the most energetic stellar explosions after SN, and have been postulated as possible progenitors of Type Ia SN (Munari & Renzini 1992), and are believed be responsible for the formation of highly aspherical PN (cf. Mastrodemos & Morris 1999, Corradi et al. 1999).

Using the same narrow band filters as for PN, as well as a red broad band filter, a number of symbiotic stars are expected to be detected in LG galaxies. The red filter (i′) will highlight the bright red continuum from the cool, giant stars of these binary stars (Kenyon 1986),whose circumstellar nebulae are characterised by strong Hα, and often also [O III] emission (e.g. Mikolajewska 1997). Note that this will be the first detection of symbiotic stars outside of the Galaxy, the Magellanic Clouds and the Draco dwarf galaxy (Mürset et al. 1996). The information that we aim to obtain is similar to that for PN: number counts, distribution, positions as input to future spectroscopic studies.

H II Regions: **Bands:** [O III], Hα, [S II], StrY, r′

Narrow band imaging of the LG galaxies in individual emission lines from their ISM will mark a valuable step between Galactic observations and those in more distant galaxies. This will enable the combination of well resolved line mapping of individual H II regions with studies of complete H II region populations.

Deep images in Hα will enable the luminosity functions of H II regions to be determined, comparing them for the different objects, and measuring down to lower limiting luminosities (c.f. Hunter et al. 1993). This will break new ground for external galaxies, and with unprecedented accuracy in luminosity and structure of individual regions. Further the emission measure of the diffuse ionized gas, will be studied as a function of geometrical relation to the H II region population (Zurita et al. 2001). The complementary deep images in [O III] will provide, for the first time in a systematic survey, the [O III] luminosity functions for the LG galaxies. We would expect to find a single power law for the LF at increasing luminosity rather than a bi-linear law found for Hα, since [O III] should not show density bounding effects (McCall et al. 1985).

The [S II]/Hα ratio provides a practical measure of the hardness of an ionizing radiation field (see e.g. Reynolds et al. 1999). Its value within the H II regions will be compared to that in the diffuse component at different distances from the major H II regions. Very detailed work on abundance gradients across the faces of galaxies will be possible using combined calibrated images in [O III] and [S II] (Diaz et al. 1991).

Massive Stars: WR's, LBV's, OB stars, supergiants: **Bands:** He II, Hα, [S II], StrY, g′, r′

The luminous star content of galaxies is intimately related to the occurance and appearance of H II regions. They are also important contributors to a galaxy's chemical and dynamical evolution (Smartt et al. 2000). Nevertheless their evolution is still poorly understood, although it is clear that the role of metallicity is crucial. The evolved descendants of massive OB stars are Luminous Blue Variables (LBVs) and Wolf-Rayet's. These more exotic massive stars are much rarer, due to the short lifetimes of these states, however they are the keys to understanding how massive stars evolve. LBVs are particularly important as they are transition objects undergoing catastrophic mass-loss events as they evolve into WR stars (e.g. Drissen et al. 1998). While a subset of Local Group galaxies have previously been surveyed for WR stars, these are without doubt far from complete in galaxies with large angular sizes, M 31 and M 33. The LGC will also detect much rarer LBV's, since these are unique in showing strong Hα emission without [S II].

It is therefore extremely important that an accurate census of OB, WR and LBV stars be carried out in nearby star-forming galaxies to enable statistical constraints to be put on their relative lifetimes (Massey et al. 2000, Massey & Johnson 1998) Since massive star evolution also depends on metallicity, which WR star counts reflect, performing this census in regimes of vastly differing metallicity (0.1–$2Z_{\odot}$) is extremely important. In fact, the ratio of blue to red supergiant stars is an extremely sensitive test of mixing and convection processes in stellar models (Massey 1998).

Supernova remnants (SNRs): **Bands:** Hα, [S II], r′

SNRs are of major importance to the evolution of their host galaxy. They are the primary source for heating and enrichment of the interstellar matter, for production and acceleration of cosmic rays, for shock induced star formation in molecular clouds, and for the formation of neutron stars and black holes.

In the Galaxy, of the 225 known SNRs only $\sim$30 have well-known distances (Green 2000). Limited Hα emission studies have been carried out to catalogue SNR's in M 31 (Braun & Walterbos 1993). The more extensive observations of the disk of M 31 (Magnier et al. 1995) suffered from poor limiting sensitivities and spatial resolution. Many of the 53 SNR's known in M 33 (Gordon et al. 1999), are embedded in H II regions, indicative of Type II SN precursors. Of the smaller dwarfs a SNR at the centre of NGC 185 was recently confirmed by Martinez-Delgado et al. (1999). The limitations in the studies above makes its obvious how our knowledge of the field would take advantage of a systemic survey of SNR in the LG galaxies.

Old Stellar Populations: **Bands:** g′, r′, i′

A wide-field imaging survey of the extended halos of nearby dwarf galaxies will be extremely useful to determine the spatial extent of the **red giant branch** population (the "Baade's sheet", Baade 1963).

The LGC will provide information which extends much further than previous, small-field CCD imagery, and to much fainter magnitudes than older photographic surveys. For the first time we can see how closely the stellar distribution matches the gas (H I) distribution. We will be able to determine a lower limit on the mean and the spread of the metallicity of stars to the outer limits of these galaxies from colour-magnitude diagram (CMD) analysis, and look for variations with the inner regions, well studied on the small scale for all these systems. Metallicity variations will be contrasted with those from e.g. PN (c.f. Walsh et al. 1999). Possible variations in the spatial density of the red giant population will indicate tidal tails.

The broad-band CMDs will be deep enough to allow detection of candidate **AGB stars** and to determine, on a statistical sense, their number size (c.f. Minniti & Zijlstra 1997; Martinez-Delgado et al. 1999). The size and luminosities of the AGB population will provide a direct link with their progeny, PN, and allow us to discuss evolutionary timescales, progenitors and core masses, such analysis is prevented in the Galaxy by the large uncertainties in the individual distances.

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Figure 1: The central region of M 33 (E top, N left, $\sim 60'$ N-S) in Hα, [O III] and StrY, shows the abundance of emission line objects to be found in this galaxy (Magrini et al, 2000). The LGC will cover M 33 to greater depths, and cover more area, including all the halo.

Exposure Times:

The total exposure times per filter are listed in Table 2. Each will be split into **3** exposures, a small dither being applied between each to aid in removing detector artifacts. Overheads on the WFC are now ∼1 minute between each exposure (of which ∼30 seconds is due to readout). One WFC image covers ∼0.27 degrees^2. For all the filters ∼6 hours is required per field.

A range of sky brightness is requested. The broad band g′ and r′ observations would be carried out dark of moon, with i′ with moon in grey periods. The narrow band imaging will require a mixture of primarily dark (for e.g. [O III] 5007Å imaging of the halo of M31) and grey (for e.g. the disk/core of M31 and nearby dwarfs (e.g. Sagittarius)). We request a moon phase distribution of 60:40, dark:grey.

In the 'A' semesters we request an allocation of 9 nights, whilst 19 nights are required per 'B' semester. In total we ask for 28 nights/year thus, assuming an average 10 hrs per night, some 840 hours over the three year period. This enables ∼**140 fields** of ∼0.27 degree^2 to be observed (assuming some overhead for std field observations), completing the targets listed in Table (assuming that a small number fields are only observed in broad band filters). We note that a Vi′ data set of ∼50% of the halo of M 31 has recently be taken at the INT and this will become available (Irwin, private communication). Thus, the i′ data will not need to be duplicated here for this area.

Table 2: Filter List and Exposure Times assuming 1 arcsec seeing

Waveband	Detection limit (mag)	Exposure Time (seconds)	Notes
He II	∼25.5	3600	s/n=∼10 (dark), ∼5 (grey)
[O III]	25.5	3600	s/n=∼10 (dark), ∼5 (grey)
Hα	∼25.5	3600	s/n=∼10 (dark), ∼5 (grey)
[S II]	∼25.5	3600	s/n=∼10 (dark), ∼5 (grey)
StrY		1800	
g′	25.0	1200	5σ
r′	24.5	1200	5σ
i′	24.0	1200	5σ
Total exposure time/field in all filters: ∼6 hrs			

These limits are obtained from experience with the Wide Field Survey data (http://www.ing.iac.es/WFS) and use of the ING's `signal` program. For 0.7 or 1.5 arcsec seeing add or subtract respectively 0.4 mag. The narrow band magnitudes are equivalent V magnitudes. For instance, $m_{5007} = -2.5 \log F_{5007} - 13.74$ (Jacoby, 1989, ApJ 339, 39)

Choice of Filters:

The filter selection has been optimised for the detection of strong emission lines. In order to extract the underlying continuum from the narrow band data, an off-band continuum image will be subtracted from the on-band image. StrY will be used to correct the He II and [O III] data, with r′ used for the Hα and [S II]. Value is added (at little additional cost in exposure time) with the inclusion of g′, i′. This enables direct study of the stellar populations directly related to the young (e.g. LBV) and old (e.g. PN) populations from the emission line data.

Calibration Frames:

Astrometry, which will be made by reference to APM and USNO catalogues will give positional accuracies of ∼0.1 arcsec (internal) and ∼0.3 arcsec (absolute).

Broad band photometry will be from Landolt standard star field observations (using the system established during the 1st round of WFS programmes - see e.g. http://www.ast.ca.ac.uk/ wfcsur/photom.html) carried out on photometric nights. Experience from existing WFS data shows that absolute photometry to 1% is possible, with relative milli-mag accuracy being obtained. The calibration of the narrow band filters will be made by observing small galactic PN standards or spectrophotometric standards.

Poor seeing policy: a long period optical variability programme.

If the 'seeing' degrades to poorer than ∼1.5 arcsec, these fields will marked for be re-observation. For 'poor seeing nights' a number of nearby dwarf fields will be re-observed, in order to search for long period variables such as Mira's (which have I-band brightnesses at peak of 22 at 1 Mpc and periods between 300–500 days).

Data Analysis and Division of Scientific Intepretational Responsibilities

Observing Strategy: This programme is envisaged to have a duration of **three years** — this determined by the weighting of the target fields towards the 'B' semester to ensure coverage of the extended targets M 31 and M 33 at ∼0 hours RA. Each field list in Table (with some caveats, for instance only ∼30% of Sagittarius will be observed because of it's large extent and contamination by the bulge) will be observed in each filter to the depths listed in Table 2. Image quality of better than ∼1.5 arcsec will be required to ensure that a sensitivity within 50% of our estimates is achieved.

The observations will be carried out by an experienced survey observer (provided from on-island staff or co-I's) assisted perhaps by a student for training purposes. It is envisaged that this programme could naturally be incorporated into any eventual queue observing system that the ING may initiate. Also, it could easily be merged with, for instance monitoring programmes, such as the current (1999B, 2000B) UK/AGAPE/MACHO M 31 micro lensing project. A yearly review of progress is foreseen.

Data Processing and Quality Control:

Preliminary data processing will occur on La Palma, making use of ING's WFC data calibration pipeline. This is based on the pipeline developed for the WFS at CASU and the ING (see e.g. Irwin & Lewis, 2000) and will run on the ING's new dedicated Gigawulf cluster (Walton et al, 2000). The pipeline includes preliminary processing (linearity corrections, bias and flat field corrections), fringe corrections, astrometry, and photometry. This will produce 'survey quality' data products. These will be stored locally on the ING's DVD-Tower system (total capacity currently ∼6 TB) and mirrored at CASU, IoA for easier UK/NL access.

The pipeline will run on a nightly basis and provide near-real time quality control data (such as delivered image quality, zero points, detector noise, etc). We will implement a quality assurance framework to ensure that the QC data is optimally employed in the delivery of image data to the required uniform level (image quality, limiting magnitude etc). Full progress reports and data distribution will be provided on-line through the WFS project WWW pages (http://www.ing.iac.es/WFS and http://www.ast.cam.ac.uk/∼wfcsur).

Data Products:

The focus when providing LGC data products will be in providing a uniform, reliable and accessible resource for the astronomical community.

In addition to the expected near-real time standard WFS data products (raw, calibrated and object catalogues), the LGC will produce additional added value catalogues of e.g. emission line maps, PN catalogues for use in follow-up spectroscopic studies (kinematics as probe of galaxy potentials, abundances for chemical enrichment histories).

We will also create large sample of stars for spectroscopic follow-up with 8m-class telescopes to determine accurate abundances and radial velocities of stars in the outer halos of these small dwarf galaxies. This will have interesting implications for the study of enrichment history and dark matter in these small, gas rich systems.

The LGC team includes key members with data processing and dissemination expertise (e.g. Irwin, Walton, Skillen, Greimel) who will have prime responsibility for ensuring that data products are rapidly made available to the wider community. Irwin is Director of CASU, Greimel (ex-CADC) is project manager for the ING data processing and Beowulf cluster, Skillen (ex-IUE) was responsible for the new IUE data distribution system, Walton is programme manager for the WFS.

Analysis and Interpretation:

The division of the applicants scientific interests among the specific projects is as follows:

Planetary Nebulae :	Corradi, Magrini, Perinotto, Pollacco, Walsh, Walton, Zijlstra
H II regions & SNR :	Beckman, Bryce, Cardwell, Zurita
Symbiotic Stars :	Corradi, Pollacco, Walton
Massive Stars :	Crowther, Lennon, Smartt, Smith
Galactic Structure :	Irwin, Peletier, Tolstoy, Zijlstra

As overall programme co-ordinator, Walton will ensure the smooth flow of data products to the science teams. It is envisaged that each team will be responsible for the scientific exploitation of the data within their field. Synergy between the fields will be promoted via bi-annual LGC workshops.

It is anticipated that the LGC will provide a valuable data set for external users. The LGC data complements both existing 1st round WFS datasets, by targeting the local universe, in fields and emission line filters not previously covered, and other wavelength (e.g. 21cm) survey data. **The LGC will be a unique resource.**