Australian Time Allocation Committee

Proposal for AAT Time

Semester: 2022B
Reference: A/2022B/1001
Submitted: No

Investigator	Affiliation	Observer	Student	PhD Thesis	Supervisor
Bryant, Julia	University of Sydney	Yes	No	No	
Battisti, Andrew	Australian National University	Maybe	No	No	
Hopkins, Andrew	Australian Astronomical Observatory	Maybe	No	No	
Lopez-Sanchez, Angel	Australian Astronomical Optics, Macquarie University	Yes	No	No	
Miszalski, Brent	AAO Macquarie	Maybe	No	No	
Foster, Caroline	University of Sydney	Yes	No	No	
Wisnioski, Emily	Max Planck Institute for Extraterrestrial Physics	Yes	No	No	
Taylor, Edward	Swinburne University of Technology	Yes	No	No	
van de Sande, Jesse	University of Sydney	Yes	No	No	
Kewley, Lisa	Australian National University	Maybe	No	No	
Owers, Matt	Macquarie University	Yes	No	No	
Colless, Matthew	Australian National University	Maybe	No	No	
Brown, Michael	Monash University	Maybe	No	No	
McDermid, Richard	Macquarie University	Yes	No	No	
Sharp, Rob	Australian National University	Yes	No	No	
Sweet, Sarah	The University of Queensland	Yes	No	No	
Vaughan, Sam	University of Sydney	Yes	No	No	
Brough, Sarah	University of New South Wales	Yes	No	No	
Croom, Scott	University of Sydney	Yes	No	No	
Oh, Sree	Australian National University	Yes	No	No	
Barone, Tania	Australian National University	Yes	No	No	
Grasha, Kathryn	Australian National University	Yes	No	No	
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Couch, Warrick	Australian Astronomical Observatory	Maybe	No	No	
Rutherford, Tomas	University of Sydney	Yes	No	Yes	Scott Croom, Jesse van de Sande
Mai, Yifan		Yes	No	Yes	Scott Croom, Sam Vaughan
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Gunawardhana, Madusha	University of Durham	Yes	No	No	
Mukty, Nabomita	The University of Sydney	Yes	No	Yes	Joss Bland-Hawthorn
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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. Here, we request 8 nights from the shared pool in addition to 42 reserved nights.

	Dark	Grey	Bright
Total number of calendar nights requested this semester	**4**	**4**	**0**
Minimum useful allocation this semester	**2**	**2**	**0**
Additional nights required to complete project in future	**534**	**0**	**0**

Number of nights already awarded to this project:	79
Type of proposal (open or paid):	Open

Are these full nights:	Yes
Remote Observing:	No
Target of Opportunity:	No
Long term status:	Yes
Large program request:	No

Preferred dates:	**Earliest**	**Latest**
	01 Aug 2022	30 Nov 2022

Impossible Dates: The highest priority H1 and H3 fields are not available all night in December and January.

Special scheduling constraints:

Instrumentation

Instrument 1: Visitor Instrument

Instrument Name:	Hector - not actually a visitor instrument but not listed in the instrument list until after commissioning.
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/2022A/15	The Hector Galaxy Survey	49n	n/a	Heavily weather affected.
A/2020B/24	Probing the outskirts of rich galaxy clusters: where and when is star formation quenched?	7n	n/a	-

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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 2022B semester. Hector commissioning is now in its final stages, though the Hector Galaxy Survey has experienced some delays due to exceptionally poor weather in semester 2022A.

1.1 The Hector Galaxy Survey Overview

What is the physical basis for the diversity of galaxy properties in the local Universe? This is the overarching 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 data that cannot be obtained with any other survey. The large survey size and spectral resolution, which is a factor of two better than any comparable instrument, will allow us to explore galaxy properties across the stellar mass function with exquisite environmental characterisation. The Hector-GS plans to observe 15,000 galaxies over 6 years, providing a groundbreaking 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 that the survey will produce, but also in unique science that cannot be accomplished 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 that allows 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 the environment, including mapping the large cluster halos out to higher cluster radii; larger IFUs to get 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. For example, the ASKAP WALLABY [17] 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. In addition, 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 - in some cases with contributions that are not telescope nights. The data will deliver a vast array of science opportunities to the already 62-strong Australian Hector team, drawn from across the country from 8 Universities and the CSIRO. The team builds from the SAMI IFS team and is expected to outgrow the 140-strong SAMI team once the survey enters the data collection stage.

Here, we request 8 nights from the common pool. The Hector Galaxy Survey science goals are built on a complete statistical sample of 15,000 galaxies, a number carefully set by predictions from simulations and experience with the SAMI data. To complete the full Hector survey on the planned 6-year timeframe requires 100 nights per year. We have 42 reserved nights from institutions participating in Hector this semester, so we require 8 more to reach our target. We seek these additional nights from the common pool, noting that some Hector institutions have adopted a policy of not reserving any nights and others are capping their reserved nights in order to put nights into the pool.

1.2 Key Science Goals

(A) **How is the accretion of gas and angular momentum (spin) influenced by the 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 [32], 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 coverage 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 is 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 [31, 30]. While the orbit transition was detected in the SDSS [33], the spin counterpart requires the power of the Hector-GS.

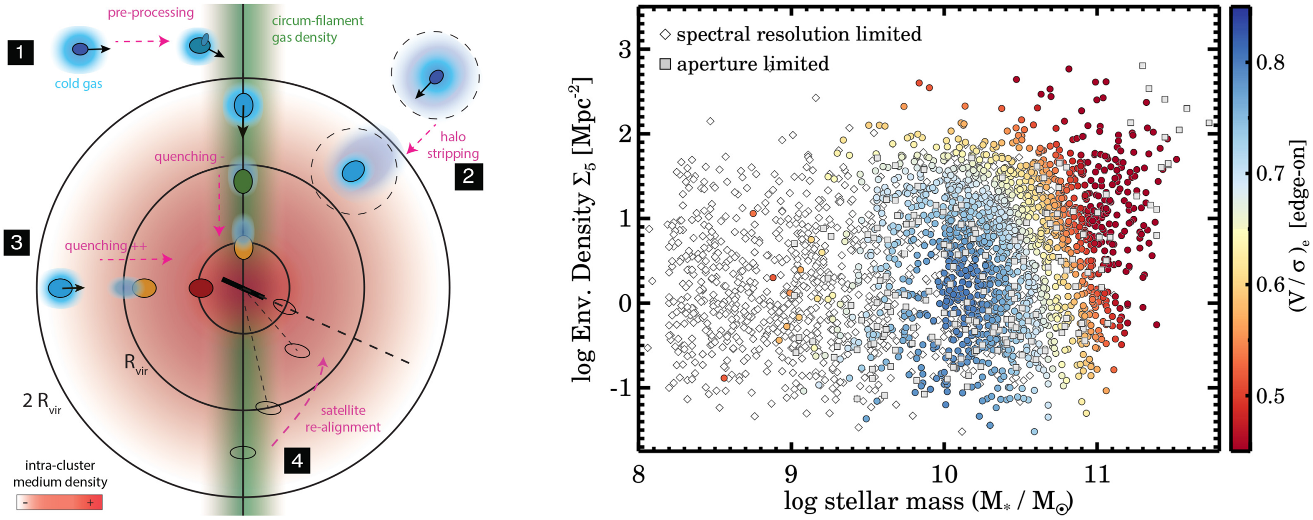

Figure 1: Left panel: Simulations predict the way filaments from large-scale structure and cluster outskirts cause transitions in galaxy evolution. 1- Large filaments (vertical line with gas density in green) re-orient inflows, disturb the plane of a galaxy and have a higher merger rate than the field. 2 - Accretion in cluster outskirts depletes 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 [31, 18])*. 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 revealed the key drivers of dynamical galaxy transformation of *all* morphological types [29]: 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 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 the environment on the stellar-dynamical properties of galaxies (e.g., Fig. 1, right panel). The largest dynamical changes are detected in 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, 29]. In this regime a factor of > 5 increase in sample size is paramount to understanding 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, 27, 2, 3], but this mass regime is currently below SAMI's spectral resolution. The higher spectral resolution of Hector will enable stellar kinematic measurements on a broader 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, while the vast majority of accreted material and transformation is predicted to take place at larger radii[$> 2R_\mathrm{e}$; 26, 4, 25]. 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 high-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 [28], 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 [24] have now demonstrated that high-order kinematic signatures detect unique orbital substructures, and cosmological hydrodynamical simulations show that high-order signatures are the best probes of determining the amount of ex-situ versus in-situ material in galaxies [23]. The Hector-GS will yield an unprecedented number of galaxies ($N \sim 4000$) where high-order kinematics can be measured, across stellar mass, morphology, and environment, enabling detailed comparisons to simulations [e.g. 20, 23] 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 small number of galaxies in the SAMI survey had the right size and orientation to identify galactic winds and outflows [15, 16, 19], the larger IFU imaging fibre bundles, called 'hexabundles', and the Hector survey strategy will 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 radii that 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

Sample Size Justification: The need for 15,000 galaxies has been carefully set by simulations and experience with the SAMI data. While the SAMI survey detected the first signature of galaxy spin alignments with cosmic filaments [32], the significance of the detection was limited to $\approx 2\sigma$ and precluded more detailed analysis. Based on predictions from simulation, it was remarkable that the faint spin-alignment signal at $z < 0.1$ was recovered above the 95% confidence interval, especially considering the relatively low number of galaxies (N=1418) in the sample [32]. However, as outlined in key science goal (A), the limited number of galaxies in SAMI makes it impossible to detect spin-alignment trends within galaxy sub-populations, nor does it allow for a detailed analysis of galaxies near cosmic walls, any multivariate analysis (field filaments, filaments in groups, filaments in clusters), or any detailed analysis of the corresponding kinematic disturbances in the outer parts of galaxies.

Furthermore, the SAMI galaxy spin alignments study [32] was carried out in projection, where angles between filaments and galaxy spins are computed on the sphere from position angles. In deep but narrow surveys such as GAMA, it is difficult to disentangle alignments with filaments and walls in close alignment. We have determined that 15,000 galaxies observed over a wider area, such as the WAVES regions, will be essential to recover the 3D alignments of galactic spins in all cosmic structures, particularly near filaments and walls. While SAMI and MaNGA combined already observed 13,000 galaxies, the environmental statistics are insufficient to carry out the proposed science goal (A) as the SDSS regions lack the required redshift completeness.

Lastly, the Hector-GS will not only provide a robust confirmation of the galaxy spin alignments with cosmic filaments, but will empower ground-breaking studies of how galaxy kinematics correlate across the hierarchy of large-scale structure. The higher spectral resolution of Hector will allow us to measure the stellar kinematics of low-mass galaxies ($\log(M_\star/M_\odot) < 9.5$) and determine variations of the high-order kinematic signatures as a function of mass, morphology and environment, something that cannot be done with SAMI, CALIFA, or MaNGA. In addition, Hector's 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.

Survey Design: 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]. Furthermore, 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 Hector-GS will comprise of a "field" and a "cluster" sample to observe galaxies across the full range of environmental densities. The field sample will be in two regions: one in the north galactic cap at $\delta \simeq 0^\circ$ (with known redshifts from SDSS, 2dFGRS and GAMA); and a second at $\delta \approx -30^\circ$ 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.

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 selects 15,000 galaxies at $z \leq 0.1$.

The 2022B semester Hector observations will focus on sub-regions in the WAVES South fields. With existing redshifts in this field from 2dFGRS complimented with the dedicated 2dF Hector Galaxy Redshift Survey we have now reached the required completeness to select targets in the WAVES-Hector-1 and WAVES-Hector-3 fields (H1 & H3). Photometry has been already compiled by the WAVES team to form the Hector input catalogue. In addition to the WAVES regions, we will use the Hector instrument to target 10 of the Hector-GS clusters. Enabled by the 2dF Hector Galaxy Redshift Survey, the clusters now also have sufficient redshift coverage for the selection of Hector targets in semester 2022B.

1.4 Plan for Semester 2022B

The Hector instrument [7] has 19 hexabundles on galaxies in each field and two that image secondary standard stars for calibration. This semester, the Hector-GS aims to target 1250 galaxies in 50 dark/grey nights, with 2 fields per night and 19 galaxies per field (with weather overhead). Our targets this semester are most efficiently observed between August and October (November is possible but not as ideal for the RAs of our highest priority fields) and are best observed in 12-13 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 2022B 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, which build further on the targeted science from 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, 27], 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^{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 2022A science case, this semester will prioritise low-mass dwarfs where the spectral resolution in SAMI would be insufficient to measure their low velocity dispersion, with repeat observations to reach the required depth (typically 2-3 repeats. Based on the tiling in these fields, this will result in 250 $\log(M_\star/M_\odot) < 9.5$ galaxies in this semester alone.

(2) **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 [16]. A more recent analysis using SAMI shows that almost all galaxies have increased velocity dispersion in extra-planar gas, suggesting that winds are much more widespread. 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 ionisation 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 ionisation structure. This semester we will intentionally target a set of ~ 40 galaxies with 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.

(3) **The future fate of ram-pressure affected cluster galaxies:** SAMI targeted galaxies in the central parts of 8 clusters, finding a substantial fraction of recently accreted star-forming galaxies were undergoing outside-in quenching due to the effects of ram-pressure stripping [22]. However, many of these galaxies are only partially quenched, exhibiting ongoing central star-formation. The outstanding question is whether these galaxies are completely quenched at the first cluster core passage, as predicted by [21], or whether the central star formation continues for long periods following pericentric passage. The Hector-GS will address this question by measuring the spatial distribution of star formation in galaxies located in the 1-2R_{200} regions. This region is dominated by two distinct galaxy populations: higher velocity galaxies on their first in-fall into the cluster, and lower velocity "backsplash" galaxies that are close to the turn-around radius after a recent cluster core passage [14]. Comparing the resolved star-forming properties of the first time in-fallers, the backsplash, and galaxies in the central virialised regions will provide a strong empirical constraint on quenching timescales following the accretion of a galaxy onto a cluster. This first semester will focus on galaxies located at 1-2R_{200} from a cluster that has SAMI data within R_{200}, thereby allowing a complete view from the core to the outskirts of this cluster.

References

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2 Technical Justification

Hector Commissioning Status: There have been three commissioning runs for Hector on December-2021 (12n), January 2022 (7n), and March 2022 (12n). The commissioning of Hector has been successful, with "first light" achieved during the first commissioning run: a detection of bright Hα emission lines of 19 galaxies simultaneously in *all* hexabundles. The Hector Data Reduction working group is currently analysing the commissioning data, with initial results showing highly promising throughput and spectral resolution of the new spectrographs for Hector (Spector) which exceeds requirements. The new guider, sky fibre system, magnetic field system and hexabundles have all been demonstrated successfully, and hardware improvements to the rotator will be completed ahead of the May run. The new positioning system is fully operational and being tweaked for speed and practicality. The training of observers is underway and will continue with extra observers in each of the A-semester runs. Due to exceptionally poor weather during the third commissioning run (11/12 nights with thick cloud cover), not all commissioning tasks have been finalised causing some delay in starting the Hector Galaxy Survey. However, the alignment and calibration of the instrument on-sky are close to completion, with remaining tasks expected to take ~ 5 clear nights of the scheduled May run. The Hector Survey will then begin and continue in the 16 nights of the June and July runs.

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 observe 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=22 mag arcsec^{-2} at $1R_e$ and the 90^{th} percentile is at r=23.65 mag 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 similar net throughput (commissioning data is currently being analysed and compared to the modelled integration time calculator).

Observing strategy: One of the Hector hexabundles on each 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).

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})	Exposure time (minutes)	Instrument
Hector-F1	9 – 21	-28.5 – -33.5	22	240	Hector
Hector-F3	39 – 51	-28.5 – -33.5	22	240	Hector
Abell 2399	329.3726	-7.7969	22	240	Hector
Abell 151	17.1092	-15.4092	22	240	Hector
Abell 119	14.0672	-1.25537	22	240	Hector
Abell 85	10.4602	-9.3032	22	240	Hector
Abell 3158	55.7704	-53.6531	22	240	Hector
Abell 3266	67.7746	-61.4436	22	240	Hector
Abell 3376	90.1529	-40.0326	22	240	Hector
Abell 3391/3395	96.58/96.88	-53.69/-54.44	22	240	Hector
Abell 3667	303.0917	-56.8152	22	240	Hector
Abell 3716	312.8600	-52.7070	22	240	Hector

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})	Exposure time (minutes)	Instrument
Hector-F1	9 – 21	-28.5 – -33.5	22	240	Hector
Hector-F3	39 – 51	-28.5 – -33.5	22	240	Hector
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Abell 3376	90.1529	-40.0326	22	240	Hector
Abell 3391/3395	96.58/96.88	-53.69/-54.44	22	240	Hector
Abell 3667	303.0917	-56.8152	22	240	Hector
Abell 3716	312.8600	-52.7070	22	240	Hector