COS GTO Program

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Space Telescope Users Committee
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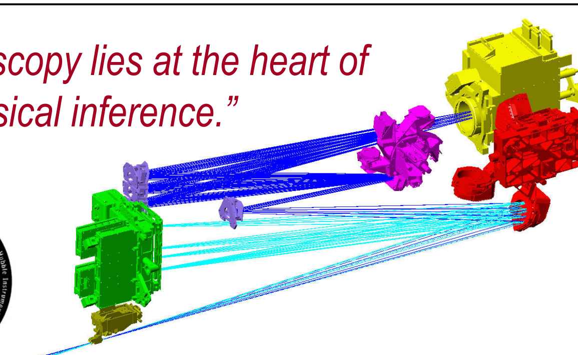
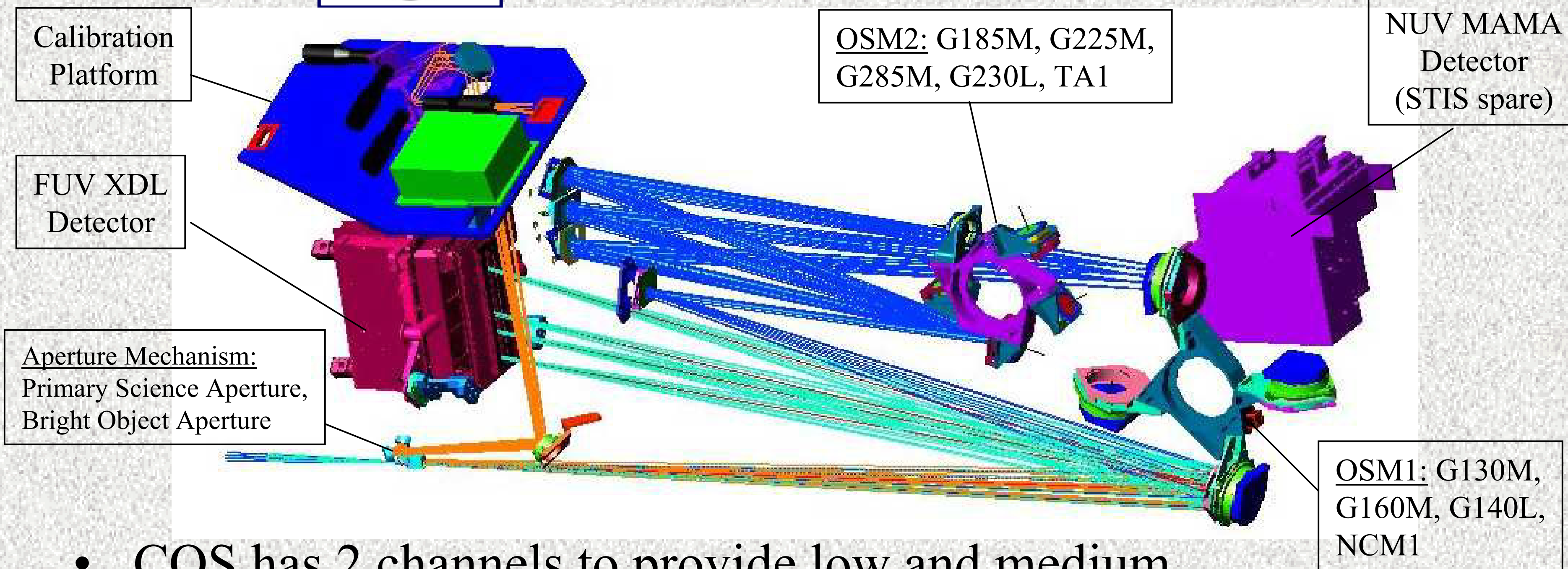
COS Science Themes

- What is the large-scale structure of matter in the Universe?
- How did galaxies form out of the intergalactic medium?
- How were the chemical elements for life created in massive stars and supernovae?
- How do stars and planetary systems form from dust grains in molecular clouds in the Milky Way?
- What are planetary atmospheres and comets in our Solar System made of?

"Spectroscopy lies at the heart of astrophysical inference."



Cosmic Origins Spectrograph
Hubble Space Telescope



Optical bench (not shown): re-use of GHRS bench

- COS has 2 channels to provide low and medium resolution UV spectroscopy
  - FUV: 1150-1775Å, NUV: 1700-3200Å
- FUV gratings: G130M, G160M, G140L
- NUV gratings: G185M, G225M, G285M, G230L
  - M gratings have spectral resolution of R ~ 20,000

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Spectral Resolution

- Moderate spectral resolution of R ~ 20,000 (= 15 km/s) is required to resolve D I on wings of H I features (4-5 resols separation), measure Doppler widths of Lyα clouds, and detect weak absorption features from continuum.
- "Survey modes" with R = ~1500 – 3500 available for characterization of spectral energy distributions, UV extinction curves, and detection of the very faintest UV sources.

Signal-to-Noise

- Most extragalactic/IGM programs require S/N > 10 per spectral resolution element, and ideally S/N = 20 – 30 is needed for accurate abundance measurements using redshifted lines of, e.g., Ly α, C IV, N V, and O VI.
- Many Galactic ISM programs require S/N > 100 to detect weak lines.

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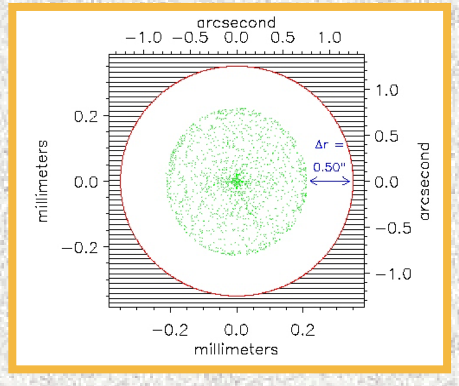

• *The aberrated HST PSF centered in the COS Primary Science Aperture.*

Wavelength Accuracy

- Extragalactic moderate resolution programs generally require absolute wavelength accuracy of ~ +/- 1 resel (= +/- 15 km/s), with relative accuracy of 1/3 resel rms across the spectrum.
- Some programs that require higher accuracy can use “tricks” to obtain needed calibration – e.g., using known wavelengths of ISM lines along sight-line.

Target Acquisition

- COS is a “slitless” spectrograph, so the precision of target acquisition (placement of target relative to calibration aperture) is the largest uncertainty for determining the absolute wavelength scale.
- Goal is to center targets routinely in science apertures to a precision of +/- 0.1 arcsec (= +/- 10 km/s).
- Throughput is relatively insensitive to centering due to large size of science apertures; centering of +/- 0.3 arcsec necessary for >98% slit throughput.

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COS FUV Spectroscopic Modes

Grating	Nominal Wavelength Coverage [a]	Wavelength Range per Exposure	Resolving Power $(R = \lambda/\Delta\lambda)$ [b]
G130M	1150 - 1450 Å	300 Å	20,000 - 24,000
G160M	1405 - 1775 Å	375 Å	20,000 - 24,000
G140L	1230 - 2050 Å	> 820 Å	2400 - 3500

[a] Nominal Wavelength Coverage is the expected usable spectral range delivered by each grating mode. The G140L grating disperses the 100 - 1100 Å region onto one FUV detector segment and 1230 - 2400 Å onto the other. The sensitivity to wavelengths longer than 2050 Å or shorter than 1150 Å will be very low.

[b] The lower values of the Resolving Power shown are delivered at the shortest wavelengths covered, and the higher values at longer wavelengths. The resolution increases roughly linearly between the short and long wavelengths covered by each grating mode.

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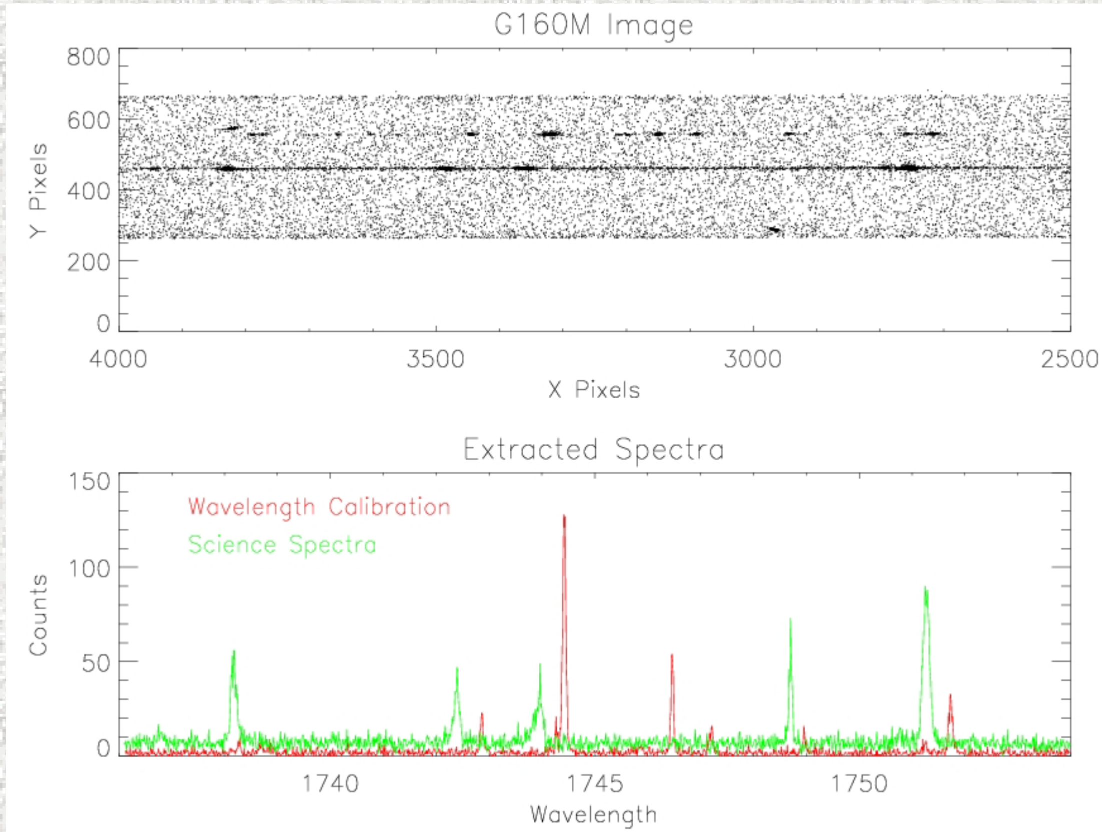
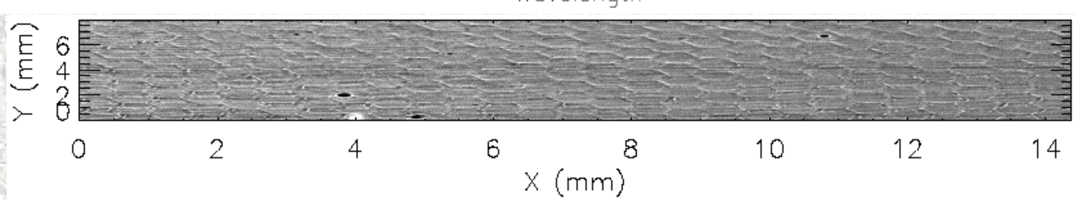


* N_2 purge data through FUV detector door window.



* Portion of FUV detector flat-field obtained during component-level testing.

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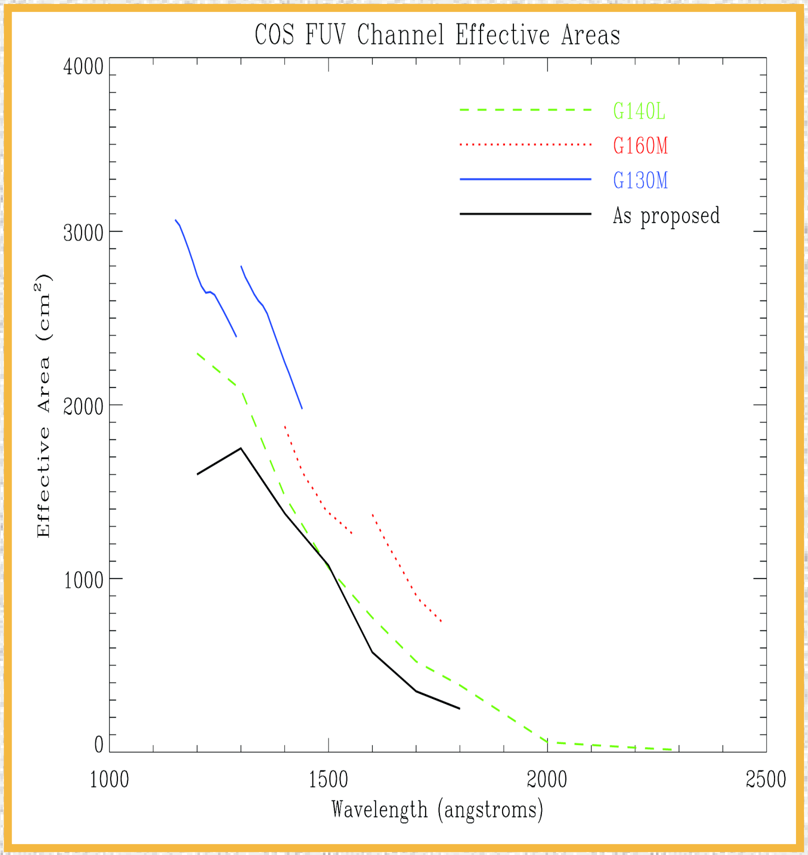
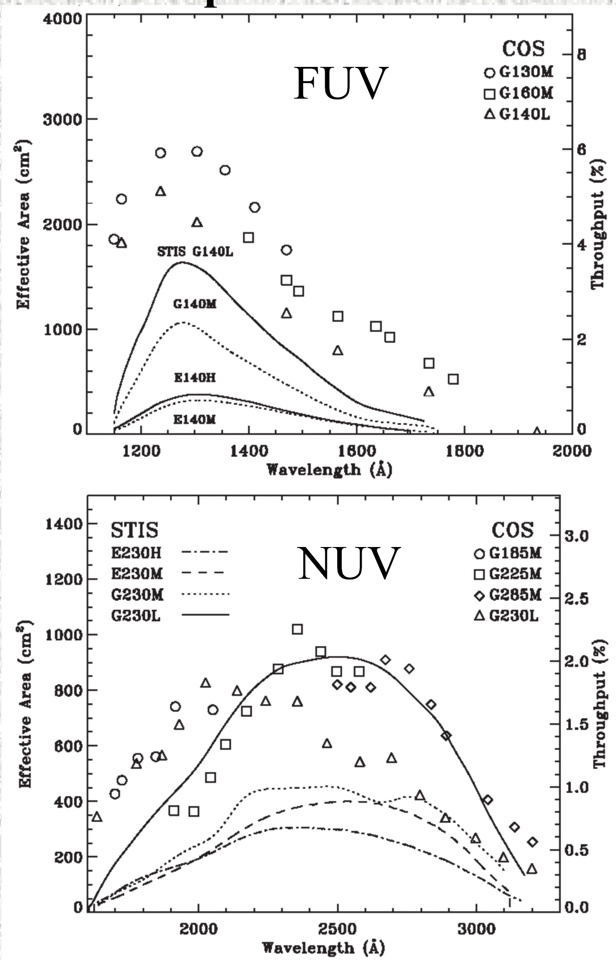
Effective Area



Comparison to STIS



Where do the photons go?

- FUV Throughput: 0.5 (HST OTA) × 0.8 (1 reflection) × 0.5 (groove efficiency) × 0.3 (DQE) = 6%
- This represents current "state-of-the-art" UV performance

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COS NUV Spectroscopic Modes

Grating	Nominal Wavelength Coverage [a]	Wavelength Range per Exposure	Resolving Power ($R = \lambda/\Delta\lambda$) [b]
G185M	1700 - 2100 Å	3 x 35 Å	16,000 - 20,000
G225M	2100 - 2500 Å	3 x 35 Å	20,000 - 24,000
G285M	2500 - 3200 Å	3 x 41 Å	20,000 - 24,000
G230L	1700 - 3200 Å	(1 or 2) x 400 Å	1500 - 2800

[a] Nominal Wavelength Coverage is the expected usable spectral range delivered by each grating mode, in three non-contiguous strips for the medium-resolution modes. The G230L grating disperses the 1st-order spectrum between 1700 - 3200 Å along the middle strip on the NUV detector. G230L also disperses the 400 - 1400 Å region onto one of the outer spectral strips and the 3400 - 4400 Å region onto the other. The shorter wavelengths will be blocked by an order separation filter and the longer will have low thruput on the solar blind detector. The G230L 2nd-order spectrum between 1700 - 2200 Å will be detected along the long wavelength strip.

[b] The lower values of the Resolving Power shown are delivered at the shortest wavelengths covered, and the higher values at longer wavelengths. The resolution increases roughly linearly between the short and long wavelengths covered by each grating mode.

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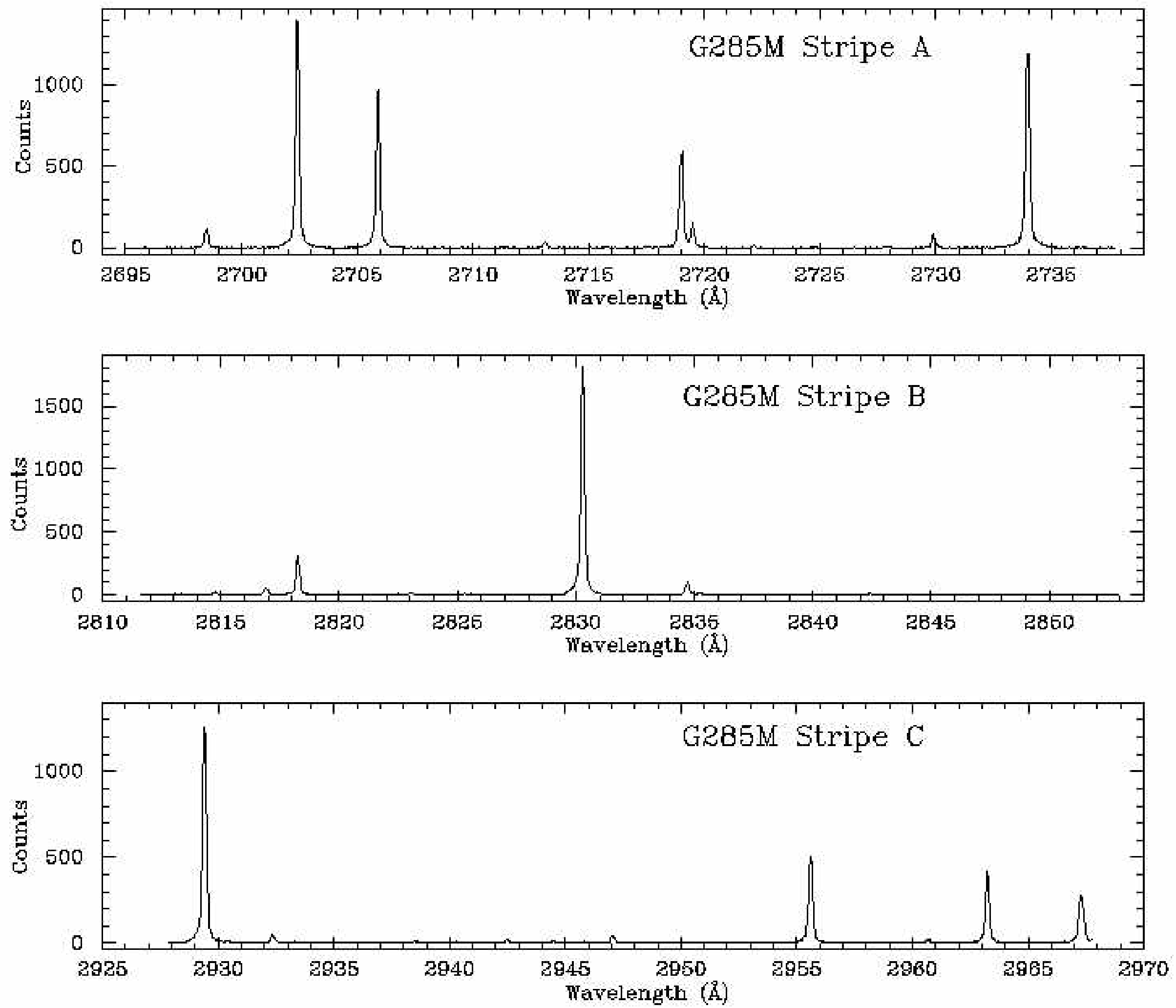

Single grating tilt yields 3 stripes

Resolution
R ~ 20,000

* NUV G285M PtNe Wavecal Spectra - N_2 Purge Data

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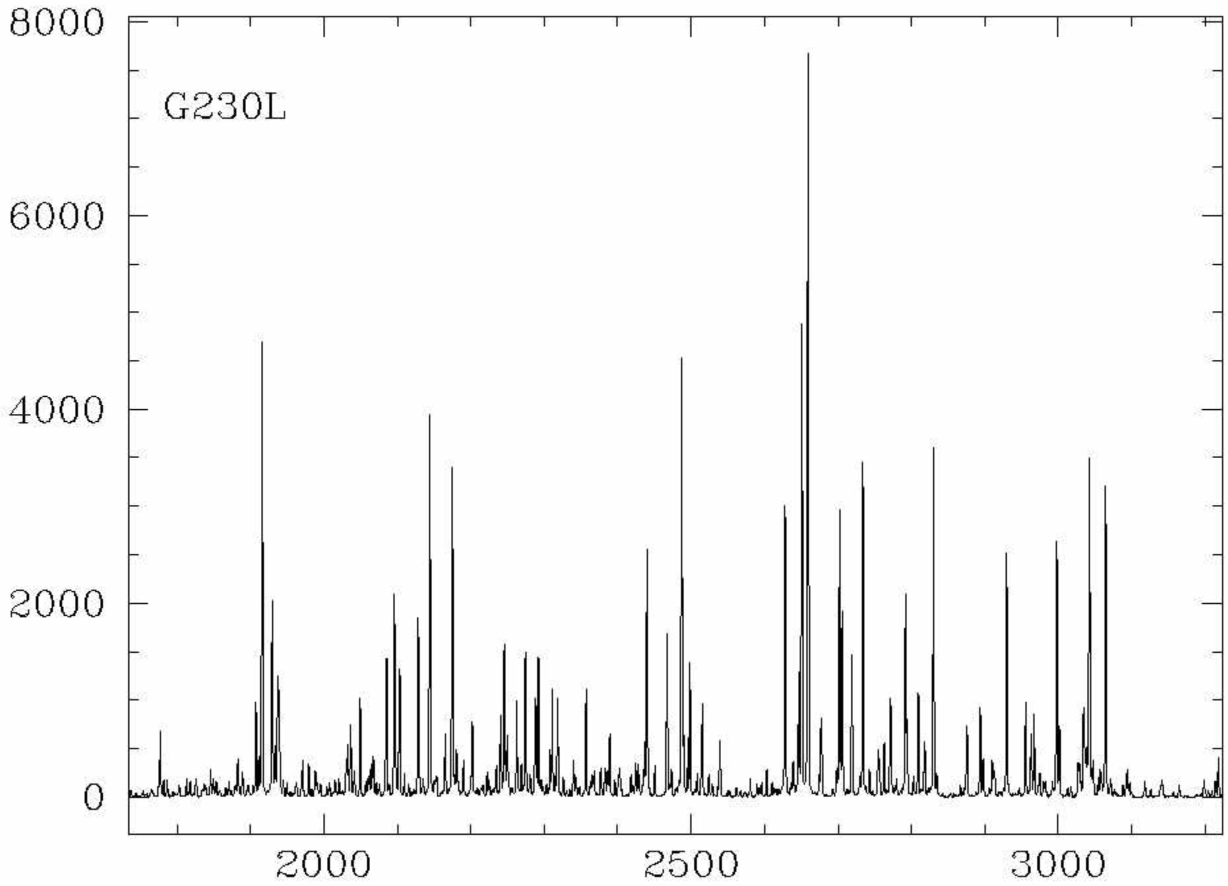

Resolution ~ 1.2 Å

Three grating tilts required
to cover the full range shown

* NUV G230L PtNe Wavecal Spectra - N_2 Purge Data

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- Cool, Warm and Hot Gas in the Cosmic Web and Galactic Halos
- QSO Absorbers, Galaxies and Large-scale Structures in the Local Universe
- Great Wall Tomography
- Studies of the HeII Reionization Epoch

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- Metal Deficient Chromospheres of Old Giants
- Atmosphere of a Transiting Planet
- Accretion Flows and Winds of Pre-Main Sequence Stars
- Alien Dwarfs
- Activity of Solar Mass Stars from Cradle to Grave

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- Search for Hydrocarbons and Nitriles in Pluto's Atmosphere
- Pluto's Mid-UV Reflectance
- Spatial Distribution of Io's Atmosphere
- Imaging of Mid-UV Emissions from Io in Eclipse
- Deep Search for an Oxygen Atmosphere on Callisto
- NUV Spectra of Bright Kuiper Belt Objects

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- Warm and Hot ISM in and Near the Milky Way
- Cold ISM

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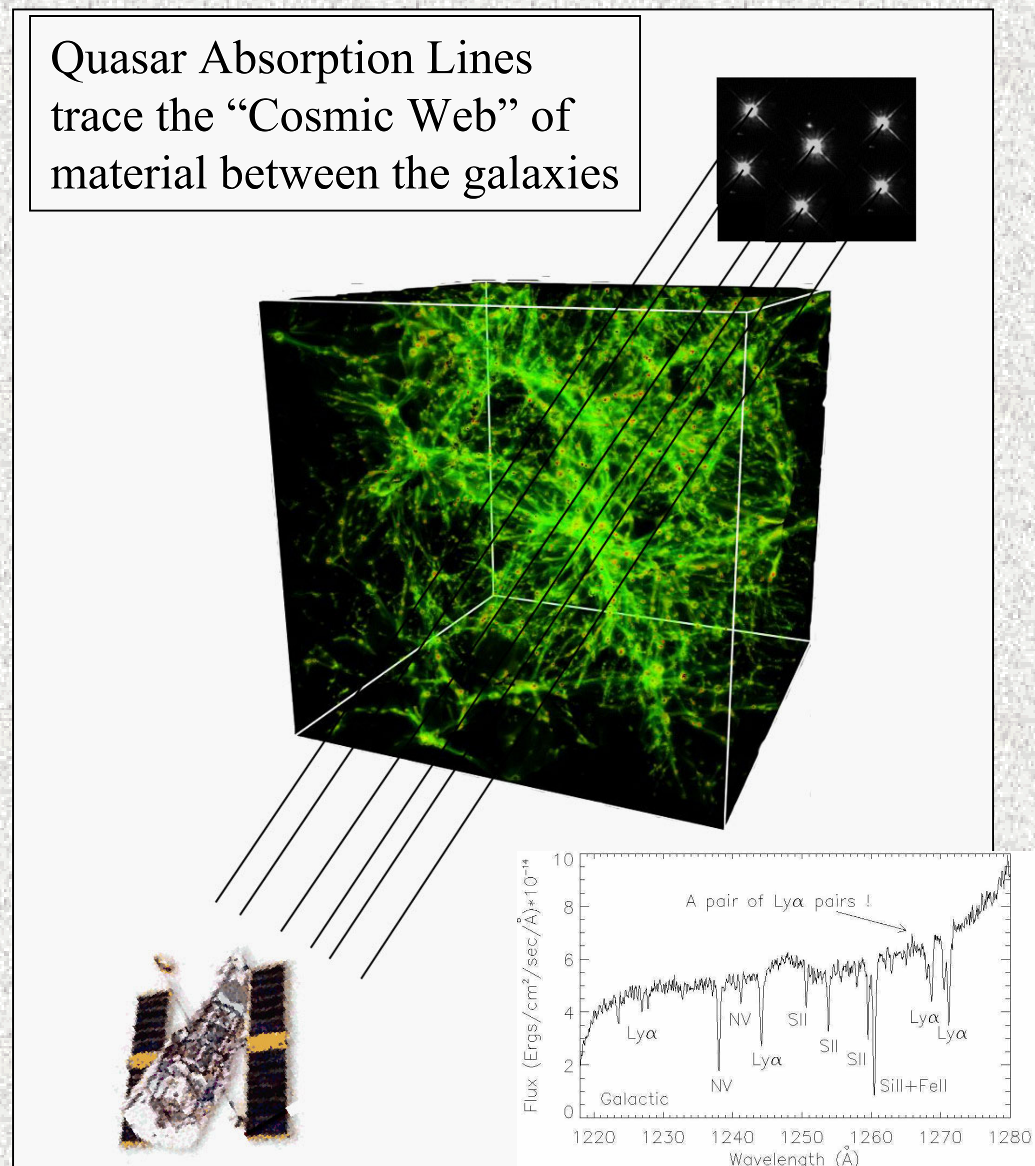
COS will study:

- Large-scale structure by tracing Hydrogen Lyman α absorptions
- Formation of galaxies
- Chemical evolution of galaxies and the intergalactic medium
- Hot stars and the interstellar medium of the Milky Way
- Supernovae, supernova remnants and the origin of the elements
- Young Stellar Objects and the formation of stars and planets
- Planetary atmospheres in the Solar System



- Visualization concept from Schiminovich & Martin
- Numerical simulation from Cen & Ostriker (1998)
- Songaila et al. (1995) Keck spectrum adapted by Lindler & Heap

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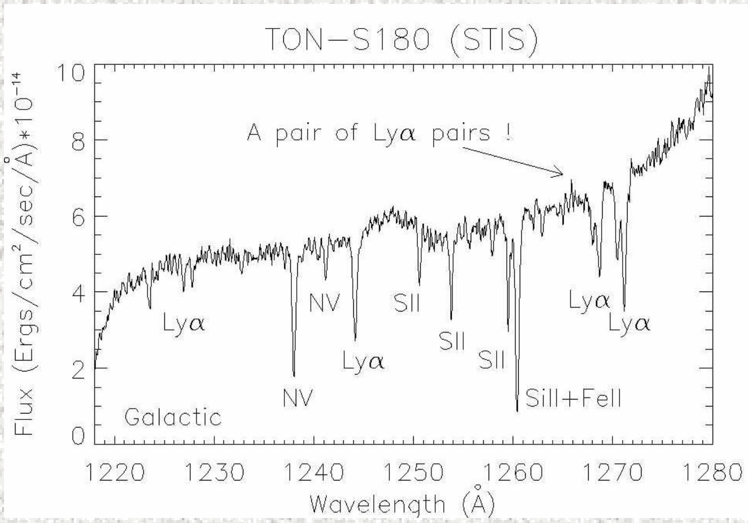
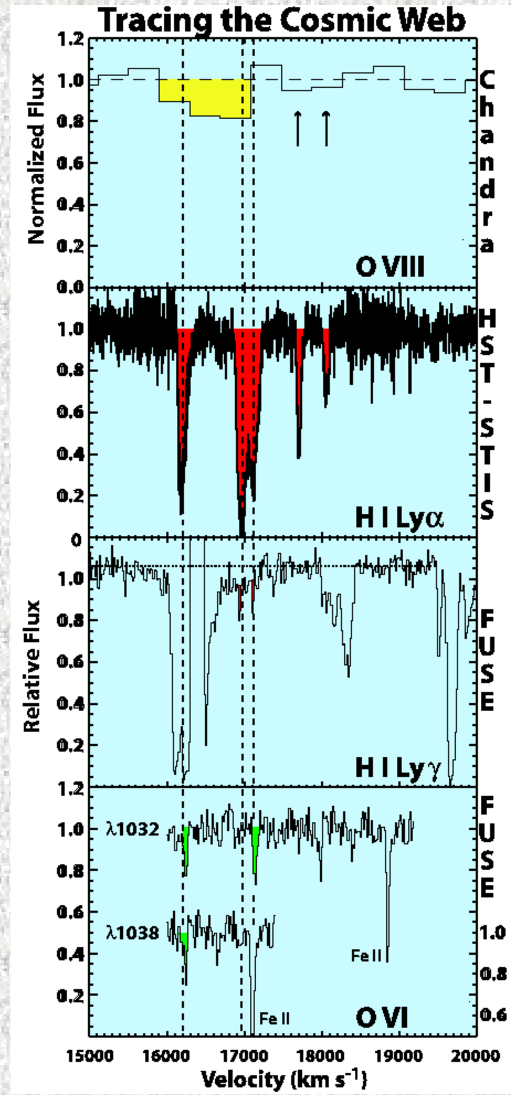
1. Large-scale structure, the IGM, and the origin of the elements



• STIS G140M spectrum (resolution ~ 19 km/s) from Penton et al. (2001) showing low-redshift intergalactic Lyman α absorbers along the sight-line to QSO TON-S180, including a pair of Lyα pairs. Significantly lower resolution would mistake the "pair of Lyα pairs" as just two broad components, leading to over-estimates of the gas temperature and under-estimates of the true H I column density.



• Comparison of Chandra, HST-STIS, and FUSE spectra of an absorber along the sight-line to PKS2155-304 (from Shull et al. 2003, Fang et al. 2002). COS will obtain complementary spectra toward the ~150 QSO sight-lines observed by FUSE where O VI absorption has been detected. COS will extend the characterization of Lyα absorbers and associated metal lines to higher redshifts for measuring abundances and metal production rates.

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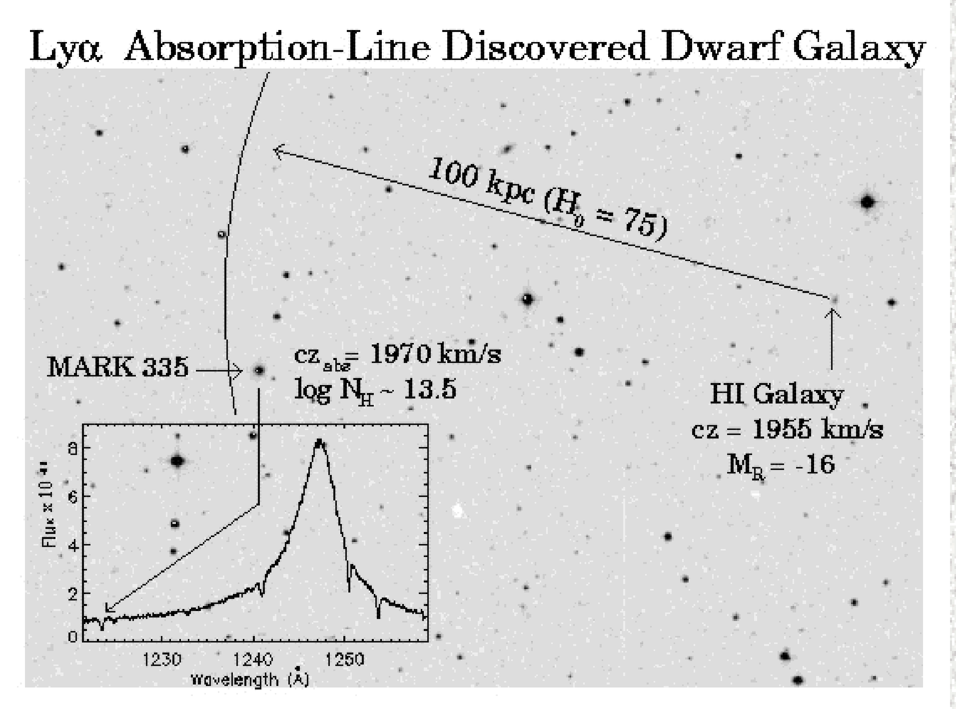
1. Large-scale structure, the IGM, and the origin of the elements



- From Stocke (1997)

- The Lyman α Forest
  - conduct baryon census of the IGM
  - derive space density, column density distribution, Doppler widths, and two-point correlation functions
  - test association with galaxies and consistency with models of large-scale structure formation and evolution
  - tomographic mapping of cloud sizes and structure, requiring multiple nearby QSO sight-lines

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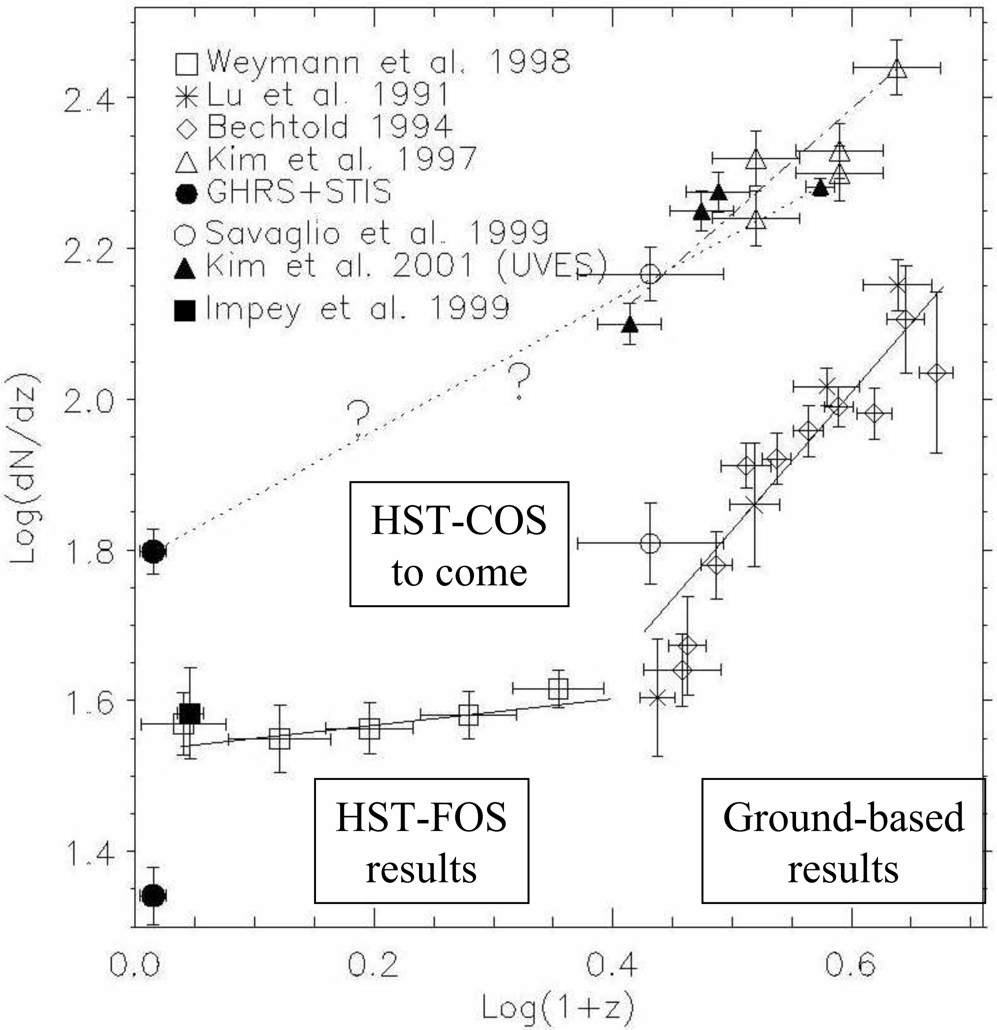

- The distribution of the frequency, dN/dz, of strong and weak Lyman α absorbers with redshift (from Shull et al. 2001). Strong absorbers (log $N_{HI} > 14$) were studied in the UV with FOS at low spectral resolution, but virtually nothing is known about the distribution of the far more numerous weak absorbers at far-UV and near-UV wavelengths.
- High signal-to-noise COS UV spectra are needed to determine the distribution of weak absorbers (log $N_{HI} \geq 13$) over the redshift range z = 0.1 - 1.6.

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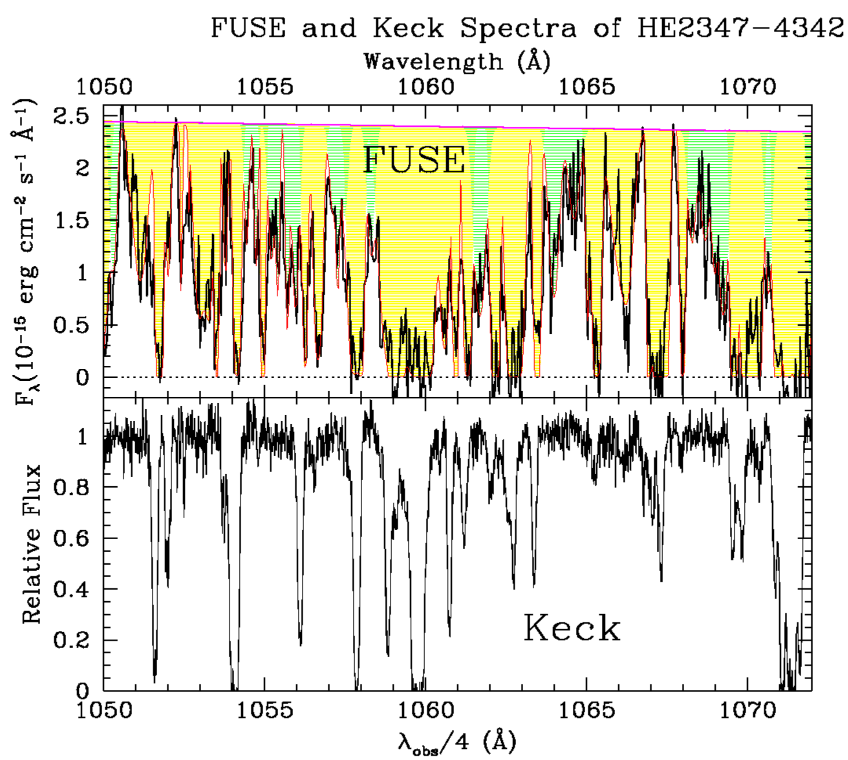
1. Large-scale structure, the IGM, and the origin of the elements

- **He II Gunn-Peterson effect**
  - trace the epoch of reionization via redshifted He II Ly α (λ304 Å) absorption in low-density IGM at redshifts $z > 2.8$
  - determine whether He II absorption is discrete or continuous
  - allows estimates of "ionization correction" in order to count baryons in the IGM
  - allows estimate of flux and spectral shape of background ionizing radiation from quasars and starbursts

• He II and H I absorption toward HE2347-4342 (from Shull et al. 2003). The high He II opacities indicate that the epoch of reionization of He is significantly delayed from that of H.



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