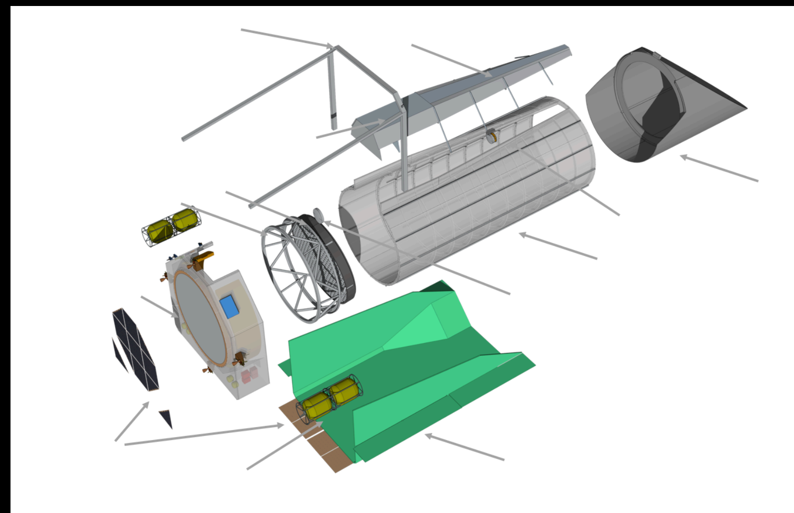
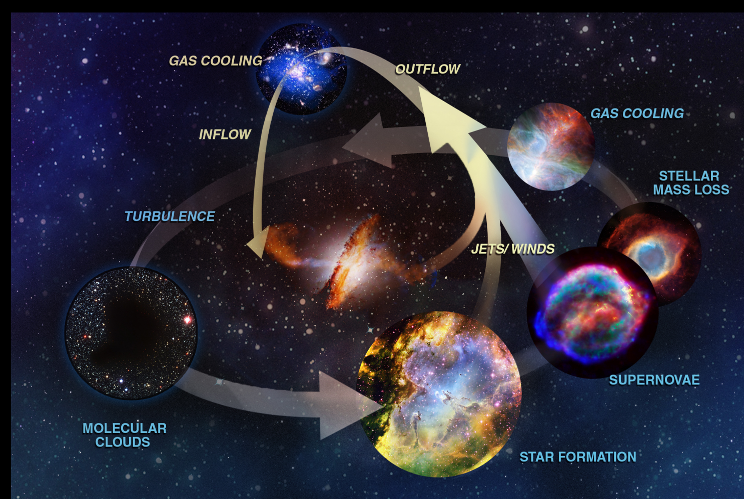
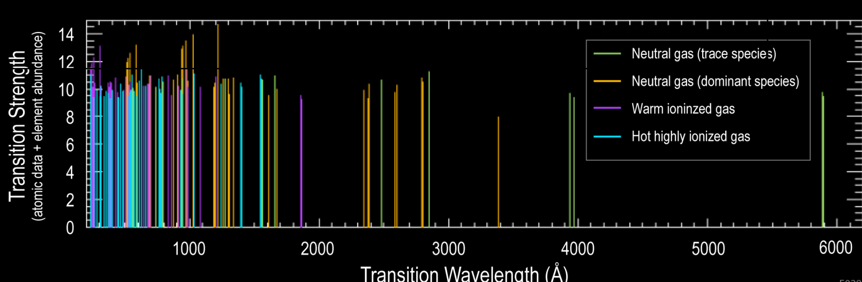
The HabEx Ultraviolet Spectrograph (UVS)

Following in the tradition of NASA astrophysics flagships, HabEx will be a Great Observatory with at least 25% of the primary mission and most of an extended mission reserved for guest observers. With the largest aperture ultraviolet (UV)/optical mirror ever deployed in space and two powerful instruments designed for this aspect of the mission, HabEx will enable unique science, not possible from ground- or space-based facilities in the 2030s, when HabEx would launch. This science will be broad and exciting, addressing the full range of primary NASA science disciplines, from solar system investigations to Cosmic Origins (COR) science to Physics of the Cosmos (PCOS). The Guest Observer (GO) time encompasses everything beyond the planned exoplanet direct imaging survey, and these competed programs are referred to as “observatory science.” It is expected that HabEx will serve a very similar role to that played by HST in the astronomical community and the world at large for decades: a flexible and powerful tool producing an extremely broad range of exciting astrophysics, and fueling the public’s interest in science, the cosmos, and NASA.



The UVS instrument is designed to enable high-resolution spectroscopy down to 115 nm in the UV. The UVS will access the large number of diagnostic emission and absorption lines available at wavelengths shorter than 300 nm. The driving science cases include understanding the life cycle of baryonic material as it is moved in and out of galaxies and into stars and planets, determining the escape fraction of hydrogen-ionizing photons from starforming galaxies and whether this can explain the reionization of the universe at early ages, and the life cycle and impact of massive stars on their environments and the subsequent generations of stars and planets that follow the first generation of massive stars. The high UV efficiency of HabEx will enable the extension of observing methods developed with HST to objects in the outer solar system, including planetary and satellite atmospheres / plumes and the ice giant planets. The needed capabilities include a wide field of view and the ability to perform multi-object spectroscopy (MOS) within that field. The science also calls for access at the shortest wavelengths possible. The baseline design specifies reflectivity down to 115 nm using Al coated mirrors protected with MgF_2, and there is a stretch goal of reaching down to 100 nm using Al mirrors protected using LiF and either AlF_3 or MgF_2 deposited using atomic layer deposition (ALD). The science also calls for a range of spectral resolutions to enable measurement of both line shape and separation of specific lines in both emission and absorption.





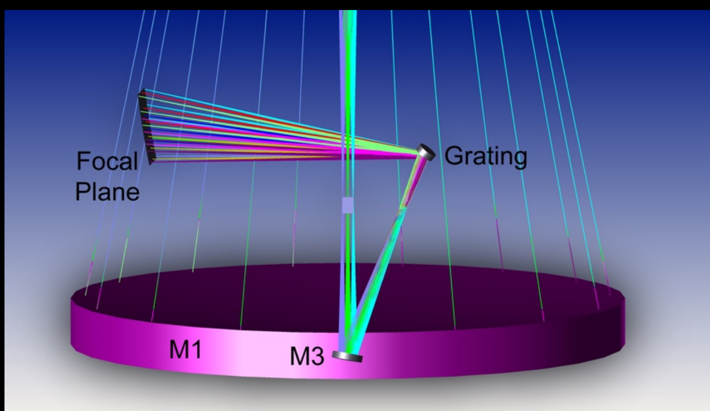
	UVS
FOV	3'×3'
Wavelength bands	20 bands covering 115 to 300 nm
Spectral resolutions	60,000; 25,000; 12,000; 6,000; 3,000; 1,000; 500
Telescope resolution	Diffraction limited at 400 nm
Detector	3×5 MCP array, 100 mm sq each
Array width	17,000 × 30,000 pixels (pores)
Microshutter aperture array	2×2 array of 171×365 200×100 µm apertures

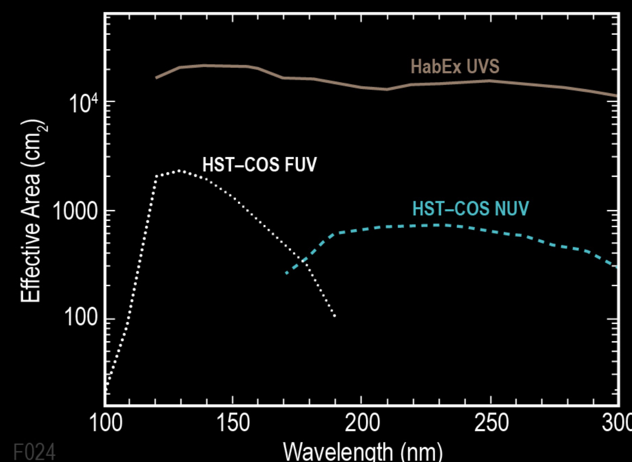
The UVS utilizes a microshutter array (MSA), situated at the two-mirror Cassegrain focus to enable selection of objects of interest from a 3'×3' FOV. With a maximum resolution of 60,000, the UVS needs a large set of gratings to cover the wavelength band. The detector area is large, requiring about 30,000×17,000 pixels (or “pores” in the case of microchannel plate detectors) to cover the FOV. In the baseline design, this area will be covered using a 3×5 array of approximately 100×100 mm microchannel plate (MCP) detectors, or a feasible alternative would use a larger array of delta doped UV-optimized CCDs. Both types of detector have similar performance and technology readiness levels.

With a Nyquist sampling criterion for the field of view at 400 nm, the pixel width is equal to $\lambda/2d$. In the spectral domain, the criterion for spectral elements to be resolved is the same so that a spectral resolution element $\Delta\lambda$ covers two pixels. For example, with R = 60,000 at 120 nm, $\Delta\lambda$ = 2 pm and the number of spectral elements needed to cover the first band 12 nm wide is 6,000. Thus, a single spectrum on the detector will cover 12,000 pixels, resulting in the rectangular shape of the focal plane.

After extensive design trials, a 4 reflection design was arrived at. In the design shown below, the beam from an off-axis tertiary mirror strikes a powered grating before falling on the focal plane. This system resides in front of the main tertiary mirror. The 4-reflection design yielded 50% throughput at 125 nm. However it requires larger gratings, about 100 mm diameter compared with 50 mm for a 5-reflection design, but this size is still considered to be practical. In addition, the 4-reflection design does not require an optical bench structure extending behind the primary mirror. Therefore, the 4-reflection design was selected for the baseline design. The set of gratings will be mounted in two rows set into a wheel of ~0.5-m diameter. Not listed here is an R=1 element – ie. a mirror – this will allow imaging over the full 3'x3' field in the FUV. The narrow and medium band filters for this mode have not been defined yet.

Resolution R	λ min	λ max	Δλ	Resolution R	λ min	λ max	Δλ
λ/Δλ	nm	nm	pm	λ/Δλ	nm	nm	pm
60,000	115	127	2.01	25,000	115	146	5.41
60,000	127	139	2.21	25,000	146	186	6.88
60,000	139	153	2.44	25,000	186	236	8.74
60,000	153	169	2.68	25,000	236	300	11.11
60,000	169	186	2.95	12,000	115	186	12.29
60,000	186	204	3.25	12,000	186	300	19.86
60,000	204	225	3.58	6,000	115	300	32.15
60,000	225	248	3.94	3,000	120	300	64.29
60,000	248	273	4.33	1,000	120	300	185.00
60,000	273	300	4.77	500	120	300	185.00





With more than ten times the effective area of HST-COS, combined with a microshutter array, the HabEx UVS provides several orders of magnitude improved efficiency for UV spectroscopic studies. This will enable the first multiplexed observations of multiple sightlines to a single galaxy, allowing a new probe of the baryon cycle in galaxies. This figure is an update to that previously cited for the instrument, since the optical design now includes fewer reflections thereby increasing the overall throughput of the instrument.

Getting Involved:

The HabEx STDT is at this time soliciting 2-page science papers on what **you** would want to do with this powerful facility, if given the chance. We have made available exposure time calculators (ETCs) for the UVS and the other instruments on the Observatory. We invite you to check it out and think about how your science could be advanced with the capabilities we describe here. We look forward to dialogue and exchange of information in both directions as we seek to define what space-based observational astrophysics in the UV-visible might look like in the 2030s.

As part of facilitating this dialogue, the HabEx study will be convening a meeting in New York to allow presentation of exemplar science cases and an opportunity for the community to step up and present their own cases for the HabEx mission. We encourage you to consider attending and to contribute:

"Science with HabEx" Community Meeting - Flatiron Institute Center for Computational Astrophysics, N.Y. - Oct. 15-16, 2018 - https://www.jpl.nasa.gov/habex/news-events/

HabEx Study Website: https://www.jpl.nasa.gov/habex/