# (H) DATA ANALYSIS ACTIVITIES

# SCIENCE OPERATIONS FOR FUTURE SPACE ASTROPHYSICS MISSIONS

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**Abstract.** Plans for astrophysics science operations during the decade of the nineties are described from the point of view of a scientist who wishes to make a space-borne astronomical observation or to use archival astronomical data. In the process of preparing a proposal, making an observation, and carrying out data processing, analysis, and dissemination of results, the scientist will be able to use a variety of services and infrastructure, including the "Astrophysics Data System". The current status and plans for these science operations services are described.

## 1. Introduction to Science Operations

Until recently, the Astrophysics community had acess to data from just a few Astrophysics missions. With a small number of datasets, the use of mission-unique data and analysis tools was considered to be acceptable. With the launch of a large number of Astrophysics missions in the timespan of a few years (see Figure 1), a better approach had to be found. The National Aeronautics and Space Administration (NASA) Astrophysics Science Operations Program was established as an Astrophysics-wide program in order to encourage multi-mission, panchromatic research in Space Astrophysics. By fostering coordination and cooperation among all mission operations and data analysis efforts in Space Astrophysics, NASA expects to maximize the scientific return from operating Astrophysics missions, as well as from existing Space Astrophysics data.

The term *Science Operations* includes four areas:

**mission operations**, typically carried out at a NASA field center or a mission center,

**research programs**, consisting of guest observations and archival research by members of the Astrophysics science community,

**science operations services**, including multi-mission archive centers and science databases, and

**Astrophysics Data System** (ADS), providing the data-related infrastructure for all of the preceding items.

## 2. Science Operations: In Transition

The principles and day-to-day execution of Astrophysics science operations are in a state of transition. Although all Astrophysics missions have their unique history and future plans, they tend to evolve towards the same long-term goals.

*Y. Kondo (ed.), Observatories in Earth Orbit and Beyond*, 317–321.

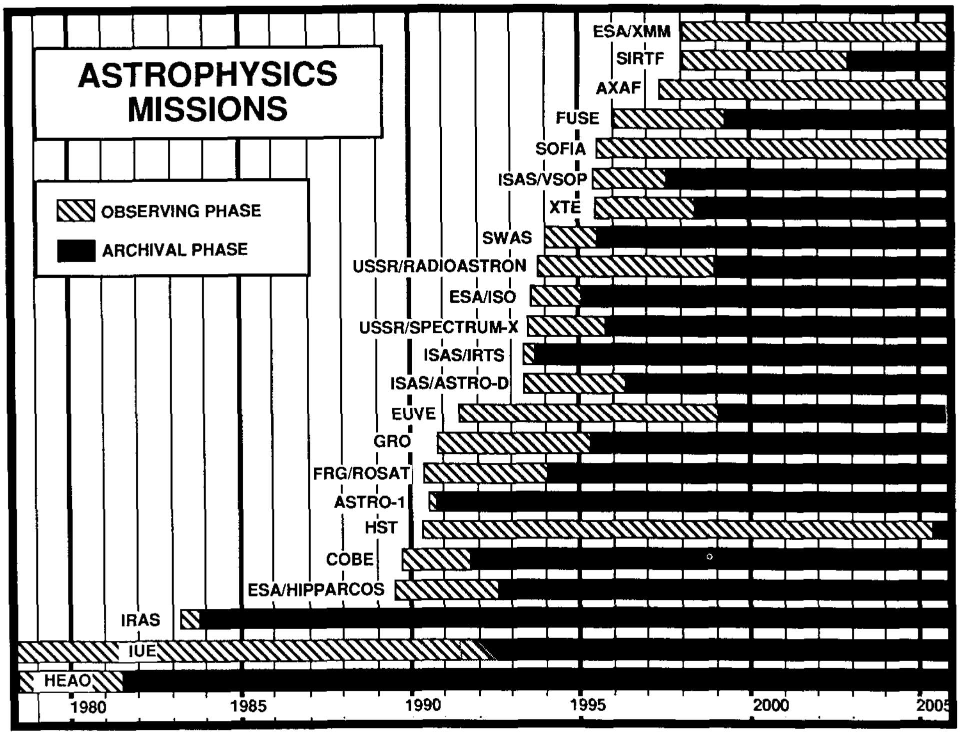


Fig. 1. Timeline of the major Space Astrophysics mission. The active operations/observation phases and subsequent archival research phases are shown as a function of time.

The character of Astrophysics missions is changing from Principal-Investigator (PI) instruments (or even PI-type missions) to facility-class observatories, where the instruments are still built by PIs, but many Guest Observers are expected to use them. Several of these missions are also planned to operate for such long periods of time that we expect a significant turnover in technical and scientific personnel during the active life of the mission. Furthermore, analysis methods and computing hardware will evolve through several generations during the data analysis phase of these missions.

For PI instruments, most of the data analysis was, in the past, carried out by members of the PI team at the PI institution. In the future we expect to see distributed analysis, primarily carried out by Guest Investigators at their home institutions.

The character of scientific research is also expected to evolve, from single-mission or single-wavelength research, to science topic-oriented, panchromatic research. For example, a recent study showed that of all the scientists who used data from the Infrared Astronomy Satellite (IRAS), only 30% considered themselves "IR Astronomers" per se, while 70% came from radio, UV/Optical, high-energy, or theoretical Astrophysics. To enable panchromatic research, we require:

– the ability to execute coordinated (simultaneous or contemporaneous) observa-

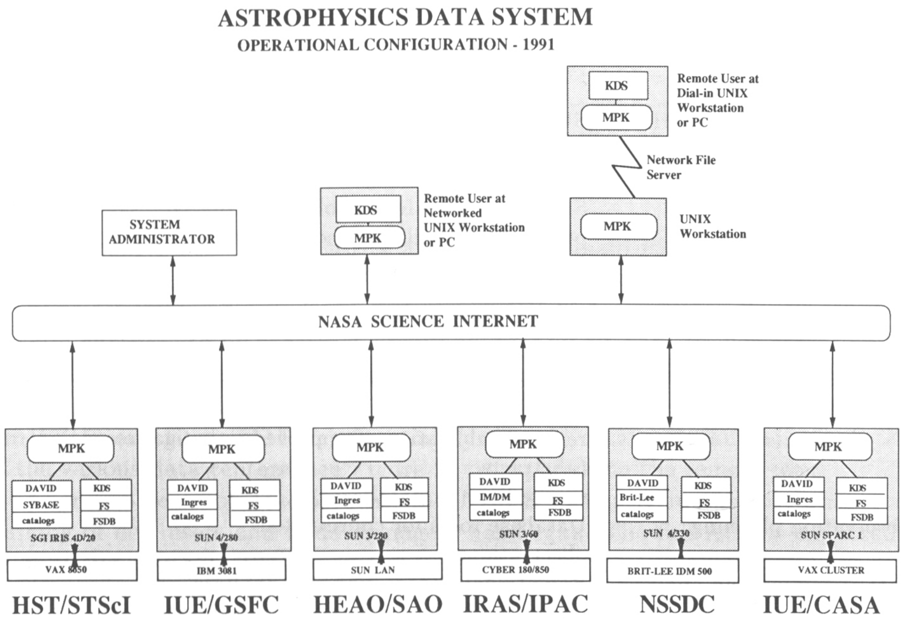


Fig. 2. The Directory Service of the Astrophysics Data System (ADS): Operational configuration of the Directory Service of the Astrophysics Data System, showing the message passing kernel (MPK), the data-independent access method to databases ("DIAM", also called "DAVID"), user interface, documentation manager, factor space (FS), and the factor space database (FSDB) poriton of the Knowledge Data System (KDS).

tions involving space- and ground-based observatories, and
– the ability to carry out multi-mission and multi-wavelength data analysis and interpretation.

This means that Astrophysics missions must supply the necessary expertise, as well as data, data analysis tools, and other services to enable and encourage such topic-oriented research.

## 3. Science Operations Needs for a Typical Guest Observation

The table below shows steps in a typical Astrophysics investigation, and examples of the types of science operations services required at each step. Some of these services are described in more detail below.

## 4. Science Databases and Other Science Operations Services

In response to requests from the science community, and after peer review, a number of services are either under development, or are already accessible to remote users. The *Astrophysics Software and Research Aids* Program explicitely solicits proposals for software packages, databases, operational tools, etc., and supports them after competitive science peer review.

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TABLE I

| INVESTIGATION TASK | SCIENCE OPERATIONS SERVICES REQUIRED BY INVESTIGATOR |
|---|---|
| Release of the NASA Research Announmncement (NRA) | Supplemental information and proposal preparation available electronically from mission science data center |
| Proposal writing | Obtain information about existing or approved observations through the Astrophysics Data System (ADS), on-line databases, or science operations services |
| Proposal submission | Electronic submission, electronic peer review, publication of approved investigations (abstracts, source lists) in databases |
| Observation planning | Database tools for coordinated observations |
| Data reduction and analysis | Remote data processing and analysis, portable software, standard software packages, software interchange, ADS, data format standards, databases, discipline-specific archives |

The science database and science operations services include:

– convenient and inexpensive access to the SIMBAD database (developed at the Centre de Donnes Stellaires, Strasbourg, France),

– the National Extragalactic Database (NED, developed at the Infrared Processing and Analysis Center, IPAC, Pasadena, California), containing comprehensive data on extragalactic objects, including cross-references, literature citations, and complete abstracts of referenced articles,

– *MultiWaveLink*, an interactive database for the coordination of multiwavelength space and ground-based observing programs (developed at Pennsylvania State University), and

– *Comprehensive Atomic Spectroscopy Database for Astrophysics* (developed at the National Institute of Standards and Technology, Gaithersburg, Maryland).

As a matter of policy, NASA encourages and supports the wide dissemination of data to the astronomical community. Examples of such dissemination are the distribution, on CD-ROMs, of the HST Guide Star Catalog, of the National Space Sciences Data Center's machine-readable versions of frequently used astronomical catalogs, and of the Einstein Observatory's Imaging Proportional Counter (IPC) and High Resolution Imager (HRI) results.

## 5. Astrophysics Data System (ADS)

The *Astrophysics Data System* provides the infrastructure for locating data, and for the subsequent data analysis. The ADS Project is managed at the Infrared Processing and Analysis Center (IPAC, Dr. John Good, Project Manager) in Pasadena, California. Figure 2 shows the current configuration of the ADS.

It is designed to

– allow remote access by scientists at their home institution through the NASA Science Internet,
– permit scientific inquires (e. g. "where are UV high-resolution spectra of active galactic nuclei?") to be answered simultaneously by all ADS science center nodes ,
– locate data holdings, select data (sensor, correlative, and ancillary data), browse through the data archives, and order data for electronic or mail-order transmission,
– make the exact nature of the operating systems or database management systems at the various data centers (see Figure 2) transparent to the remote user.

After two years of development, the ADS is currently in the test phase, and training of new users and node managers has begun. The full ADS is expected to be operational in mid-1991.

The ADS is very similar in philosophy and design to ESA's European Space Information System (ESIS, developed by ESRIN, Frascati, Italy). Access to the ADS from outside the US will bepossible through the NASA Master Directory (developed at the Goddard Space Flight Center, Greenbelt, Maryland) and via direct connection through the NASA Science Internet.

Two very important components of the infrastructure for Astrophysics science operations are communications and data format standards. As a result of the recommendation of the International Astronomical Union for the adoption of the "Flexible Image Transport System (FITS), NASA has adopted a policy for the use of FITS formats for the exchange of data (NOT for data files internal to reduction and analysis programs). In addition to special, mission-specific extensions, the FITS system accomodates basic images, random groups, ASCII tables, IEEE floating-point data, 3-D floating-point data, keyword hierarchies, and single-photon data. In order to assist missions and individual scientists in the use of FITS structure, a FITS Standards Office has been established at the Goddard Space Flight Center, Greenbelt, Maryland.