Unveiling the Dawn of the Early Universe in X-rays

Martin C. Weisskopf (NASA/MSFC)

I submit that the future direction of X-ray astronomy is clear, indeed as clear today as it was to Riccardo Giacconi within a year after that famous sounding-rocket experiment that discovered the first extra-solar X-ray source Sco-X1 and what appeared as a diffuse X-ray background. Giacconi saw then that x-ray astronomy needed true (focused) imaging in order to resolve the diffuse X-ray background and that the angular resolution must be compatible with observations in other wavelength bands in order to facilitate identifications and multi-wavelength studies. His insight, of course, proved correct and that particular vision was realized 36 years later with the launch of the Chandra X-ray Observatory. Currently we are faced once more with a "diffuse X-ray background". The new "background" is comprised of galaxies at redshifts that are only hinted at by stacking the Chandra Deep Surveys. The resolution of this background promises to be as rich in new and fundamental discoveries as Chandra has been..

I am sure that several abstracts will emphasize the science of such a mission. Certainly the need to study the first populations of black holes (BHs), whose existence may be attributed to the deaths of the first massive stars, will be a driving factor. Another factor is study of the formation and growth of supermassive BHs (SMBHs) that power quasars. Objectives include determining the relation between SMBH mass and galaxy bulge properties thus probing feedback between black-hole growth and galaxy evolution, especially at high redshift. Obviously another major impetus and scientific driver is to provide a unique probe of the first generation of stars and galaxies at redshifts as large as z=15, where this first star formation may take place. It is important to realize that this can only be done at X-ray or infrared wavelengths (> 2 μm), as absorption by the neutral intergalactic medium removes all optical and UV photons with wavelengths $< 0.12(1+z)$ μm.

In order to accomplish such a mission, the over-riding prerequisite is to develop the necessary X-ray optics. Current programmatic and technical approaches to such optics, for the most part, leave much to be desired and have played their own role in projecting huge costs for such missions. X-ray astronomy (as all other space-based astronomies involving telescopes) must also deal with the fact that the NASA's primary scientific thrust in astronomy and astrophysics is concentrated now, and for several years to come, in the development of JWST. I plan to describe a realistic and effective approach for the development of the required optics. The approach has strong similarities to the highly successful Chandra program. Note that Chandra ended up costing, accounting for inflation, almost exactly the amount projected by the MSFC/SAO Chandra Project to the Field Committee, in 1980. Note too, the mission had essentially no cost over-run (< few percent) and, apart from a short delay (6 mo), was on-schedule. Obviously Chandra is also an outstanding scientific success.

Essential ingredients for the success of the next mission are topics that I shall discuss. They include (1) a multipronged, competitive approach to the optics involving industry, NASA centers (GSFC and MSFC), and other scientific institutions with experience in X-ray optics (e.g., SAO); (2) a physics-based approach to the optics development (sorely needed); (3) use of a technical steering group involving members of the community to ensure objective evaluation of technical progress and to recommend allocation of resources; and (4) a technically (not programmatically) driven approach where optics are developed and X-ray tested before proceeding further. The Chandra Project had first to demonstrate via X-ray testing that it could build sub-arcsecond optics (technology readiness) and that it could fabricate the largest flight optic to specification (manufacturing readiness) before proceeding into a full-blown mission. Finally, I will detail the technological challenges and potential approaches to meeting those challenges.