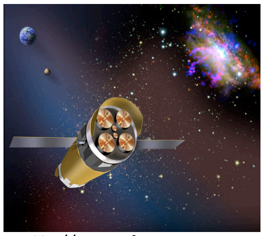
Con-X and JWST:

NASA's Next Generation X-ray and Infrared Great Observatories



http://conx.gsfc.nasa.gov
(See Michael Garcia's poster for mission information)

Great synergy has been enjoyed between NASA's current Great Observatories and we expect that this will continue in the next decade with the concurrent operation of both Constellation-X and JWST. Con-X plays an essential role in JWST science goals #1-#3 (#1: First Light and Reionization, #2: The Assembly of Galaxies, and #3: Birth of Stars/Planetary Systems). Here we highlight a few science areas (focusing on goals #1 and #2 although important constraints on star formation and metal production also address goal #3). These investigations are in direct synergy with the Con-X goals to understand the evolution of supermassive black holes, to constrain dark matter and dark energy via studies of clusters of galaxies, and to perform a census of hot baryons in the Universe.

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How do black holes grow in galaxies at the time of reionization?

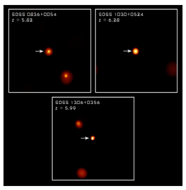
Are we missing a large fraction of the actively accreting supermassive black holes in the Universe?

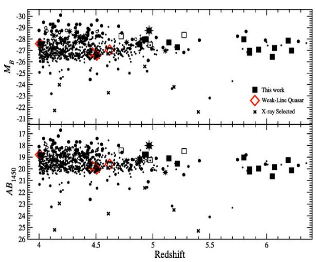
How are black holes affecting the growth of their host galaxies?

How does the large-scale structure of the Universe evolve to that seen today?

High-redshift (z>4) AGN

Chandra and XMM programs the last several years have placed good X-ray photometric constraints on a population of high-z AGN that are well-suited for high spectral resolution studies by Con-X with exposures of 30-100 ks (e.g., Brandt et al. 2002; see figure to the right and Bechtold et al. 2003).





From Shemmer et al. (2006b): X-ray selection has provided lower-luminosity AGN at fairly high redshifts as compared to current optically-selected high-z AGN.

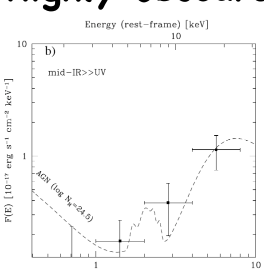
• There has been recent rapid increase in our knowledge of the high-redshift X-ray universe: the number of X-ray detections of z>4 AGN has increased from 6 in 2000 to more than 100 today. These observations probe the inner regions of AGN when the Universe was less than 1 Gyr old. X-rays can efficiently reach AGN near the epoch of reionization and are essential for a proper census of AGN at z = 6-10.

•What is the nature of AGN at z>6? Con-X and JWST must work in unison to study very high redshift AGN as they likely will be viewed along dust-obscured sight lines (e.g., Hines et al. 2006). X-ray spectra will measure the unobscured emission and IR spectra will yield metallicities and dust properties. Note that classical diagnostics (Hα/[NII], Hβ/[OIII]) will be available with JWST to z≈6.6 and beyond.

•Do the accretion properties of AGN evolve strongly at early times in the Universe? Con-X and JWST will test whether the lack of difference seen at low to high redshift in the X-ray and rest-frame optical properties of AGN continue upon closer scrutiny (e.g., Vignali et al. 2006 and Hines et al. 2006 but see also Kelly et al. 2007). For instance, using the FWHM of Hβ and/or Mg II jointly with measurements of the hard X-ray slope may provide crucial constraints on the history of black hole growth at the end of the dark ages (e.g., Shemmer et al. 2006a) where only crude measurements exist now.

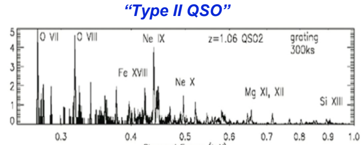
•What is the nature of more typical, lower-luminosity AGN at z>4? Most lower-luminosity high-z AGN have been detected in moderate-depth X-ray surveys with very few X-ray counts: Con-X, with its large collecting area, will measure detailed X-ray spectral properties. This forms an important complement to current high-z studies of broad-line, SDSS-like, Type 1 QSOs.

Highly-obscured AGN



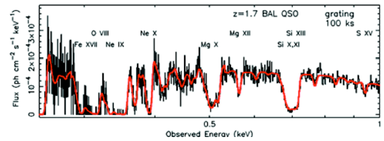
From the Chandra/Spitzer work of Daddi et al. (2007):
The data points are stacked X-ray spectral constraints of mid-infrared excess sources. The overplotted line is an AGN model with $N_H = 10^{24.5}$ cm^{-2} (Gilli et al. 2007). Through the mid-infrared excess one is able to identify heavily obscured AGNs which are missed at shorter wavelengths (e.g., Fiore et al. 2007; Daddi et al. 2007) and JWST will ensure that we do not miss any such sources and that we understand the contribution to the IR flux from star formation. X-rays are required to confirm whether AGN are Compton-thick or not: Con-X will provide these constraints.

Con-X simulations of faint z=1.06 "Type II QSO"



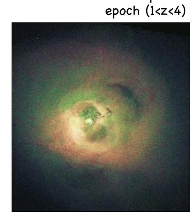
•What is the true nature of the obscuring material in the most obscured AGN and how much radiation is being re-emitted after reprocessing by dust? Con-X's capabilities over the 1-40 keV bandpass (XMS and HXT) will measure the *direct* measure of the power of the central source and will also constrain the nature of the obscuring material for the most highly obscured sources (via measurement of the Fe K line and reflected components in the X-ray spectrum). JWST will measure the *re-emitted* nuclear emission with moderate resolution spectroscopy (required for decoupling star formation contributions). Note that there may be a significant population of obscured (perhaps Compton-thick) AGN required to explain the >50% of the 5-10 keV cosmic X-ray background that remains unexplored by Chandra and XMM. It is only with a combination of JWST and Con-X that we will know if a source is truly Compton thick because X-rays probe the absorbing column (a weak X-ray detection in an IR bright source indicates Compton thick material; e.g., Daddi et al. 2007).

Black Holes & Cosmic Feedback



Con-X simulation of a BAL QSO at z=1.7 (S. Gallagher).
Con-X will reach the powerful AGN outflows in the quasar epoch (1<z<4)

•What is the origin of the strong correlation observed between black hole mass and stellar bulges in galaxies? High spectral resolution studies with both observatories will reveal the AGN winds that likely move into the surrounding intergalactic medium (IGM) and heat it sufficiently to prevent it from condensing onto galaxies (e.g., Scannapieco et al. 2005). Large scale-structure simulations *require* this AGN feedback to regulate the growth of massive galaxies (e.g., Di Matteo et al. 2005, Croton et al. 2006). For AGN in centers of clusters, where the energy output of the AGN is trapped in the ICM, Con-X's non-dispersive X-ray spectroscopy will be required to probe hot plasma in cluster cores (Begelman et al. 2005), forming an important comparison with the JWST-determined star formation histories of galaxies.



Perseus Cluster of Galaxies (Chandra image):
Con-X will provide spatially-resolved X-ray spectroscopy of the hot gas in these systems, providing detailed density and temperature maps of the energy input into the ICM.

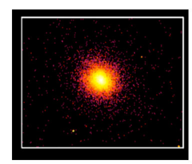
Large Scale Structure of the Universe

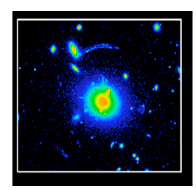
•Where does most of the matter in the largest gravitationally-bound structures in the Universe reside? For JWST to obtain a complete picture of formation of galaxies and large scale structure, it will be required to know where the hot X-ray emitting gas resides. Con-X will measure the hot [10^6 - 10^8 K] Intracluster Medium (ICM) and JWST will measure the galaxy starlight; (see figure to the right). The observatories must work together as occasionally one even finds mass peaks without galaxies present (e.g., Abell 520; Mahdavi et al. (2007).

•How are the heavy elements distributed and made? The spatially-resolved spectroscopic capability of Con-X will enable mapping of the metals in the multiphase ICM whereas JWST will provide complementary measurements of the galaxies in clusters. The distribution of various heavy elements in the ICM folds into galactic wind enrichment and supernova yields, critical to a full picture of galaxy evolution (e.g., Loewenstein 2006).

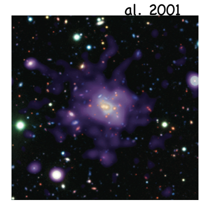
•What is the missing link between the galaxy overdensities at z≈2-3 and the well-formed galaxy clusters at z≈1? JWST and Con-X will work in unison to identify high-redshift (2 < z < 3) proto-clusters and groups via multi-object spectroscopy of member galaxies (JWST NIRSpec) and constraint on the dominant baryonic component, the hot ICM (Con-X XMS). Note that Spitzer has already identified proto-cluster candidates at z ≈ 2 (e.g., Brodwin et al. 2005).

•What can clusters tell us about the evolution of the Universe (cosmology)? JWST will measure the evolution of the stellar mass fraction (1/7 of the baryonic mass in clusters) whereas Con-X will measure the evolution of the X-ray gas mass fraction (6/7 of the baryonic mass in clusters). Together this will provide a complete census of the baryons in clusters of galaxies permitting detailed constraint of dark matter and dark energy in a highly complementary fashion to other techniques available circa 2015-2020. (e.g., Allen et al. 2007)





X-ray (Chandra) and Optical (Hubble) images of the giant galaxy cluster MS2137.3-2353 (z=0.313) from Allen et al. 2001



RDCS 1252.9-2927: z=1.2 cluster (Rosati et al.2004)

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