SOME IDEAS TO HELP SEED THE PANEL DISCUSSION ON WEDNESDAY, MAY 24

Each panelist was asked to outline potential Great Observatory related projects that they believe would most benefit future telescopes.

=======================================

GROUND-BASED OPTICAL AND IR OBSERVATIONS

Here are two potential projects related to GSMT.

1. First light. We need a Spitzer survey to find more galaxies like this:

http://www.journals.uchicago.edu/ApJ/journal/issues/ApJL/v618n1/18798/brief/18798.abstract.html

These will be GSMT targets for spectroscopy, for example of He 1640.

2. Star formation history of nearby galaxies. We need to extend the ACS Nearby Galaxy Survey HST Treasury Program:

http://www.stsci.edu/observing/phase2-public/10915.pro

GSMT will observe the main sequence turnoff of these and more galaxies like them within 5 Mpc. HST data is needed for the giant branches and full field CMD.

Other potential topics are outlined in:

http://www.aura-nio.noao.edu/gsmt_swg/SWG_Report/SWG_Report_7.2.03.pdf
and
http://www.aura-nio.noao.edu/gsmt_swg/SWG_Oct05/

- Jeremy Mould

====

ALMA

1. The main preparatory work that the Great Observatories can do for ALMA comes down to one word: Targets. ALMA will be an incredible leap (close to two orders of magnitude) in sensitivity, spectral coverage, and spatial resolution over existing (sub)mm facilities. It's ability to image cool gas and dust, with exquisite fidelity, sensitivity, and spatial resolution, will be truly unique, and represents the recognized next major step in the study of planet, star, and galaxy formation throughout the Cosmos. The main limitation of ALMA is the relatively small Field-of-View, especially at the high frequencies (about 15" diameter at 350 GHz). Hence, ALMA will rely heavily on pre-defined samples of objects. Key samples include:

(i) 'normal' star forming galaxies out to z ~ 1 to 3 (eg. the Spitzer 24 micron samples and/or the LBGs)

(ii) luminous starbursts out to cosmic reionization, z > 6 (eg. Lyalpha emitting galaxies (LAEs))

(iii) Dust-obscured AGN (type-II) at low and high z (eg. Xray or Spitzer selected samples)

(iv) Galactic proto-planetary disks and dark molecular clouds (eg. proplyds and proto-stellar systems found by HST and Spitzer)

2. Another important point is that Gunn-Peterson absorption essentially precludes study of objects within cosmic reionization at (observed-frame) optical wavelengths. Hence, the study of the first galaxies and AGN, which is one of the prime scientific drivers for all future telescopes, will be the regime of near-IR through radio wavelengths, and hard Xrays. Definition of samples of near-IR drop-outs, and z > 6 LAEs, enables crucial ALMA follow-up to image at sub-kpc resolution the molecular and atomic gas, and dust -- the fundamental fuel for star formation.

One thing that has become clear over the last decades is that proper study of galaxy evolution requires a pan-chromatic approach, with the optical revealing the stars and warm gas, the IR and (sub)mm revealing the cool gas and dust, the cm revealing the star formation, and the Xrays revealing the hidden AGN. Fortunately, with the advent of ALMA, the EVLA, and the current and future Great Observatories, such a panchromatic view of galaxy formation, right back to the very first galaxies within reionization, is within reach.

- Chris Carilli

========================

PRESENT TELESCOPES - HST

Random thoughts on supporting projects from HST, Spitzer & Chandra
----

JWST

It is worth considering HST, Spitzer & Chandra observations in or near the JWST continuous viewing zone (CVZ; within 5 degrees of the Ecliptic poles).

Near the South ecliptic pole, HST observations are already scheduled to observe some LMC fields to allow JWST astrometric calibration. Proper-motion is a bit of an issue.

The North Ecliptic Pole (NEP) (18h, +66:33:38) is better from the point of view of deep extragalactic observations, since it doesn't have contamination from the LMC. Very little has been done by HST near the NEP. It is not generally considered ideal for extragalactic work because the extinction is not all that low. But given the JWST CVZ advantage, it might be worth some investment. Deep observations shortward of 0.8 microns with HST will help JWST distinguish very high redshift Lyman-break objects from foreground contamination.

There are some interesting targets near the JWST CVZ:

    Abell 2218 -- Lensing cluster
    HS1700+64 -- z=2.3 QSO well-studied for He GP test; surrounding
        protocluster
    Spitzer IRAC Skydark field

The skydark field may be of particular interest for long-term monitoring of AGN, since it is regularly observed by Spitzer. Spitzer + JWST will provide a long near-IR time baseline.

Planet Finding (SIM & TPF in particular)

Constraints binarity of potential targets via FGS would presumably help refine the target lists for SIM and TPF. Close binaries may be hard to use for planet searches.

Constraints on Exo-zodiacal dust from Spitzer are critical. While exo-zodi disks orders of magnitude fainter than those that can be seen by Spitzer are still a problem for the TPFs, Spitzer will greatly improve our understanding of the demographics and evolution of exo-zodi disks. HST studies of exo-zodi disks are also valuable, and may help to reveal how planets shape these disks.

HST is testing the concept of spectral deconvolution to improve our ability to detect planets amidst the speckles from a nearby star.

JDEM

Continued HST high-z supernova searches are essential, whether or not JDEM emerges as a SNAP-like mission. The HST observations are helping to inspire new ways of looking at the data and test for systematics. HST can also make further progress in constraining dark energy by improving constraints on H0 from local measurements.

Planck

Planck is expected to find about 40000 clusters via the Sunyaev-Zeldovich effect. HST and Chandra will be important components of the followup (and Spitzer too if it is still around).

- Harry Ferguson

The Chandra X-ray Observatory

Chandra provides the only sub-arcsecond spatial resolution in X-rays for at least the next 15 years. We need to perform sufficient high-resolution studies to allow Con-X, with its much higher throughput, to facilitate deeper, more detailed investigations without the high spatial resolution.
The following are examples:

1) X-ray/radio Jets in Quasars: The structure of these jets is very detailed and often unresolved even with Chandra. The spatial resolution of Con-X will prevent the detection of many/most of these jets and their emission will be convolved with the quasar itself.
The Chandra/HST/Spitzer combination define the jet SEDs and thus strongly constrain the emission mechanisms, jet composition and answer long-standing questions concerning jets. Chandra alone provides information on the electron spectrum and very low and very high energies. Chandra also provides a probe of the Cosmic Microwave Background (CMB), whose photons interact with those in the jet to generate X-ray emission. Jets can be found to very high redshift with Chandra since the CMB photon density increases with redshift at the same rate as the surface density of the resulting emission decreases.

2) Central Structure of extended sources: Clusters, Galaxies, Supernova Remnants (SNR): Chandra has given birth to new "industries" in the study of extended X-ray sources, including finding/not the central compact objects of SNR, resolving ultra-luminous X-ray sources from within galaxies, identifying sharp transitions in temperature, magnetic field, density and emissivity. Chandra is the only way to directly observe the positions and geometries of the shocks that are the main sources of heating and emission, constraining the energetics and facilitating modeling and the development of a broad-band picture. At a minimum, Chandra needs to observe these sources in sufficient numbers to be able to avoid or quantify the confusion in deeper, lower resolution studies with Con-X. For example, deep Chandra observations of a complete sample of clusters (only patchily covered in the archive to date).

3) Surveys wide/shallow to narrow/deep: the spatial resolution of Chandra is needed to isolate and uniquely identify X-ray sources. Con-X sensitivity is needed to obtain detailed spectra for the majority of X-ray sources found in medium deep and very deep surveys. Chandra needs to have found enough sources of all known source types to provide clean and unconfused samples for Con-X to observe in detail. For example, to understand, relate and characterise the variety of obscured AGN that contribute to the Cosmic X-ray Background, Con-X needs to study a sufficiently large sample already found but not studied in detail by Chandra/XMM-Newton.

-- Belinda Wilkes

Spitzer Space Telescope

The Spitzer cryogenic mission is currently predicted to last about five and half years. Cycle-4 will be a full cryogenic year and Cycle-5 will be the last cryogenic cycle, lasting 6-10 months. Spitzer is currently developing plans for a five-year extended mission that includes observations with the 3.6 and 4.5 micron IRAC channels and a vigorous archive program. A sampling of projects for the rest of the cryo-mission and extended mission are:

1. Complete spectroscopic surveys of star-forming galaxies at low and high redshift. Taking complete advantage of the galaxies discovered in the wide and deep imaging surveys that Spitzer has devoted several hundred hours to seems a must before the cryogen runs out.

2. Characterization of extra-solar planets. Kepler is expected to identify ~100 of these systems in its first year of operation. Ground-based surveys should also identify large numbers. This work could continue throughout the extended mission.

3. During the extended mission, a wide-area deep survey of ~250 square degrees to the same depth as SWIRE (3.5/6 microJy) in IRAC 3.6/4.5 microns would identify a large sample of $1 < z < 2$ galaxy clusters and moderately obscured AGN. Surveying the SDSS southern equatorial stripe to 10 microJy (5-sigma) at 3.5 microns would allow identification of > 1000 QSOs with $z > 4$.

4. Extended mission high latitude survey to assess scale-height of L/T dwarfs.

-- Lisa Storrie-Lombardi

==============================
X-RAY TELESCOPES OF THE FUTURE

1. Pinpointing the X-ray Confusion Limit with an Ultradeep Chandra survey

It is scientifically compelling to constrain the accretion history of high redshift AGN and star-forming galaxy population with deep Chandra surveys that may detect AGN to z=10 and normal/star-forming galaxies to z=1-2. Of equal importance is the characterization of the X-ray number counts of all X-ray emitting sources to fluxes below 1e-17 erg cm/s2/s1 to avoid confusion problems for future planned X-ray missions as this unique imaging capability of Chandra will not be repeated in the next 20+ years. For maximum benefit, such an ultradeep (5-10 Ms) Chandra survey field should also have deep HST and Spitzer imaging over the Chandra survey area, allowing host galaxies to be identified and characterized.

2. Significant enhancement of future Dark Energy cluster surveys with a large Chandra cluster survey program

X-ray studies of clusters of galaxies provide a crucial scientific complement to SN Ia and microwave background studies of dark energy. Currently we lack a sufficiently large sample of relaxed, high-mass clusters at higher redshift (0.3 < z < 1.2). Con-X may need to take snapshot X-ray images of ~2000 clusters and then determine which ones are sufficiently relaxed and/or lack AGN contamination. This imaging "pre-survey" may also require that Con-X exceed its design requirement of 15" angular resolution. The other avenue to enabling dark energy science is for Chandra to follow-up a large sample of clusters with its high angular resolution optics. Since there is currently no planned wide-field X-ray mission, the best avenue appears to be targeted follow-up of e.g., Sunyaev-Zeldovich surveys. Such high-redshift cluster surveys likely would not have sufficient numbers of candidates until ~2009, but at that point, a large time investment by Chandra in its "golden years" in targeted follow-up of such clusters would be highly beneficial to future DE constraints by X-ray missions.

3. Pathfinder atomic astrophysics with 500+ ks Chandra HETG observations

X-ray spectra are information-rich as all ionization stages of every abundant element contribute emission and/or absorption lines somewhere in the 0.25-10 keV bandpass. Analyses of existing Chandra grating datasets have demonstrated the power of X-ray spectroscopy, but cannot take full advantage of this power due to insufficient signal-to-noise in all but the strongest lines. The large amount of parameter space remaining to be probed in X-ray spectroscopy (illustrated by science program for the Constellation-X mission) suggests a number of important ultradeep (500+ ks) gratings projects that might be carried out as "atomic astrophysics" pathfinders to characterize important weak X-ray transitions. Such observations will become routine in the Constellation-X era and these apparent "subtle" astrophysical effects will need to be understood. As an example, I discuss a possible ultradeep observation of a coronal X-ray source and how better measurements of e.g., electronic densities, abundances and spectral models, using a variety of X-ray spectral diagnostics, will greatly improve our understanding of relevant atomic astrophysics before Constellation-X launches.

- Ann Hornschemeier

====
JWST

1) Complete the extra-galactic surveys. JWST will have sensitivity from 0.6 to 29 microns. JWST surveys will probably be done in the same wide, deep-wide, ultra-deep series as the HST/Spitzer/CXO surveys COSMOS, GOODS, UDF. A JWST ultra-deep field, needed to find an identify the first galaxies to form in the early universe, will probably be done in the HST UDF, so as to take advantage of the deep blue and UV and X-ray data, as well as the 70 & 160 micron MIPS observations. Likewise, a JWST deep-wide survey will overlap the GOODS areas, and a wide-area survey will need to be in the COSMOS field. In order to average over cosmic variance, additional fields would be useful, some of which do not have full wavelength coverage. For example, the Lockman Hole has a Msec XMM exposure, excellent

radio and pretty good Spitzer coverage, but no HST. Chandra would also be useful to get greater depth and spatial resolution. The Extended Groth Strip is another field with only partial wavelength coverage. The CDFS has no radio coverage. Herschel observations of these fields are also needed. Getting complete wavelength coverage in the existing surveys, and increasing the areas would be helpful.

2) Find z>10 quasars. One of JWST's science goals is to study reionization. JWST R~1000 spectroscopy of the brightest known source(s) at z>10 will reveal absorption by the intergalactic medium and map out the (perhaps extended) epoch of reionization. The ideal target source may reside in one of the above-mentioned surveys, or it may be found or identified by JWST. However, the SDSS z~6 quasars are bright and rare: about one per 600 square degrees. To find their progenitors at z~10 may require imaging 10s or 100s or square degrees in the infrared. If SWIRE is not big enough, we may need a larger Spitzer survey, perhaps 200 square degrees imaged by Spitzer in the post-cryogen mission.

3) Complete the galactic and planetary datasets. Within galactic and planetary science, the targets tend to be bright, and there is a risk that some objects observed by ISO have been skipped by Spitzer. The result is that we may have somewhat incomplete samples of objects observed in a homogeneous way, i.e. better Spitzer measurements of more difficult objects to go with not-so-good IRAS or ISO measurements of easy ones. Debris disk surveys are example where this is true. There should be a comprehensive look at the archives to determine where a modest investment of time could produce a homogeneous data set.

4) Photometric calibration sources in the JWST continuous viewing zone, which is 5 degrees radius around each ecliptic pole. Astrometric images of star clusters.

5) Here is an incomplete grab-bag list of Great Observatory observations that will want JWST follow-up: dusty AGN; a map of M31; lenses of distant objects; supernovae host galaxies; weak lensing fields; galaxies and clusters with high dark matter content; gravitational lensing maps of clusters; GRB host galaxies; nearby star clusters; dust disk maps of potential planet-bearing stars; deep exposures of the outer reaches of nearby galaxies; star-forming regions in the LMC & SMC; seasonal changes in the outer Solar System.

- Jonathan Gardner

========
HERSCHEL

Herschel sits in a place that makes determination of such projects for the current Great Observatories difficult. Since Herschel fits in wavelength between Spitzer and ground based submillimeter, it is exploring new and uncharted parts of the SED range. Much of the initial work will follow in the areas where ground has already been broken -- such as deep fields, star formation studies, Galactic structure, stellar evolution, etc. Current ground based work that can support Herschel include ongoing molecular line studies and spectral scans, in addition to the types of studies mentioned above. As such, the best things the current Great Observatories can do is continue cutting edge explorations. My proposals of things that can be done to best support Herschel by the Great Observatories will come more in the form of requests to observers and the Science Centers to pay attention to the types of science Herschel will do best, and the types of regions that can give good results for Herschel and across the wavelength range available from space. These might include a request that Spitzer observers please publish their 160 micron results; a request that when choosing fields to take into account the structure of the ISM and how that might impact follow-up studies at far-IR and submm wavelengths; and a request for support of theoretical studies into molecular emission properties at THz wavelengths.

- Bill Latter