Circumgalactic H-alpha Spectrograph: Initial Results from the First Engineering Runs

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Introduction

- The Circumgalactic H-alpha Spectrograph (CHaS) is an integral field unit (IFU) spectrograph.
- Designed to detect faint H-alpha and other line emissions from the CGM of nearby galaxies.
- It is to be installed in the 2.4 m Hiltner telescope at the MDM Observatory in Arizona.
- Wide-field spectral imaging: 10 arcminute
- High spectral resolution (R: 5000 to 10000) in 2.5 arcsecond diameter sky pixels (>60,000 separate spectra per frame).
- Narrowband spectra ~3 nm wide with 0.05-0.1 nm resolution.

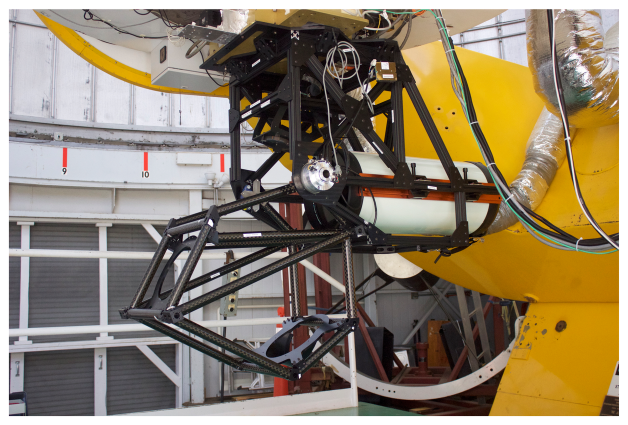


Figure 1 – CHaS in its first engineering run (05/2019)

Figure 2 – CHaS in its second engineering run (12/2019)

The Circumgalactic Medium (CGM)

- Loosely defined as the gas in between a galaxy's disk and its virial radius.
- Serves as interface between galaxy and intergalactic medium (IGM).
- Crucial to understand how galaxies evolve; IGM and CGM gas feeds galaxy disks. [3]
- Studying the CGM can lead to better understanding of galaxy gas inflows and outflows that fuel star formation. [4]
- Galaxy disks only account for ~10% of the baryonic mass produced at the Big Bang. [1] Evidence shows that these missing baryons can be found in filaments in the warm-hot intergalactic medium. [2]
- Studying the CGM could aid in investigating these missing baryons.

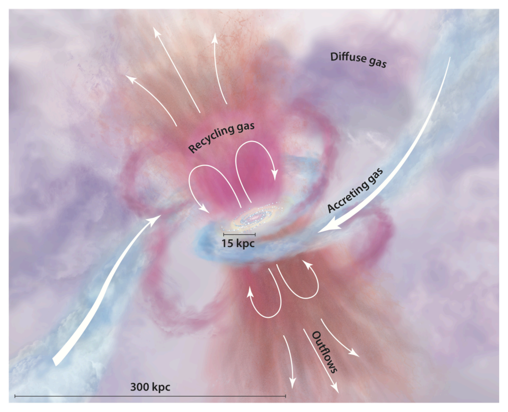


Figure 3 – CGM image from J. Tumlinson *et al.* (2017) [4].

Optics

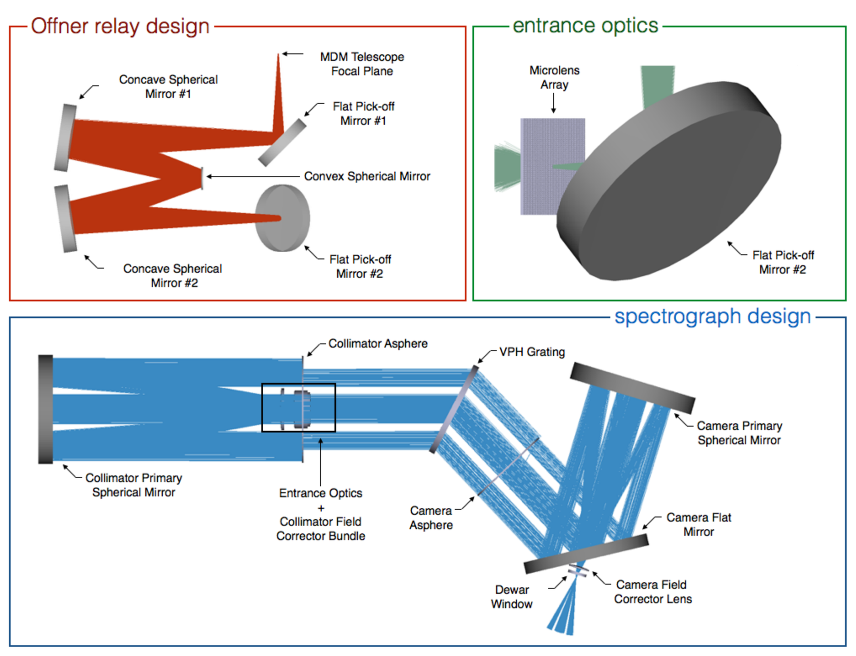


Figure 4 – Optical design and diagram by Nicole Melso.

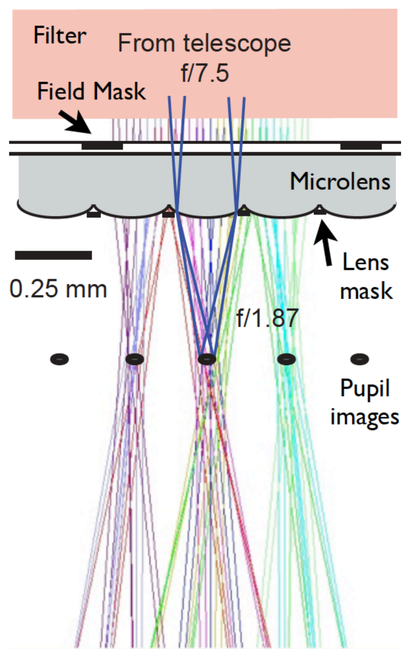


Figure 5 – Microlens array diagram.

- The light from the 2.4 m telescope first hits a flat mirror and is guided by relay optics (figure 4).
- It then goes through a Celestron 36cm Rowe-Ackermann Schmidt Astrograph (RASA) telescope that serves as a collimator before the light hits a diffraction grating.
- The diffracted light is guided to the MDM 4K CCD detector by a Schmidt camera (asphere, flat, sphere and field corrector).
- A lenslet array (figure 5) focuses the light from the telescope into several different spots, seen as dots on our observations (figure 8), allowing us to observe the narrowband spectrum from every spot in the observed nearby galaxy.

Mechanical Design

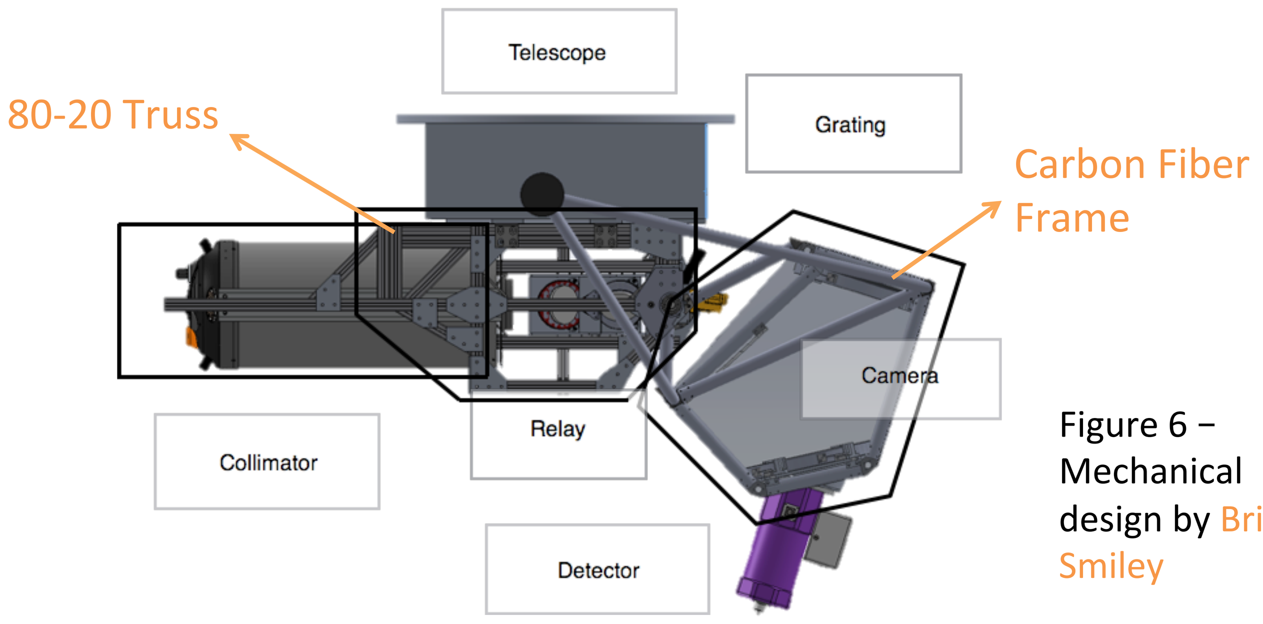


Figure 6 – Mechanical design by Brian Smiley

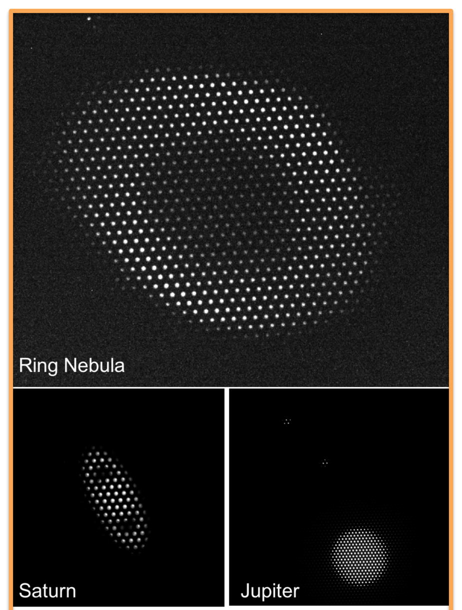
1st Engineering Run – May 2019

Pointing/balancing and observation tests using a Celestron telescope of 11'' in place of the main optical components.

Testing full motion, we found out that the camera wouldn't fit through the telescope fork with its attached protective posts.

Lenslet array and relay optics were first installed, with results seen on the right.

Figure 7 – Component installation



We successfully observed well-known objects to test our lenslet array. Above, you can see the Ring Nebula, Saturn and Jupiter.

Figure 8

- After the 1st engineering run, we needed to make its frame smaller so the attached camera would fit through the MDM's 2.4 m telescope fork, which required a redesign of the relay optics positioning.
- The lenslet array worked successfully when we aimed at different targets, leaving the installation of remaining optical parts for the December 2019 run.

2nd Engineering Run – December 2019

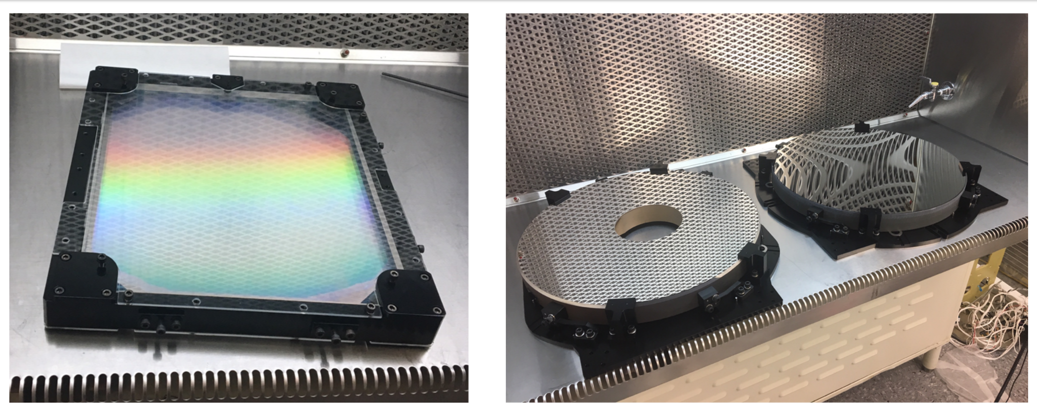
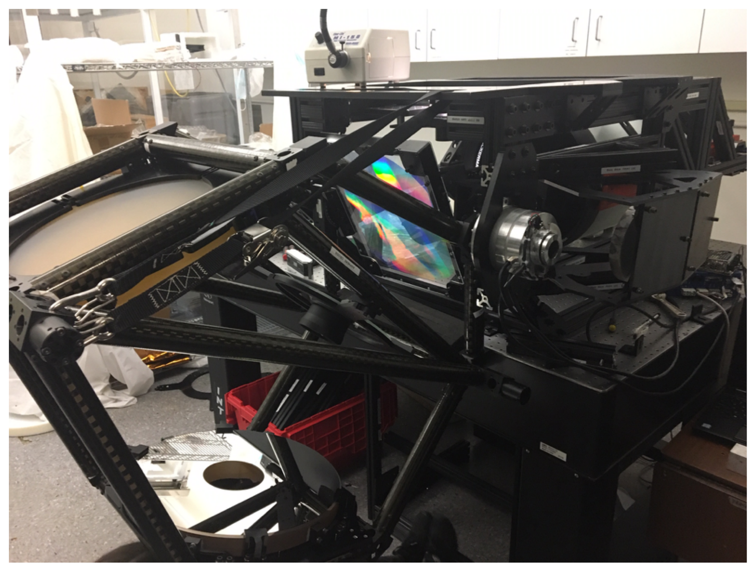


Figure 9 – Diffraction grating (left) and flat and spherical mirrors (right) installed in December 2019.

Figure 10 – CHaS prior to installation at MDM with optical components integrated on the mechanical structure. The diffraction grating is mounted on its rotation stage between the main 80-20 truss and the camera carbon fiber truss. The new camera mirrors were also attached to the carbon fiber truss.



- During camera alignment, we obtained spectra from the focus points, observing small trefoil aberrations caused by the mounted camera optics (see figure 11). Minor adjustments should reduce these for the next run.

2nd Engineering Run – December 2019 (cont'd)

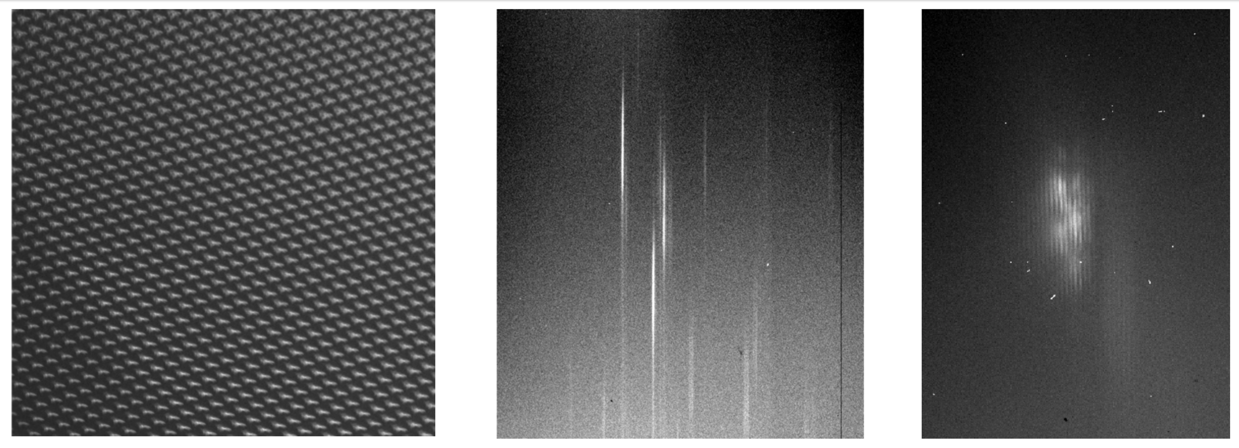


Figure 11 – Image of spectra from focus points (left). Pointing test images from star cluster NGC2281 (center) and galaxy M82 (right), both with the grating cover on.

Electronics

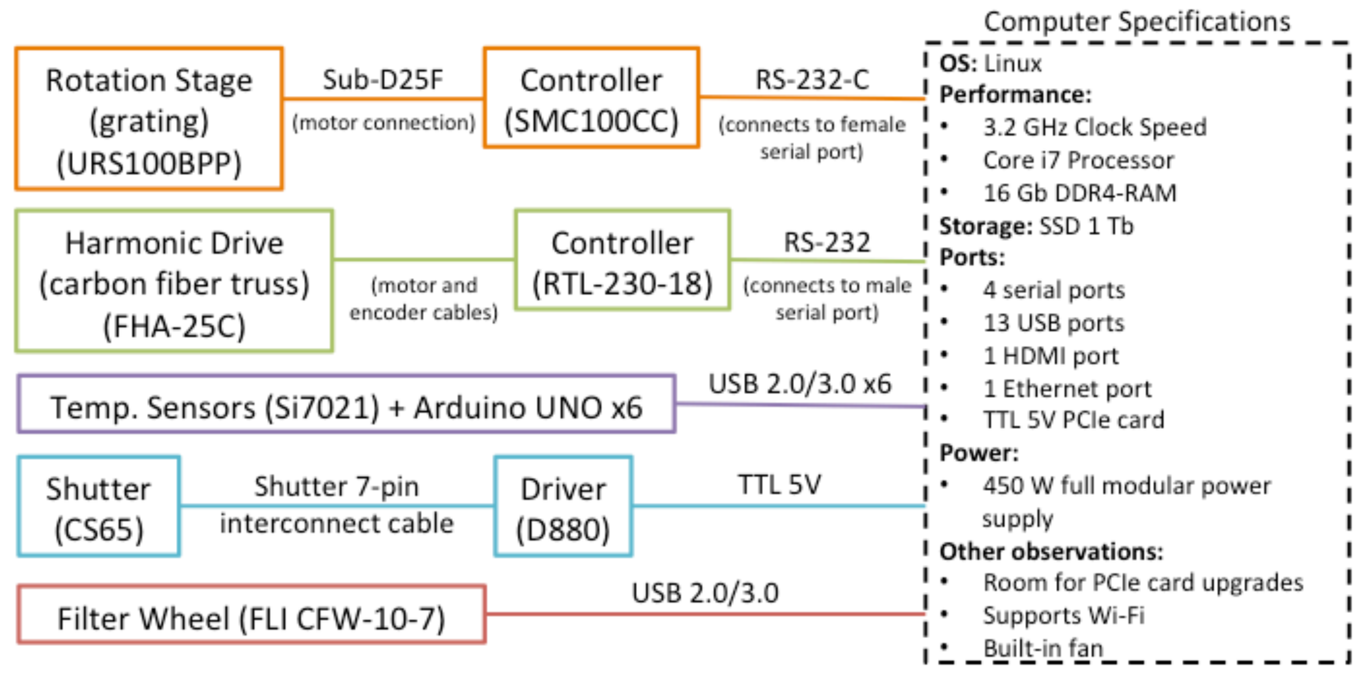


Figure 12 – Electronics diagram with electronic pieces to be integrated and computer specifications to meet these needs.

- We are currently developing custom software coded in C++ to control the rotation stages and the Harmonic Drive, which will allow us to fully control the motion of CHaS' optical components remotely.

Future work (then science!)

	Eng. Run 1	Eng. Run 2	Sci. Run 1	Sci. Run (2-5)
Date	May 2019	Dec 2019	Jan 2020	Spring 2020
Telescope IF	X	X	X	X
Collimator	X	X	X	X
Relay	Old config	X	X	X
Lenslet/Nose		Old config	X	X
Camera (Truss)	X	X	X	X
Camera (Optics)		X	X	X
VPH Grating		w/ Cover	X	X
Enclosure		Camera	X	X
Harmonic Drive		Break	X	X
Elect. Interface			X	X

Acknowledgments

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