	Australian Time Allocation Committee **Proposal for AAT Time**	**Semester:** 2022A **Reference:** A/2022A/1019 **Submitted:** No

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The Hector Galaxy Survey

The Hector Galaxy Survey aims to investigate the influence of environment on galaxy evolution with more precision than has ever been possible with previous or existing integral field spectroscopic (IFS) galaxy surveys. The uniqueness of the Hector Galaxy Survey lies in the combination of large integral field units, called 'hexabundles' giving resolved spectra across a larger field of view in each galaxy, and the highest spectral resolution of any large IFS instrument. This will enable us to determine the role of detailed large and small scale environment on how galaxies accrete material to form stars and build their angular momentum. We request 50 Hector nights and 9 2dF nights for the second semester of the Hector Galaxy Survey.

	Dark	Grey	Bright
Total number of calendar nights requested this semester	**50**	**9**	**0**
Minimum useful allocation this semester	**30**	**2**	**0**
Additional nights required to complete project in future	**540**	**0**	**0**

Number of nights already awarded to this project: 0

Type of proposal (open or paid): Open

Are these full nights: No

What part of the night is required: Other

Remote Observing: No

Target of Opportunity: No

Long term status: Yes

Large program request: No

Preferred dates:	**Earliest**	**Latest**
	01 Feb 2022	31 Jul 2022

Impossible Dates:

Special scheduling constraints: The portion of the 2dF nights in Feb are requested in case the AAOmega intervention delayed. Hector observations not affected.

Instrumentation

Instrument 1: AAOmega + 2dF

Gratings:	580V, 385R
Central Wavelengths (Ã…):	4800, 7250
Blaze Wavelengths (Ã…):	4800, 7250
Beamsplitter:	570nm dichroic
Nod & shuffle:	No
Originating catalogue used for astrometry of targets:	DES
Do guide stars and targets share the same catalogue astrometry?:	Yes
Other requirements:	

Instrument 2: Visitor Instrument

Instrument Name:	Hector - not actually a visitor instrument but not listed in the instrument list until after commissioning this se
Focus:	Prime f/3.3 doublet
Director's permission:	Yes
Other requirements:	

Related proposals (in this semester)

Telescope/satellite	Title of the proposal

Previous related proposals

Reference	Title	Allocation	Percentage useful	Comments (Data ok? publications? etc.)
A/2021B/13	The Hector Galaxy Survey	23n	n/a	
A/2020A/17	Probing the outskirts of rich galaxy clusters: where and when is star formation quenched?	0	n/a	
A/2020B/24	Probing the outskirts of rich galaxy clusters: where and when is star formation quenched?	7n	50%	Heavily weather affected.
A/2021A/15	Probing the outskirts of rich galaxy clusters: where and when is star formation quenched?	0	n/a	

Description of the proposal for the general public

Where a galaxy grows up in the Universe can influence what it turns out to look like, and how it spins. Whether a galaxy is within large scale structures such as filaments or massive clusters, or on its own in voids can set how easily it can accrete stars and gas to grow in size and angular momentum. Using the new Hector instrument on the AAT, we working on what will be the largest '3-D' survey in the world, giving a spectrum at many points across each of 15,000 galaxies. The high resolution of the new Hector instrument and large field of view across the galaxies means we can measure not only the galaxy compositions but the rotations and dynamics in their gas and stars as well. This is crucial to understanding how galaxies grow.

1 The Hector Galaxy Survey Science Case

The ATAC Chair has granted an extra two pages for this proposal to outline the big picture of the full Hector Galaxy Survey (Hector-GS) as well as the focus of the 2022A semester. Hector commissioning has been delayed by the current COVID lockdown and Hector will be commissioned with observations scheduled in Dec and Jan (COVID permitting).

1.1 The Hector-GS Overview

What is the physical basis for the diversity of galaxy properties in the local Universe? This is the overarching science question driving the Hector-GS. The answer lies in connecting the internal properties of galaxies to the detailed role of their environment. For the Milky Way, accretion from and interactions with satellite galaxies have shaped our galaxy. In extragalactic studies there has been a paradigm shift from local and global density-based environment properties to defining environments based on both large-scale structure (filaments, walls, nodes) and where galaxies sit in velocity space. The unique capabilities of the Hector instrument will enable us to tackle this question with the data that cannot be achieved with any other survey. The large survey size and spectral resolution that is a factor of two better than any other comparable instrument, will explore from the high to low-mass end of the stellar mass function with exquisite environmental characterisation. The Hector-GS plans to observe 15,000 galaxies over 6 years, providing a ground breaking data set that maximises the science productivity of the remaining life of the AAT.

The legacy of the Hector-GS will lie not only with the vast and rich data set produced by the survey, but in unique science that cannot be done with any other instrument in the world. SAMI [10, 5, 12] and MaNGA [8] have been the largest IFS surveys to date. However, they lack a combination of the higher spectral resolution which enables stellar kinematics to be measured in a larger fraction and broader diversity of galaxies; the broad range in halo masses required to test the influence of environment, including mapping the large cluster halos out to higher cluster radii; larger IFUs to give resolved spectra of galaxies to a larger galaxy radius; and a larger sample that will allow the key drivers of galaxy evolution to be statistically determined by sub-dividing the sample in physical parameter space with sufficient statistical accuracy.

The Hector-GS has optimised the science synergies with other large Australian projects. The ASKAP WALLABY [16] and DINGO (https://dingo-survey.org/) surveys will combine their HI data with the Hector-GS to link gas accretion mechanisms and total gas masses from the inner galaxy to the scales probed by HI observations. A group of simulators are already active in the Hector science team, focused on a range of fundamental questions that can be addressed with the Hector-GS regarding the impact of large-scale structure on galaxy evolution. The Hector-GS regions have been selected to be within the ESO 4MOST WAVES North and South sky areas, which will provide exquisite environmental metrics to confirm the place of our galaxies within local and large-scale structures as well as their kinematic flows (https://wavesurvey.org/).

The Australian community selected the Hector instrument as the next dark-time instrument for the AAT. Membership of the Hector science team is open to all astronomers working in Australia. The data will deliver a vast array of science to the already 62-strong Australian Hector team, drawn from across the country from 8 Universities plus the CSIRO. The team builds from the SAMI IFS team and is expected to outgrow the 140-strong SAMI team once the survey is collecting data.

Here we request the second observing semester of the Hector-GS. We will apply for a large program once the instrument is fully commissioned (scheduled from December 2021 to January 2022). The main part of the current proposal focuses on observations with Hector that continue the full survey, but also enable a number of short term science goals. However, we also request nights with 2dF to complete the redshift measurements for the Hector-GS input catalogue. This relatively small investment is important to enable an unbiased input catalogue and to optimize Hector observations.

1.2 Key science goals

(A) **How is the accretion of gas and angular momentum (spin) influenced by local and global environment?** Cosmic structures over the mega-parsec scale, such as cosmic filaments and clusters where they intersect, strongly constrain the flows and thermodynamics of baryons in their vicinity. Simulations and theory predict that this impacts the accretion onto galaxies, and therefore their spin, structure and more generally their dynamics. The world-leading Australian surveys WALLABY and WAVES (2023+) will map galaxies and their peculiar velocities in the local Universe with unprecedented detail. They will locate the Hector galaxies both in 3D space and dynamically within cosmic flows, permitting the most extensive analysis of correlations between large-scale structure morphology and galaxy-scale dynamics.

SAMI demonstrated the feasibility of such studies through the first detection of the alignment of galaxy spins with filaments [29], but the limited statistical power capped the significance of the results at $\approx 2\sigma$. It also precluded any analysis of cosmic walls, any multivariate analysis (field filaments, filaments in groups, filaments in clusters) and any detailed analysis of the corresponding kinematic disturbances in the outer parts of galaxies. With its increased sampling, wider field of view and wider covering of clusters up to $2\,R_{\rm vir}$, the Hector-GS will allow for a deep analysis of how filament/wall, filament/group and filament/cluster interactions impact galactic inflows, spin and structure. Such studies are very timely. Modern simulations predict for instance that cluster outskirts $(0.75 - 2\,R_{\rm vir})$ are regions of multiple transitions, strongly impacting the structure of galaxies (see Fig.1, left panel). It's where satellite galaxies are expected to progressively align their orbit and spin to the central galactic plane, while aligned to the nearby cosmic filament at outer radii [28, 27]. While the orbit transition was detected in the SDSS [30], the spin counterpart requires the power of the Hector-GS.

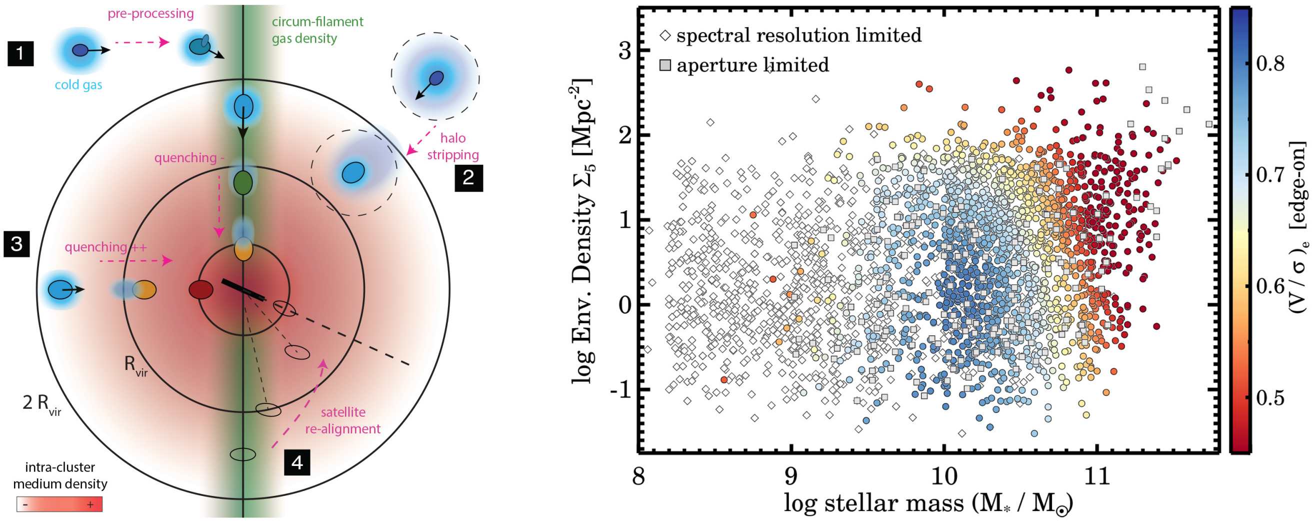

Figure 1: Left panel: Simulations predict the way filaments from large-scale structure and cluster outskirts cause transitions in galaxy evolution. 1- Large filaments (vertical line with gas density in green) re-orient inflows, disturb the plane of a galaxy and have a higher merger rate than the field. 2 - Accretion in cluster outskirts deplete outer gas reservoirs of infalling galaxies. 3- Clusters increase quenching through stripping and strangulation but these processes are reduced in intra-cluster filaments. 4- Satellites re-orient their orbit and spin in clusters. Dominant mechanisms are expected to differ depending on galaxy mass *Adapted from [28, 17].* The Hector-GS will have the statistical power and range of environments to robustly test these processes. **Right panel: The impact of stellar mass and environment on the dynamical properties of galaxies.** SAMI successfully revealed the key drivers of dynamical galaxy transformation of *all* morphological types [26]: towards higher stellar mass and denser environments, galaxies transform from being rotationally supported to dispersion dominated. However, non-coloured points indicate galaxies for which SAMI's spectral resolution (diamonds) and limited bundle size (squares) hamper kinematic measurements for low mass and high-mass galaxies. *The Hector-GS will open up these largely unexplored regimes.*

(B) **Tracing the mass accretion and dynamical evolution of galaxies through utilising Hector's spectral resolution.** The SAMI Galaxy Survey was the first to clearly demonstrate the impact of environment on the stellar-dynamical properties of galaxies (e.g., Fig. 1, right panel). The largest dynamical change is detected for the most massive galaxies ($\log(M_\star/M_\odot) > 11$) in the most extreme environments. Between $9.5 < \log(M_\star/M_\odot) < 11$ the dynamical transformation as a function of both mass and environment is significantly smaller [9, 11, 26]. In this regime, a factor > 5 increase in sample size is paramount to understand what physical processes determine a galaxy's morphology and dynamical structure. Nonetheless, the highest impact science is expected to come from the mass regimes currently out of reach of SAMI. Towards low stellar mass (Fig 1, right panel), there are hints that galaxies become more dispersion dominated [see also 13, 23, 2, 3], but this mass regime is currently below SAMI's spectral resolution. The higher spectral resolution of Hector will enable stellar kinematic measurements in a wider range of galaxies than any other survey. Similarly, for the most massive galaxies in extremely dense cluster environments, SAMI's current bundle size restricts measurements to the very core of these galaxies, when the vast majority of accreted material and transformation is predicted to take place at larger radius[$> 2R_e$; 22, 4, 21]. It is in these low and high-mass regimes where the Hector-GS will lead to a breakthrough.

Hector will also revolutionise our ability to measure higher-order kinematic signatures that offer a complementary yet unique insight into the orbital structure of galaxies. Measurements from SAMI have resulted in well-cited results for high stellar mass galaxies [25], but the Hector-GS will probe the stellar kinematics of the low-stellar mass population in large numbers for the first time. Detailed Schwarzschild's orbit-superposition models have now demonstrated that higher-order kinematic signatures can efficiently and accurately detect orbital substructures (e.g. counter rotating bulges) without the need of full dynamical modelling [20]. The Hector-GS will yield an unprecedented large sample of galaxies ($N \sim 4000$) where higher-order kinematics can be measured, across stellar mass, morphology, and environment that will enable detailed comparison to simulations [e.g. 19, 22] that relate galaxy formation models to the stellar kinematics, to unravel the formation paths of galaxies as drivers of their present-day physical properties.

(C) **Directly identifying feeding and feedback in galaxies**. The Hector-GS will evaluate the balance of gas supply for star formation in all environments by imaging outflows from kinematic signatures and emission line diagnostics of shocks and AGN. While a limited number of galaxies had the right size and orientation in the SAMI survey to identify galactic winds and outflows [14, 15, 18], the larger IFU imaging fibre bundles called 'hexabundles' and survey strategy in Hector allow for the gas kinematics to be traced to higher effective radii within each galaxy. This, in turn, better captures the velocity structure, including the maximal rotational velocity, and the subtle signs of inflows, outflows and re-accretion at large radii, for a much larger fraction of emission-line galaxies. Our modelling has shown that the higher spectral resolution in the blue will enable multi-component line fitting and distinguishing of AGN outflow signatures in the [OIII]500.7nm emission line, which are ambiguous with the lower resolution IFS surveys.

(D) **Testing the origin of gas and its influence on star formation in galaxies.** The kinematic misalignment of gas and stars is a key tracer of the origin of gas and the impact of gas accretion and mergers on star formation and the build-up of mass. It has been shown with SAMI [6] that the larger IFU size in Hector is needed to map the merger signatures and in-coming accretion from larger radius, which is necessary to constrain galaxy formation models.

The broad interests of the Hector Science team met by this survey also include i) spatially resolving star formation rates, metallicities and stellar ages; ii) tracing galaxy star formation histories from stellar populations; iii) separating the formation histories and mechanisms for the disk and bulge components of galaxies and much more.

1.3 Survey Design and Target Selection

Target selection for the Hector-GS will follow a similar philosophy to that of the SAMI galaxy survey, using a selection function described by a series of steps in the redshift – stellar mass plane (see [5] for details). To avoid an overabundance of L_*-mass galaxies, we will sparsely select in the mass range $\sim 10^{10} - 10^{11}\,\mathrm{M}_\odot$. The final target selection will select 15,000 galaxies at $z \leq 0.1$.

The need for 15,000 galaxies has been carefully set by simulations and experience with the SAMI data. This will be fully explained in the long-term proposal for the full survey. While SAMI detected the first signature of galaxy spin alignments with cosmic filaments [29], the significance was limited to $\approx 2\sigma$ and precluded more detailed analysis. We have determined that with 15,000 galaxies over a wider area, the Hector-GS will not only provide a robust confirmation of this result but will also allow for ground-breaking studies of how galaxy kinematics correlate across the hierarchy of large-scale structure. The wider field of view, covering the outskirts of many of these galaxies, will allow us to integrate properties of galactic-scale inflows, thought to be the missing link between large-scale and galactic scale dynamics, into this analysis.

The Hector-GS will be comprised of a "field" and a "cluster" sample in order to observe galaxies from a range of environmental densities. The field sample will be in two regions: one in the north galactic cap at $\delta \simeq 0°$ (with known redshifts from SDSS, 2dFGRS and GAMA); and a second at $\delta \approx -30°$ in the south galactic cap (with known redshifts from 2dFGRS). These are the "WAVES North" and "WAVES South" fields that will be observed with unresolved single-fibre spectroscopy using 4MOST as part of the upcoming WAVES survey from 2023. The alignment of the Hector Survey to these WAVES fields enables the environmental and large-scale structure information from WAVES which is essential to the key science cases for the Hector Survey. Photometry for the target selection is based on deep optical KiDS imaging.

The Hector-GS field sample will probe a significant range in environmental densities, from the lowest density voids all the way to the centres of low mass clusters. However, the Hector-GS field sample volume does not contain rare massive clusters ($M_{200} > 10^{14.5} M_\odot$). To sample the full range in environment density, the Hector-GS will observe an additional 11 galaxy clusters with $M_{200} > 10^{14.5} M_\odot$, which have existing high-quality optical *griz*-band imaging from the Dark Energy Survey [DES; 1]. The Hector-GS will go beyond the cluster science possible with SAMI by covering the cluster outskirts, out to twice the virial radius. This will bridge the density regimes of field and cluster galaxies. These intermediate density regions are a crucial environment for the morphological transformation of galaxies. Thus, the Hector-GS will be the first IFS survey that truly covers the full range of environmental densities, allowing for the most comprehensive investigation of environment-driven galaxy transformation to date.

The 2022A semester Hector observations will focus on sub-regions in the WAVES North field. The GAMA G12 and G15 regions are within WAVES North. The SAMI Survey observed 80% of the G12 and G15 fields but excluded a band in Declination at the edge of each of those regions. We will begin the survey in the WAVES North region with those missing declination stripes because: (a) it allows rapid science by combining Hector data to SAMI data to extend linked structures in those regions, and (b) within the same new field tiles, there is opportunity to repeat a small number of targeted science objects from SAMI (see justification below) within the tiles of new galaxies. The GAMA regions have the complete redshift coverage needed for the Hector Survey selection, and the remaining WAVES North regions have redshifts from SDSS as well as photometry already compiled by the WAVES team to form the Hector input catalogue.

In addition to the WAVES North field, we will use the Hector instrument to target 9 of the Hector-GS clusters; the clusters have sufficient redshift coverage for target selection in 2022A. However, the redshift depth and coverage in the cluster regions is not sufficient for future semesters and the precise environment metrics required to meet our science goals (sub-group detection, local density, projected phase-space definition for robust cluster membership). These environment metrics require $\Delta cz < 100\,\mathrm{km/s}$, which cannot be obtained with photometric redshifts. In 2022A we therefore also request 2dF time to measure redshifts for remaining targets to 19.5$^{\mathrm{th}}$ magnitude in the r-band in all 11 Hector-GS clusters. This will provide complete redshifts for the Hector-GS targets and for galaxies a factor of 10 lower in stellar mass, which will probe the environment local to our main targets. Our request is for grey time and, including weather allowances, comprises 5 full nights in late July (7 clusters up for > 1 hour) and 8 half nights in Feb (5 clusters up for > 1 hour; only possible if there is any delay to the AAOmega intervention). This 2dF time will complete the redshift survey of the clusters, which is essential to both target selection and science goals for the cluster portion of the Hector-GS.

1.4 Plan for Semester 2022A

The Hector instrument [7] has 19 hexabundles on galaxies in each field and two that image secondary standard stars for calibration. The Hector-GS aims to target 1195 galaxies in this semester in 50 dark/grey nights, with 2 fields per night and 19 galaxies per field (with weather overhead). During the dark time at the start of March, we have assumed only 12 galaxies per field because we will be observing with one of Hector's two spectrographs during the AAOmega intervention. Our targets this semester are available in every month and are best observed in 8-9 night blocks centred on dark time. To reach 15,000 galaxies, a future request of 100 nights (2,500 galaxies) per year over 6 years is required.

Targets for 2022A will be chosen from the main Hector survey input catalogue, but be specifically chosen to allow key early science results. They will deliver immediate papers on the following 3 science cases, two of which build further on the targeted science from 2021B but have additional advantages in the Northern regions available in 2022A:

(1) **The unexpected dynamics of low-mass dwarf galaxies.** Recent results indicate that both low-mass ($\log(M_\star/M_\odot) < 9.5$) spirals and spheroidals have unusual low ratios of V/σ as compared to more massive galaxies [13, 23], and break away from fundamental galaxy scaling relations [e.g., Faber-Jackson, $M_\star - S0.5$; 2, 3]. Determining the physical cause for low-mass galaxies to be outliers is currently restricted by 1) a bias towards spheroidal galaxies and those with early-type morphology residing in over-dense cluster environments, and 2) limited spectral resolution in the largest IFS surveys (e.g., ATLAS$^{\rm 3D}$, CALIFA, SAMI, and MaNGA). Due to its higher spectral resolution, the Hector-GS will be the first IFS survey to properly measure the stellar dynamics of low-mass galaxies. We will test whether the offset from current dynamical scaling relations is real or whether this is caused by the limited spectral resolution of previous surveys. Building on the 2021B science case, this semester gives the opportunity to constrain kinematics in 56 low-mass dwarfs that had insufficient spectral resolution in SAMI to measure their low velocity dispersion. As these targets lie in the G12 and G15 regions they are alongside the new declination stripes targeted in this semester and can be efficiently interspersed in tiles among the new Hector survey galaxies. We anticipate repeat observations to reach the required depth (typically 2-3 repeats) for these low-mass galaxies will occur within this semester. This will result in kinematics of 56 pre-elected SAMI low-mass dwarf galaxies, along with a further 324 $\log(M_\star/M_\odot) < 9.5$ galaxies in the new Hector Survey regions.

(2) **The Kinematic Properties of Milky Way Analogues.** Despite the wealth of data from our own Galaxy, the origin of its different components – the thin and thick disks, the bulge and bar – remain elusive. Milky Way Analogues (MWAs) offer a unique insight into how our own Milky Way might have formed and bridge the gap between the detailed measurements in our own Galaxy and the predictions from (zoom-in) cosmological simulations. While a number of Milky Way-like galaxies were already identified within the SAMI Galaxy Survey sample [24], the lack of spectral resolution limited a detailed study of the higher order kinematic signatures and orbital distribution within the disks of these galaxies. Hector's higher spectral resolution is ideally suited to determine the kinematic disk properties of Milky Way analogues. Based on the final SAMI Galaxy Survey sample of ~ 3000 galaxies, with Hector we will be able to determine the kinematic properties of ~ 50 galaxies with stellar mass between $10.4 < log M_* M_\odot < 10.8$ with Milky Way disk-like morphology during semester 22A. Similar to (1), we will employ repeat observations to reach the required depth in the disk beyond one $R_{\rm e}$ to measure the higher-order kinematic signatures and link these to their assembly history. Few kinematic studies of Milky Way analogues exist and even with a relatively small sample ($N \sim 50$) obtained in 22A, Hector will be able to make a significant impact in this rapidly growing field.

(3) **Inflows and outflow at large radius.** Using SAMI we found that at least $\sim 40\%$ of edge-on star-forming galaxies show evidence for outflows [15]. More recent analysis using SAMI shows that almost all galaxies have increased velocity dispersion in extra-planar gas, suggestive that winds are much more wide-spread. Hector can make fundamental steps forward in this area for two reasons. First, the higher spectra resolution in the blue part of the spectrum will allow us to decompose all the spectral lines (e.g. Hβ, [OIII]5007) into multiple components to provide much clearer ionization diagnostics. Second, the spatial extent of these outflows was limited by the small fibre bundle sizes of SAMI. With the larger fibre bundles of Hector we will probe much further out, tracing the radial decline of the outflows and their ionization structure. This semester we will intentionally target a set of ~ 40 galaxies that have effective radii larger than the SAMI hexabundles and that are preferentially edge-on galaxies where outflows will be more easily detected in ionised gas to the edge of the Hector hexabundles. This number alone will substantially build on the outflows results from SAMI.

References

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2 Technical Justification

Instrument setup and exposure times: Hector uses two spectrographs simultaneously - AAOmega and Spector (the new Hector spectrograph). In both spectrographs the wavelength range is selected to include [OII]λ3727Å to the [SII] doublet at λ7424Å for our maximum survey redshift of 0.1. Important lines in between are [NII], [OI], [OIII], Mgb, D4000, Fe lines, Hα and the rest of the Balmer series. AAOmega will cover a wavelength range of $3700-5700$Å with the 580V grating giving a resolution of $R \sim 1700$ in the blue arm. The 1000R grating on the red arm will cover $6300-7400$Å at $R \sim 4500$. Spector has a fixed instrumental resolution of 1.3Å from $3727-7761$Å delivering $R \sim 3460$ at 4500Å and $R \sim 5000$ at 6500Å.

Both spectrographs will use the same exposure times because they are observing galaxies simultaneously. The exposures are set to achieve S/N sufficient to measure stellar velocity dispersions out to 1 effective radius, and $H\alpha$ emission line out to 2 effective radii. The Hector-GS pipeline allocates galaxies to the different sized hexabundles and different resolution spectrographs based on a formula that has been extensively modelled to optimise the fraction of each hexabundle that will contain useful data for stellar kinematics and/or emission line physics. The median surface brightness of the Hector-GS galaxies is $r = 22mag/arcsec^2$ at $1R_e$ and the 90^{th} percentile is at $r = 23.65mag/arcsec^2$. Both Spector and AAOmega will achieve that median at a S/N=20/Å unbinned and the 90^{th} percentile at a S/N=5/Å unbinned (higher with binning) in a 4 hour exposure (see plots from the exposure time calculator as presented in the Hector Science document Fig.10] https://hector.datacentral.org.au/uploads/hec-spc-001-science-case-document-v-1-0-signed.pdf). The throughput of the AAOmega instrument and the fibre cable to AAOmega is well characterised from SAMI. The new front end hexabundles will not change the throughput from SAMI. The Spector spectrograph requires a longer fibre cable which entails a slightly higher loss, but was built to optimise for throughput, giving a net similar throughput (which will be compared to the modelled integration time calculator during commissioning).

The 2dF observations will use the 580V and 385R gratings for a spectral resolution or R 1000-1600, sufficient for redshift precision $\Delta cz \sim 20-30$ km/s which is required for cluster membership allocation. $3700-8800$Å includes key optical emission and absorption features required for redshift determination.

Observing strategy:

Hector: One of the Hector hexabundles on each of the Spector and AAOmega spectrographs will be used to measure a secondary standard star for both flux and PSF calibration. The remaining 19 hexabundles will be on galaxies. Each field of 19 galaxies will be observed in a 7-point dither pattern (previously optimised for SAMI) using 30 minute exposures plus calibration overheads for arcs and flat exposures. We will observe an average of 2 fields per clear night (slightly more in winter and less in summer). The complete Hector-GS aims to target 15,000 galaxies in 100 nights per year for 6 years (38 galaxies per night, then accounting for weather overheads).

2dF: Using 2dF, in grey time requires 60 minute exposures for a SNR=9Å^{-1} with 15 minutes for overheads, giving 9 fields per night in July and 4 per half-night in Feb/Mar. To complete the clusters to 95% completeness requires 16,600 galaxies or 47 fields at 350 per field in 5 full plus 8 half nights (allowing for weather).

A full observing preparation pipeline exists for Hector, which tiles the fields using a modified Greedy algorithm to maximise tiling for sky coverage, then calculates positions on the field plate accounting for distortions in the optics, and thermal changes. Next the configuration code sets the 3D rotation of the hexabundles for placement while the collision code optimises positioner magnet placement order and then delivers the observing tile files and plots [7]. We will use the SAMI data reduction pipeline, modified to handle data from the Spector spectrograph, to process all observations. By using a well-established pipeline we will be able to produce publication-quality data cubes immediately after observations take place, allowing rapid turn-around of the data. We are continuing to optimise the SAMI/Hector pipeline, supported by $\sim$ 30k (equivalent value) funding from ADACS, resulting in continuous improvements in the (already excellent) data quality, as demonstrated in the recent SAMI DR3 [12].

A highly qualified team: The Hector Science team has a wealth of experience with observing on the AAT, data reduction of integral field data, and with the instrumentation. This comes from a strong overlap with the SAMI science team members, and senior team members who have used many instruments on the AAT. The observing process for Hector will be similar to SAMI. New observers will be trained throughout the Hector-GS to ensure the team can provide two observers per Hector observing run.

Availability of data: The data is available immediately to team members and will be publicly released over time. We anticipate the first public data release 2 years into the survey once the first 5,000 galaxies are observed and quality controlled. The second data release will be at 10,000 galaxies and the final release at the end of the 15,000 galaxy survey.

Team Expertise

The Hector Science team has a wealth of experience with observing on the AAT, data reduction of integral field data, and with the instrumentation. This comes from a strong overlap with the SAMI science team members, and senior team members who have used many instruments on the AAT. The observing process for Hector will be similar to SAMI. New observers will be trained throughout the Hector Survey to ensure the team can provide two observers per Hector observing run. More than 30 members of the Hector Science team have previous AAT observing experience.

Table 1. Principal Targets

Field Name	R.A (°)	Dec (°)	Median r-band surface brightness (mag arcsec^{-2} at 1 r_e)	2σ range of r-band surface brightness (mag arcsec^{-2} at 1 r_e)	r-band magnitude	Exposure Time (minutes)	Instrument	Priority
G12	174.0 – 186.0	-3 – 2	22.0	19.7 – 24.5	–	240	Hector	High
G15	211.5 – 223.5	-2 – 3	22.0	19.7 – 24.5	–	240	Hector	High
Cluster A0085	10.460211	-9.303184	22.0	19.7 – 24.5	–	240	Hector	High
Cluster A0119	14.067150	-1.255370	22.0	19.7 – 24.5	–	240	Hector	High
Cluster A0151	17.10920	-15.40920	22.0	19.7 – 24.5	–	240	Hector	High
Cluster A3376	90.15290	-40.03260	22.0	19.7 – 24.5	–	240	Hector	High
Cluster A3391	96.58590	-53.69330	22.0	19.7 – 24.5	–	240	Hector	High
Cluster A3395	96.88000	-54.43740	22.0	19.7 – 24.5	–	240	Hector	High
Cluster A3667	303.0917	-56.8152	22.0	19.7 – 24.5	–	240	Hector	High
Cluster A3716	312.8600	-52.7070	22.0	19.7 – 24.5	–	240	Hector	High
Cluster A2399	329.372605	-7.796920	22.0	19.7 – 24.5	–	240	Hector	High
Cluster A0085	10.460211	-9.303184	–	–	< 17.7	60	2dF	Medium
Cluster A0119	14.067150	-1.255370	–	–	< 17.7	60	2dF	Medium
Cluster A0151	17.1092	-15.4092	–	–	< 17.7	60	2dF	Medium
Cluster A3158	55.7704	-53.6531	–	–	< 17.7	60	2dF	Medium
Cluster A3266	67.7746	-61.4436	–	–	< 17.7	60	2dF	Medium
Cluster A3376	90.15290	-40.03260	–	–	< 17.7	60	2dF	Medium
Cluster A3391	96.58590	-53.69330	–	–	< 17.7	60	2dF	Medium
Cluster A3395	96.88000	-54.43740	–	–	< 17.7	60	2dF	Medium
Cluster A3667	303.0917	-56.8152	–	–	< 17.7	60	2dF	Medium
Cluster A3716	312.8600	-52.7070	–	–	< 17.7	60	2dF	Medium
Cluster A2399	329.372605	-7.796920	–	–	< 17.7	60	2dF	Medium

Table 2. Backup Targets. Our poor-weather backup targets will be brighter objects from the same fields.

Field Name	R.A (°)	Dec (°)	Median r-band surface brightness (mag arcsec^{-2} at 1 r_e)	2σ range of r-band surface brightness (mag arcsec^{-2} at 1 r_e)	r-band magnitude	Exposure Time (minutes)	Instrument	Priority
G12	174.0 – 186.0	-3 – 2	22.0	19.7 – 22.0	–	240	Hector	High
G15	211.5 – 223.5	-2 – 3	22.0	19.7 – 22.0	–	240	Hector	High
Cluster A0085	10.460211	-9.303184	22.0	19.7 – 22.0	–	240	Hector	High
Cluster A0119	14.067150	-1.255370	22.0	19.7 – 22.0	–	240	Hector	High
Cluster A0151	17.10920	-15.40920	22.0	19.7 – 22.0	–	240	Hector	High
Cluster A3376	90.15290	-40.03260	22.0	19.7 – 22.0	–	240	Hector	High
Cluster A3391	96.58590	-53.69330	22.0	19.7 – 22.0	–	240	Hector	High
Cluster A3395	96.88000	-54.43740	22.0	19.7 – 22.0	–	240	Hector	High
Cluster A3667	303.0917	-56.8152	22.0	19.7 – 22.0	–	240	Hector	High
Cluster A3716	312.8600	-52.7070	22.0	19.7 – 22.0	–	240	Hector	High
Cluster A2399	329.372605	-7.796920	22.0	19.7 – 22.0	–	240	Hector	High
Cluster A0085	10.460211	-9.303184	–	–	< 17.7	60	2dF	Medium
Cluster A0119	14.067150	-1.255370	–	–	< 17.7	60	2dF	Medium
Cluster A0151	17.1092	-15.4092	–	–	< 17.7	60	2dF	Medium
Cluster A3158	55.7704	-53.6531	–	–	< 17.7	60	2dF	Medium
Cluster A3266	67.7746	-61.4436	–	–	< 17.7	60	2dF	Medium
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Cluster A3391	96.58590	-53.69330	–	–	< 17.7	60	2dF	Medium
Cluster A3395	96.88000	-54.43740	–	–	< 17.7	60	2dF	Medium
Cluster A3667	303.0917	-56.8152	–	–	< 17.7	60	2dF	Medium
Cluster A3716	312.8600	-52.7070	–	–	< 17.7	60	2dF	Medium
Cluster A2399	329.372605	-7.796920	–	–	< 17.7	60	2dF	Medium