Science Objectives for the Cosmic Origins Spectrograph

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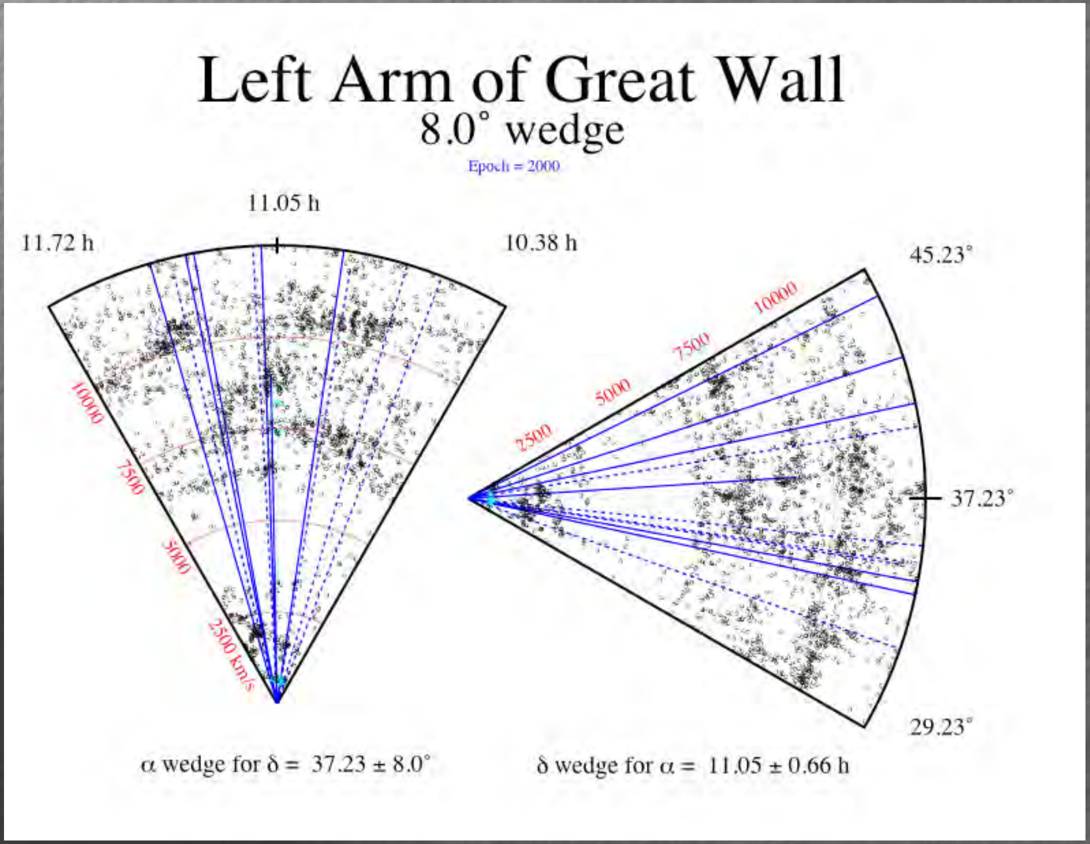
Four key science questions — united by the theme of Cosmic Origins

- What are the origins of large-scale structure and the intergalactic medium?
- How do galaxies form and evolve?
- What are the interstellar origins of stars?
- What are the properties of extrasolar planets

The origins of large-scale structure and the intergalactic medium

- COS will quantify the cosmic web of matter through UV absorption-line spectroscopy.
- Over 80 – 90% of the baryons reside in the cool and warm IGM, with 40% in the IGM with $T > 10^6$ K.
- 10% of the baryons are in stars and galaxies.
- COS will probe the cool photoionized IGM and the warm part (10^5 – 10^6 K) of the warm-hot IGM.
- COS will obtain information on the physical state and distribution of ~60% of the baryonic matter.
- Imaging is only sensitive to ~10% of the baryons.

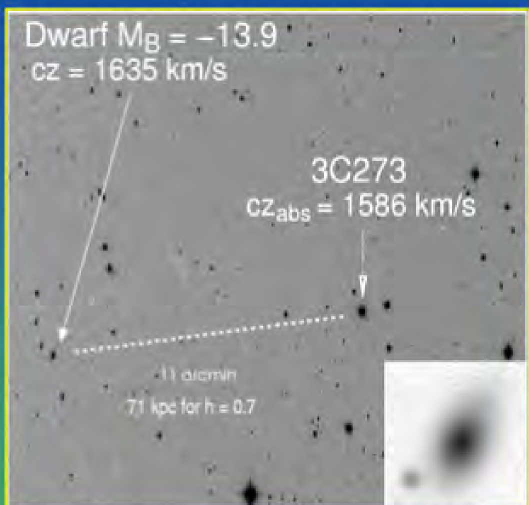


- Dashed lines indicate lines of sight to QSOs accessible to COS at S/N = 20 in <5 orbits (<3 orbits for the solid lines).
- Factor of ~10 better sensitivity results in 50 – 100 more background QSOs.
- Unprecedented sampling of the IGM.
- Detection of absorbers in the most diffuse IGM.
- Identification of weak tracers of Z enhancement of the universe over time.

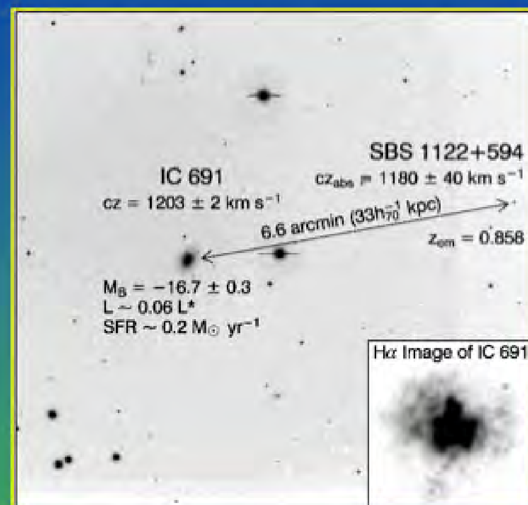
Formation and evolution of galaxies

- Envelopes around galaxies out to radii of 100 – 200 kpc are a common prediction of galaxy formation models.
- Absorption-line experiments trace the low-density gas as it cools and falls onto the galaxy.
- Stars and supernovae eject enriched matter into the ISM, thereby heating the gas to high temperatures.
- The heated gas can escape, enriching the IGM with heavy elements.
- The only method for directly measuring the properties of the escaping gas relies on searching for absorption from the wind gas against a bright background QSO.

Dwarf Galaxy Winds



Reproduced from Stocke et al. 2004, ApJ, 609, 94.



Reproduced from Keeney et al. 2006, in prep.

3C 273 / 0.004 L* Dwarf

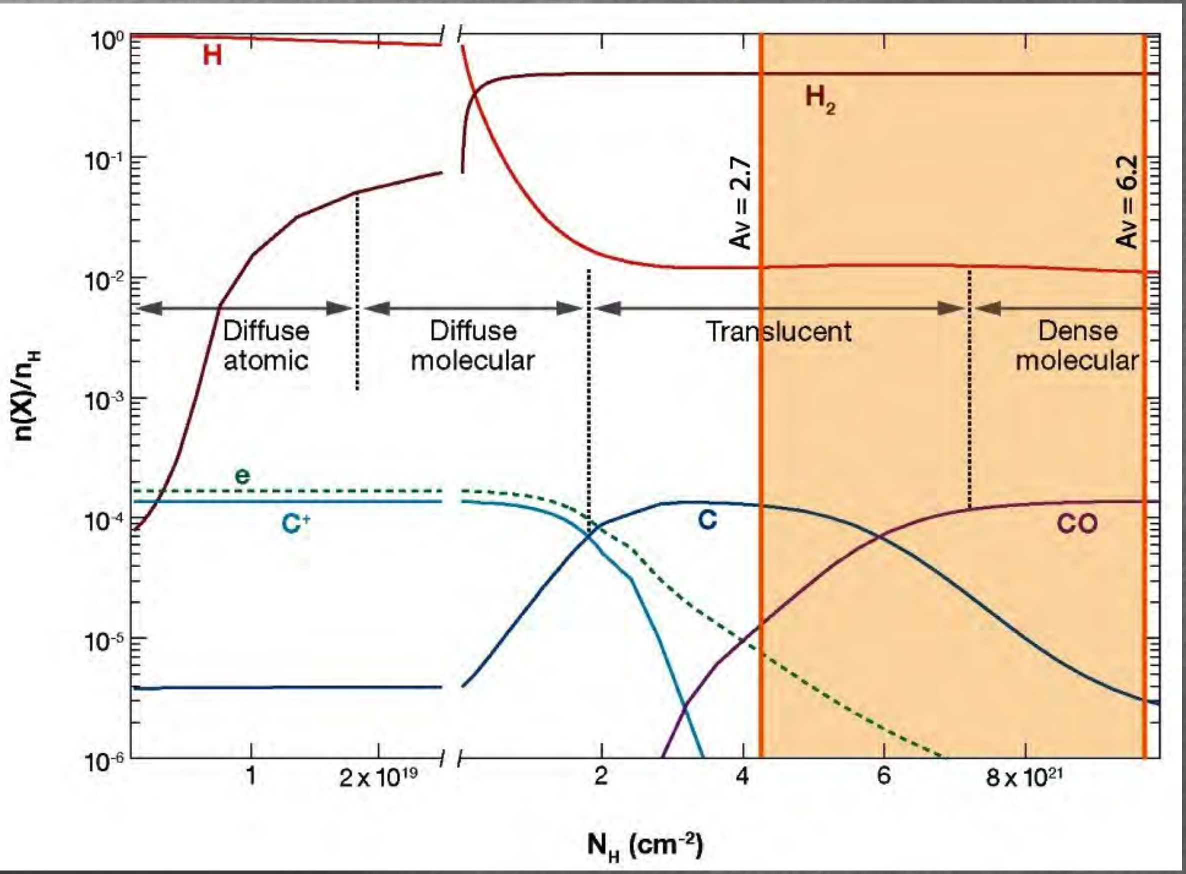
SBS 1122+594 / IC 691 (0.06 L*)

Dwarf galaxies produce unbound winds!

- **Observations of QSOs near dwarf galaxies reveal mass and energy transport into the IGM from unbound outflows.**
- **Origin of the mass versus metallicity relation of galaxies.**
- **Previously limited to a handful of objects with STIS.**
- **COS will increase the available number of QSO sightlines by a factor of >100.**

Interstellar origin of stars

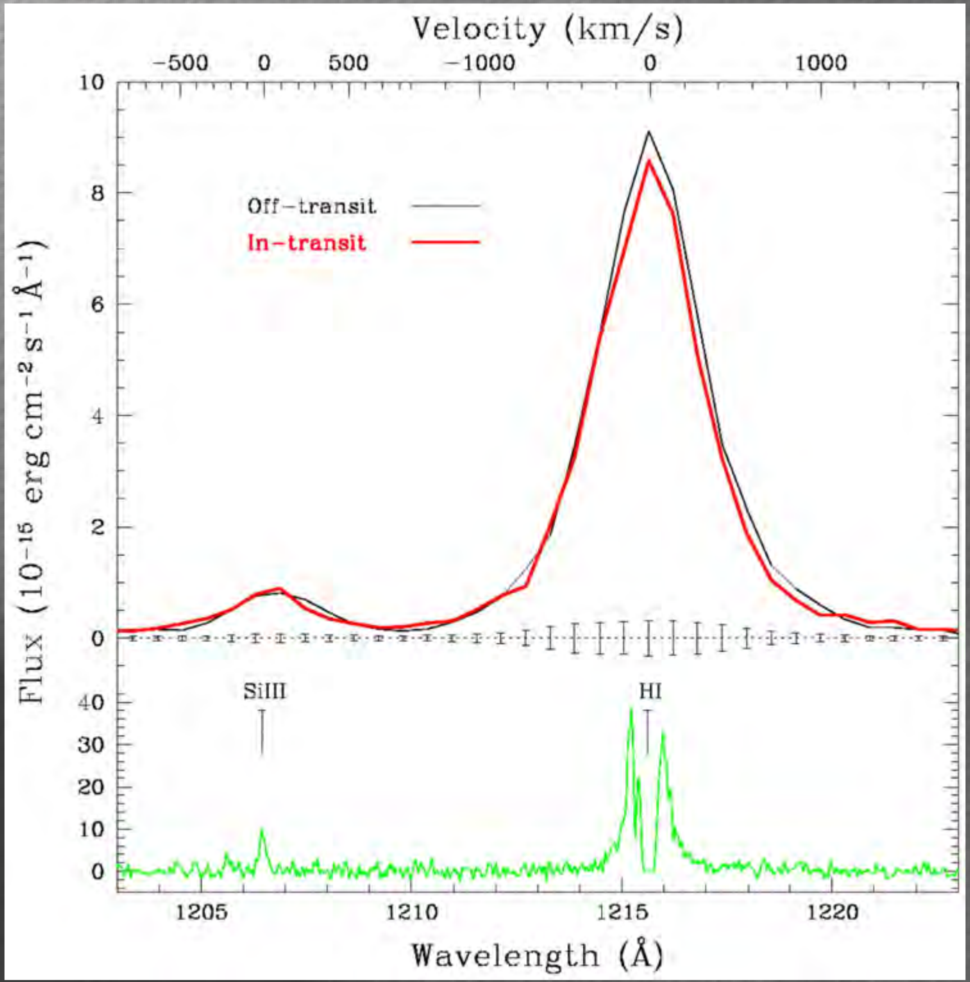
- **COS will study the physics and chemistry in the cold gas and dust phases of the ISM.**
- **Star forming regions are categorized as diffuse atomic, diffuse molecular, translucent, and dense molecular clouds.**
- **Translucent clouds mark the transition between diffuse and dense molecular clouds where star and planet formation begins.**
- **Only COS can probe sightlines dominated by translucent clouds.**



- **Classification of interstellar clouds on the basis of the forms of H and C.**
- **COS can probe diffuse molecular clouds at greater optical depth than any previous UV spectrograph, and can observe translucent clouds for the first time.**
- **COS will yield extinction curves very deep in the clouds and measure grain size and composition, as well as atomic and molecular abundances.**

Properties of extrasolar planets

- **COS will investigate many transiting extra-solar planets newly found by Kepler and other missions.**
- **UV spectroscopy is a prerequisite for understanding the physical conditions and the chemistry in the atmospheres of close-in, extra-solar planets.**
- **STIS detected an extended atmosphere via excess absorption of background star light in HD 209458b.**
- **The much higher sensitivity and low instrumental background of COS will enable fundamentally new advances in extra-solar planet research.**



- **Comparison of STIS off-transit and in-transit spectra for the Si III and H I in HD 209458b.**
- **The detection of significant hydrogen evaporation implies a transformation to planets with a hydrogen-poor atmosphere.**
- **COS will be uniquely positioned to better pursue quantification of mass loss rates by UV absorption-line spectroscopy.**

Impact of COS on astronomy in general

- **Solar system: composition and structure of atmospheres of planets and their satellites.**
- **Star formation: accretion processes and jet formation around young stars.**
- **Stellar astrophysics: coronae and winds around cool and hot stars; geometry of binaries.**
- **Stellar populations: age dating and IMF determinations of young and old star clusters**
- **AGN: masses of black holes and structure and kinematics of circumnuclear gas**

Unique capabilities offered by COS

- Maximum spectroscopic sensitivity in the UV.
- No other NASA mission with a high-resolution, high-sensitivity spectrograph is in development.
- COS is the only instrument with significant detector response around and below Ly-α.
- COS uses time-tag mode, where the detector time-tags each count.
- COS will re-enable scientific areas that were shut out after STIS' failure.