Observing Time Request
MDM Observatory

Date: November 1, 2013	*Proposal number:*

TITLE: proto-CHAS: Prototype for the Circumgalactic H-Alpha Spectrograph

PI: David Schiminovich ds@astro.columbia.edu Y

CoI: Erika Hamden erika.hamden@gmail.com Y

CoI: Sam Gordon sbg2133@columbia.edu Y

Abstract of Scientific Justification: The Circumgalactic H-Alpha Spectrograph (CHAS) is an instrument concept that will obtain ultra-deep Hα images and kinematics of gas in the circumgalactic medium of galaxies in the nearby universe. CHAS is a monochromatic nebular spectrograph designed to fully utilize the working field of view of the MDM 2.4m and 1.3m telescopes. We propose here continued science observations for our prototype version of CHAS, which has already been used on both the 1.3m and 2.4m telescopes.

- *Is this proposal part of a PhD thesis?* Y
- *Requesting long-term status? If 'Y', please give # of semesters and nights on the next line.* Y

Details to follow. Expect min. 10 nights/semester.

Summary of observing runs requested for this project

Run	Telescope	Instrument, detectors, grisms, gratings, filters, camera optics, etc.
1	2.4m	Visitor-proto-CHAS with MDM4K
2		
3		

Run	No. nights	Moon age (d)	Optimal dates	Acceptable dates
1	10	7		
2				
3				

- *List dates you cannot use for non-astronomical reasons on the next line.*

Scientific Justification *Try to include overall significance to astronomy.*

The Circumgalactic H-Alpha Spectrograph (CHAS) is an instrument concept that will obtain ultra-deep Hα images and kinematics of gas in the circumgalactic medium of galaxies in the nearby universe. CHAS is a monochromatic nebular spectrograph designed to fully utilize the working field of view of the MDM 2.4m (FOV: 15 x 15 arcmin) and 1.3m (FOV: 30 x 30 arcmin) telescopes. Our design combines an ultra-narrowband Hα filter, a microlens array, and a fast, wide-field spectrograph. In a 10 hour exposure, CHAS will obtain 10σ detection sensitivities between 4-15 mR over $\sim 1 - 4'$ angular scales, with 1.5 mR sensitivity after 100 hours. This will provide the first images of the extended warm ionized gas component in the circumgalactic medium around normal galaxies, measuring the distribution of infalling and outflowing gas within the central 50-100 kpc of a galaxy's halo (emission measure $\lesssim 0.01$ cm^{-6} pc), and will establish a new technique for testing the modes of accretion and outflow in galaxies across cosmic time. See Figure 1 for estimates of sensitivity vs. exposure time and sky pixel size, as well as comparison to other instruments.

We propose here new science observations for our prototype version of CHAS, which has already had one engineering run on the MDM 1.3m. Proto-CHAS has a field of view that is 1/20th-1/40th of that of CHAS (e.g. FOV 7×7 arcmin on the 1.3 m and 3.5×3.5 arcmin on the 2.4 m) but comparable efficiency and is in fact a powerful instrument in its own right. Thirteen nights of observations in September 2013 with a finely aligned version of Proto-CHAS allowed us to obtain our first usable astronomical data from the prototype. For this prototype we installed a 200 μm diameter mask over the lenslet array to cover the interstitial boundaries, to eliminate cross-talk between lens elements, and also masked half of the lens elements in order to lower the spectral filling factor in the focal plane, simplifying our initial reduction and calibration. The masking resulted in a net filling factor of 25% on the sky, with a grid of 80×40 lenslets, yielding 3200 spectra. Two central pixels were also masked to provide a fiducial for alignment and calibration. The instrument performed well as part of the MDM system, making use of the existing MIS (lamps, guider) and TCS and camera control software.

For these first runs we observed and successfully detected Hα and NII from numerous galaxy and nebular targets, including M27, M57, Crab, M31, M33, IC10, NGC628, NGC660, NGC925, NGC1012, NGC1569, NGC2146, M33, NGC6239, NGC7331 and Arp213, all of which were easily detected in 1-10 min exposures. Target images, calibration flats and spectra were also obtained. We have already performed a preliminary reduction of one of our primary galaxy targets NGC 7331. As a proof-of-concept these runs were stunningly successful, and we are currently in the process of further reducing our data and preparing initial publications. First results will also be presented at the January 2014 AAS meeting. We will continue performing observations with Proto-CHAS in 2014 in order to further test our methods and analysis.

Goals of the next set of runs are to: 1) continue to optimize theoretical optical performance with the fully integrated instrument. This may include small modifications to the HW, depending on funding, time etc.; 2) use measurements to quantify sky backgrounds and potential sources of systematic error; 3) observe complex fields to demonstrate initial spectral extraction methods, particularly at increased spectral filling factor, which is likely to be challenging, yet potentially quite efficient; 4) perform deep observations in order to demonstrate as-built sensitivity limits.

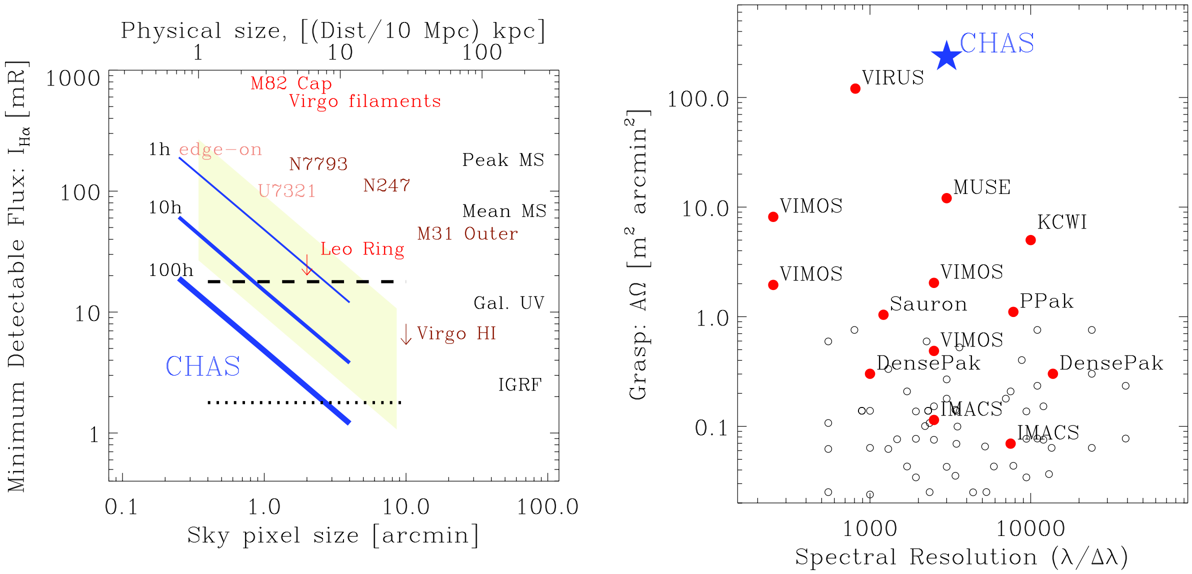

Figure 1: *Left:* Minimum detectable intensity as a function of integration time and "sky pixel" size. Blue lines of increasing thickness correspond to 1, 10, 100 hours of CHAS integration time. *Horizontal lines* estimate $I_{H\alpha}$ for $N_{HI} = 10^{18}$ cm^{-2} and $N_{HI} = 10^{17}$ cm^{-2} (*dashed and dotted*), assuming photoionization (w/ Case B recombination) by EUVB $= 4 \times 10^{-14}$ s^{-1}. *Shaded region* shows predicted intensity assuming a range of clumping factors (2-25) and hydrogen densities ($\log n_H/\mathrm{cm}^{-3} = -4.5$ to -3.5; overdensity $\delta \sim 100 - 1000$). Target names indicate detections and upper limits (over approx scale distance) for narrowband Hα (*red*), FP (*brown*) and IFU (*orange*) observations. *Black text* indicates surface brightness observations/model predictions for Magellanic stream from Bland-Hawthorn et al. (2007). *Right:* Effective grasp ($A_{eff}\Omega$) vs. spectral resolution ($\lambda/\Delta\lambda$). CHAS (*blue star*) vs. other other current and planned integral field unit spectrographs, (*open circles; filled red circles are listed*). CHAS has a grasp larger than other more costly IFUs being developed for 8-10m class telescopes, with similar spectral resolution and a much larger field of view and a much smaller bandpass, by design. Comparison instrument data taken from Bershady (2009; instrument efficiency 0.2, when not provided). Proto-CHAS has 1/20th of the grasp of CHAS with comparable spectral resolution, and is still quite powerful!

Technical and Scientific Feasibility *List objects, coordinates, and magnitudes (or surface brightness, if appropriate), desired S/N, wavelength coverage and resolution. Justify the number of nights requested as well as the specific telescope, instruments, and lunar phase. Indicate the optimal detector, as well as acceptable alternates. If you've requested long-term status, justify why this is necessary for successful completion of the science.*

Our first science runs were designed to demonstrate the feasibility of our design concept and test whether we could achieve usable science data from a breadboard instrument system with the MDM telescope, detectors and MIS. It was remarkably successful and we thank the MDM staff for their help with this! We have no concerns regarding the feasibility of future tests at either telescope. CHAS/proto-CHAS science requires exposures of 10 hours or more per object, which is why we have requested runs of 5 nights. We can shorten the runs to satisfy staffing constraints. We did opt to avoid using the R4K camera because of concerns regarding exposure to light. We have a preference for the MDM4K.

Why MDM? *If other optical/IR facilities are being used for this project, explain the role that MDM observations will play.*

How is it Going? *List your allocations of telescope time at MDM during the past 3 years, together with the current status of the project (cite publications where appropriate). Mark with an asterisk those allocations of time related to the current proposal. For ongoing projects, are they achieving their goals?*

We were allocated 4 nights in Spring and 13 nights in Fall 2013. Eight of the last 9 nights yielded high quality data that we are currently in the process of reducing. We will report on these data at the AAS and also have planned one science and one technical paper based upon this initial work.