# Concept of
# The Hot Universe Baryon Surveyor
# (HUBS)

## Scientific Motivation

The primary scientific objective is to conduct a census of baryons in the warm-hot circumgalactic and intergalactic media and thus to directly address the issue of “missing baryons” in the local universe. The results are expected to impact our understanding of galaxy formation. Secondary objectives are many, including hot interstellar medium, diffuse X-ray background, supernova remnants, as well as charge exchange processes in the solar system.

## Methodology

The most effective approach is to carry out high-resolution spectroscopy in the UV and soft X-ray bands, where the warm-hot baryons are expected to manifest themselves in emission and absorption lines. HUBS will focus on the hotter phase of the media. It is being designed to employ superconducting transition-edge sensors (TESs) in photon-counting mode, to achieve both high throughput and high resolution. The key technologies include: TES array, SQUID readout and multiplexing, magnetic shielding, cryogen-free cooling system (to reach an operating temperature of about 50 mK), fast X-ray optics (with a field-of-view of about 1 square degree), and so on. Three modes of operations are envisioned: deep pointing, medium surveys, and all-sky survey .

## Waveband of Interest

For HUBS, the most relevant waveband is between 0.1 and 2 keV (similar to ROSAT). The most prominent spectral lines of interest are those of O VII and O VIII at around 0.6 keV, due partly to the high abundance of oxygen. In general, the thermal emission of million-degree gas is expected to be dominated by lines in this energy range.

Preliminary Design

- TES array: 60x60 (of roughly 500-1000 μm pixels), with 2 eV resolution, plus a 9x9 central sub-array of smaller pixels with sub-eV resolution
- Cooling: ~50 mK bath temperature
- Optics: 1 $deg^2$ FoV (F~2), angular resolution ~1'
- Effective area: ~1000 $cm^2$
- Orbit: near Earth orbit, low inclination

Participating Institutions

At present, the team consists of many universities and research institutions in China, including Tsinghua University, Xiamen University, Tongji University, Shanghai Astronomical Observatory (SHAO), Technical Institution of Physics and Chemistry, Shanghai Institution of Microsystem and Information Technology, and Purple Mountain Observatory (PMO), as well as international collaborators, including SRON in the Netherlands and University of Wisconsin-Madison. Many more institutions have expressed strong interest.

Scope and Status

HUBS is envisioned to complement ESA's ATHENA mission in scientific objectives and capabilities around the same time. The cost will probably be limited to around 300M Euros.

Starting this year (2018), HUBS has entered the R&D phase of key technologies (including detectors, cooling, and optics), as part of the CAS program on space science. The project is also being pushed through a more traditional path through the China National Space Administration (CNSA), and has attracted the attention of high-level people. It is recently listed in CNSA's 3-step "Exploring the Extreme Universe" strategic plan (which includes the operating Hard X-ray Modulation Telescope, the proposed enhanced X-ray Timing and Polarization Observatory, and HUBS).

Organization

For the purpose of optimizing HUBS' scientific output, the following Scientific Working Groups (SWGs) have been formed:

- Intergalactic Medium (Group Leader: Taotao Fang, Xiamen University)
- Circumgalactic Medium (Group Leader: Daniel Wang, UMass)
- Feedback Processes (Group Leader: Feng Yuan, SHAO)
- Theory (Group Leader: Houjun Mo, Tsinghua University)
- Hydrodynamical Simulation (Group Leader: Xi Kang, PMO)
- Active Galactic Nuclei (Group Leader: Tinggui Wang, USTC)
- Supernova Remnants (Group Leader: Yang Chen, Nanjing University)
- Diffuse X-ray Background (Group Leader: Li Ji, PMO)
- Cluters of Galacies (Group Leader: Haiguang Xu, Shanghai Jiaotong University)
- Stars (Group Leader: Xiaojie Xu, Nanjing University)

International Advisory Committee

Plan is being made to form a committee of scientific and technical experts in China and abroad, which is expected to provide guidance as the project proceeds. At the moment, observing strategies are still being discuss; this is where the committee's guidance would be of great value. They will probably be a combination of deep pointing (mainly for absorption line studies), medium exposure of selected regions, and perhaps even an all-sky survey (at the later stage of the mission, which would have 2 eV energy resolution; for comparison, the upcoming eRosita survey with CCDs will have a resolution of ~150 eV).

Technology trade-offs are also being made. For instance, energy range vs energy resolution, angular resolution vs field of view, all due to constraints of the detector technology chosen; lower upper energy bound and lower angular resolution would be less demanding on the detector system, but would have scientific implications. This is another area that the project needs guidance.

Efforts will be undertaken to minimize the workload of the committee. It is expected that the members of the committee will obtain certain data rights, once the project is approved; this will be negotiated with CNSA soon.