ASCHOT — Astrophysical Schmidt Orbital Telescope

Summary

The need for a wide-angle UV Space Telescope for astrophysical investigations is outlined. Some of the main scientific goals are discussed, e.g. a full sky survey and a comprehensive study of UV emission of extragalactic and galactic objects, which may be achieved with the Astrophysical Schmidt Orbital Telescope ASCHOT, now under construction.

The concept of the telescope design, its optical system and the detectors, and its system of guidance are described. The limiting sensitivity of the telescope is about 24^m for stellar objects at 1500 Å.

1 Introduction

Sky surveys of celestial objects with wide-angle telescopes at different wavelength regions and the discovery of objects having certain peculiarities are among the main goals of observational astrophysics. Catalogues of a variety of objects have been compiled as a result of such surveys. The newly detected objects are then studied with the use of all possible observational means and methods.

Sky surveys and the investigation of the morphology of extragalactic objects in the far UV wavelength region, the discovery of young stars and the study of their distribution in space can be done most successfully with the use of fully reflecting Schmidt cameras.

The Astrophysical Schmidt Orbital Telescope (ASCHOT) project was started by the initiative of the Byurakan Astrophysical Observatory (Armenia, USSR) and the Central Institute of Astrophysics (Potsdam, Germany) in 1987.

The ASCHOT is a fully reflecting telescope for obtaining prime images and low dispersion spectra of all objects in a wide (2.°5) field of view. The virtues of such a telescope have been thoroughly debated within the astrophysical community for about two decades. ASCHOT advantageously differs from all launched telescopes for sky surveys. Firstly, it will be the largest telescope of this type. Secondly, the use of fully reflecting optics reduces the loss of far-UV radiation, which is crucial for the realization of many observations. At the same time the fully reflecting Schmidt optical system gives a very useful field of view with a high angular resolution.

The ASCHOT telescope will permit for the first time the study of weak (down to 24^m at 1500 Å) stars, galaxies and quasars in the vacuum ultraviolet (down to 1300 Å). This telescope will permit the study of galaxies and their details with the lowest surface brightness in visible light, because of the very low sky background level in orbital observations. A major advantage of the ASCHOT wide-field telescope is that a full-sky survey can be carried out. Thus, the ASCHOT telescope may play the same rôle for the HST as the 48″ Schmidt camera at Palomar did for the 5 m Hubble telescope.

2 The Scientific Goals

The ASCHOT telescope is designed for deep sky surveys in the vacuum ultraviolet by obtaining images of large areas of the sky and low resolution spectra of all objects in the field of view of the telescope.

The sky maps obtained by ASCHOT observations will be of great value for astrophysical research. They will serve as an important supplement to the maps obtained by ground-based telescopes in the visible wavelength region (e.g. Palomar, SERC and ESO surveys). Many important discoveries have been made using these maps and they will continue to serve astrophysics during many decades to come.

Low dispersion spectra of somewhat brighter objects will permit the study of the distribution of energy in the far-UV spectra of all observed objects. The importance of such observations is evidenced by the Byurakan objective prism sky survey which resulted in the discovery of over 2000 Markarian galaxies, many of which turned out to be active or starburst galaxies.

It will for instance be possible to observe images of distant galaxies with lower surface brightness than ever detected by wide-field ground-based telescopes. This is very important for solving problems such as the identification of weak radio sources and for cosmological studies.

The comparison of sky surveys in far-UV and in visible light made with the orbital Schmidt telescope opens many possibilities for interesting investigations.

3 The Optical System of the Telescope

The optical system of the telescope is of the fully reflecting Schmidt type (Fig. 1). The diameter of the main spherical mirror is 1.2 m. The diameter of the correcting mirror is 0.8 m. The focal length is 2.3 m. The field of view is 5°, of which 2.°5 will be used for science. The outer part of the field of view will be used for star trackers.

Stabilisation of the telescope pointing will be done by two axes with accuracies better than ±0.3 arcsec. Rotation of the field of view around the guiding star will be avoided to an accuracy of about 5 arcsec. Where the guiding star is near the edge of the guiding field, the image of the farthest star on the opposite side of the field will be increased due to field rotation only by about 2.5 μm or 0.2 arcsec. Thus the image size of point sources will vary over the field of view of the telescope and will be of the order of about 2 arcsec, or about 20 μm. The real angular resolution of the telescope will be 2–3 times larger. None of the wide-angle space telescopes launched for sky surveys, up to now, has ever had such a high angular resolution.

The optical system of the telescope also contains one diagonal flat mirror, by means of which the focal surface is placed outside the telescope tubus. This mirror is also used as one of two elements in the fine guiding system of the telescope. The location of the focal surface outside the tubus makes the change of detectors by crew members of the space station very easy.

All three mirrors will be coated by aluminium and magnesium fluoride, which have good reflection characteristics down to 1200 Å.

By 180° rotation of the diagonal mirror it will be replaced by a grating which will operate for convergent rays and allow low dispersion (1000–1500 Å/mm) spectra of all objects in the 2.°5 field of view of the telescope to be obtained.

The telescope construction guarantees the safety of its adjustment and normal functioning in orbit after the launch. The adjustment of the telescope optics will be done at conditions which eliminate deformations of the tubus and mirrors and any

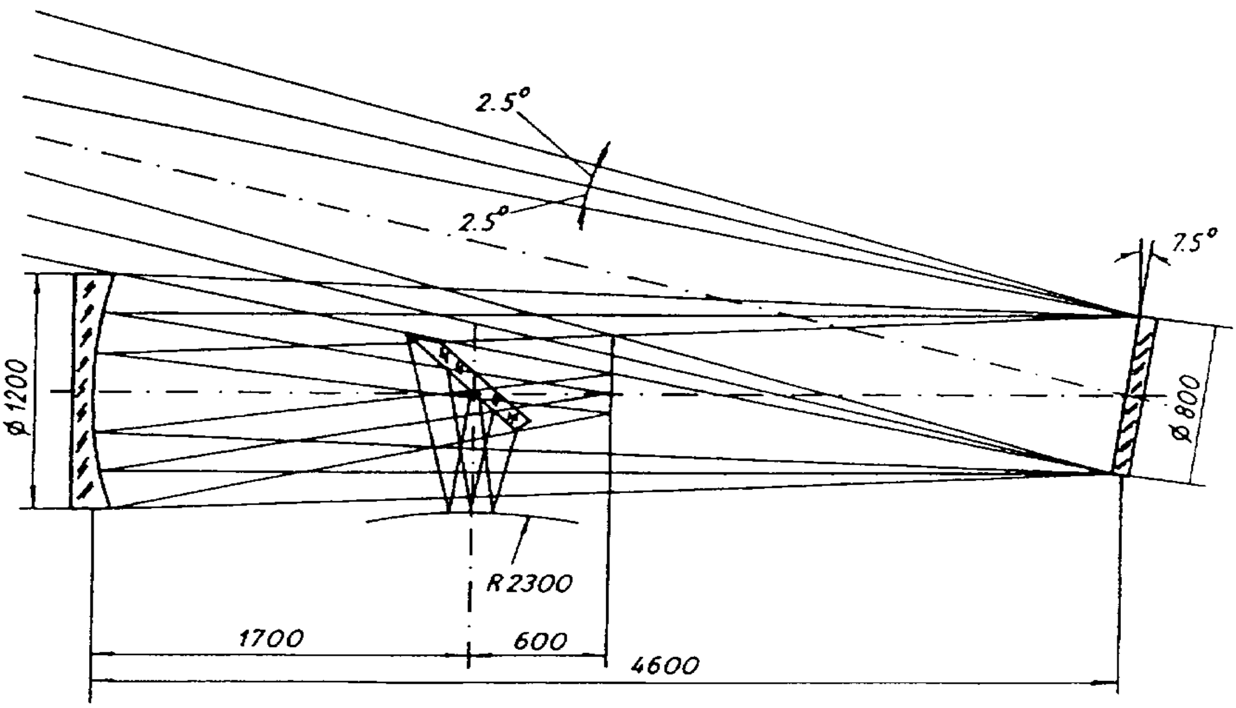

Figure 1: Optical system of the telescope ASCHOT.

relative displacements of the latter.

4 Detectors

The displacement of the focal surface out of the telescope tubus permits the use of several detectors for different purposes.

It is intended that two of the detectors will consist of multichannel intensifiers with cathodes made of CsI and TeCs, sensitive in the 1200–2000 Å and 2000–3200 Å regions respectively. The multichannel intensifiers may be coupled with CCDs using corresponding fibre optics to decrease the linear size of the field. Electron delay devices may have more perspectives. The diameters of the channels of microchannel intensifiers are about 8–10 μm and the resulting resolution of electron delay devices is about 25 μm, which just corresponds to the resolution of the telescope, including guiding errors.

An electronographic camera with CsI or TeCs cathode presents an interesting alternative as a detector. It has a better resolution, but its use with a space telescope is difficult, mainly because of the need to change films, which must be done during space walks.

With each of the UV detectors a set of interference filters will be used to determine the observational passband and to reduce the diffuse Lyman-α emission.

A film sensitive to the visible light will be used for the discovery of weak, low surface brightness galaxies. The length of the film in each cassette will be enough for about 300 photographs. In each frame its number, position of the centre of the photographed area, exposure and the date will be marked.

The cathodes of all detectors and the cassette for the film must have a surface whose shape corresponds to the curvature of the field of view.

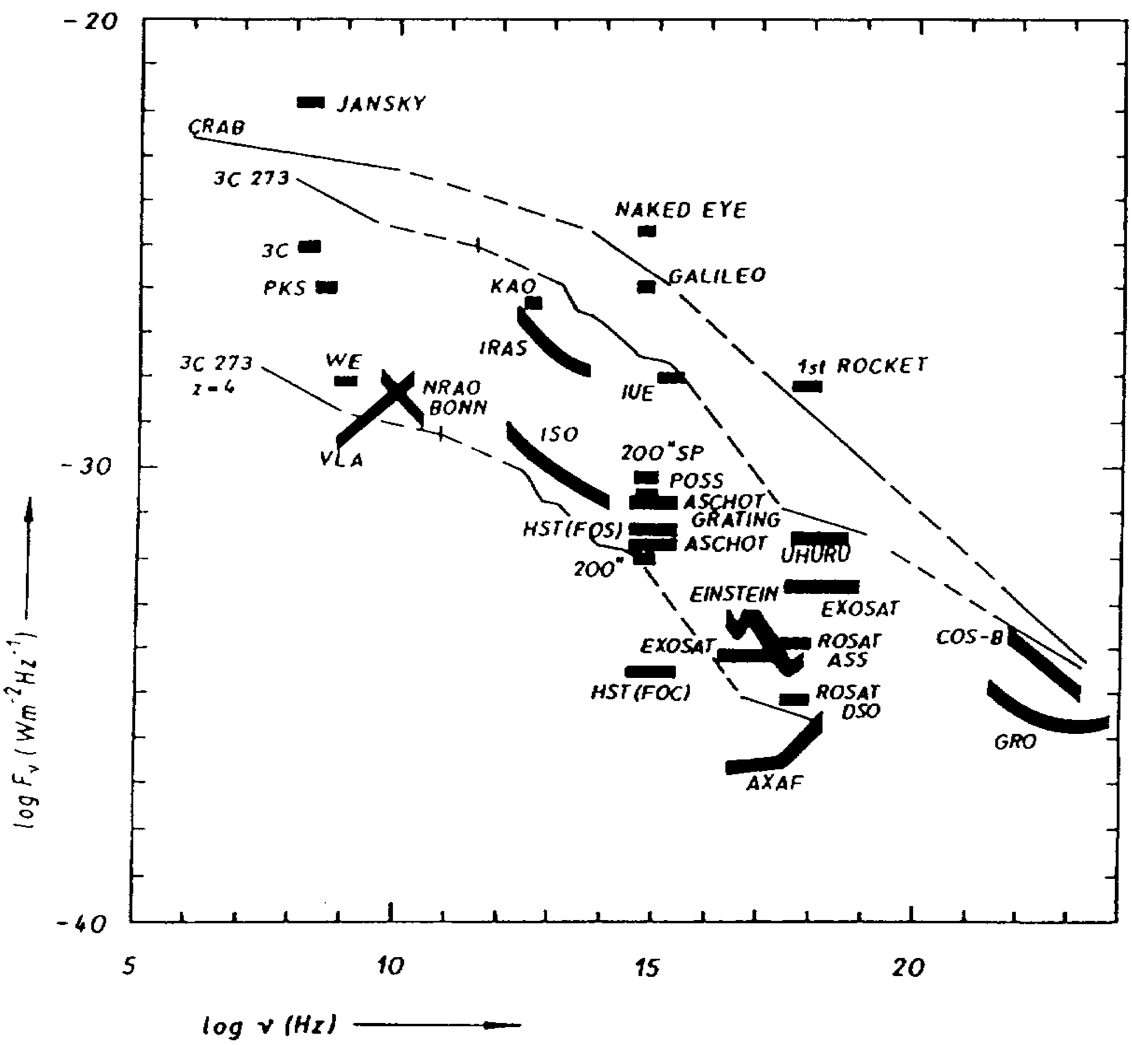

Figure 2: The sensitivity limits versus frequency for different telescopes and some projects, in order to compare the capability of ASCHOT. Most of the labels are self-explanatory, but a few should be explained: WE = Westerbork radio telescope, NRAO = National Radio Astronomy Observatory 91 m telescope, BONN = MPI Radioastronomy 100 m Effelsberg telescope, 200″ SP = Palomar 5 m telescope (spectrograph), HST (FOC) = Hubble Space Telescope (Faint Object Camera), KAO = Kuiper Airborne Observatory, 1st ROCKET = 1962 rocket discovering Sco X-1, ROSAT ASS = ROSAT All Sky Survey, ROSAT DSO = ROSAT Deep Sky Observations, GRO = Gamma Ray Observatory, the EGRET experiment only.

The registration with each of the electronic detectors may be done with exposures from 1 s to 30 min. Photographs on film may be taken with exposures of several minutes (up to 30 min). The change of cassettes with films will be made about once a month.

5 The Sensitivity of the Telescope

The sensitivity of the telescope has been estimated in the case of multichannel intensifiers coupled with CCDs as the main detector. The signal-to-noise ratio then depends on the statistics of photoelectron events and errors in the amplification and detection process. There are practical limitations from both. The uncertainty in the flux measurements is determined by the registered photoelectron events, including contributions from the objects and the sky background.

Taking into account the aperture of the telescope (80 mm), the bandwidth of the system (300 Å), and the losses (0.7^3) for reflections from three mirrors and a sky background of 300 photons $\mathrm{cm^{-2}s^{-1}str^{-1}}$ Å^{-1}, we obtain an estimate for the limiting magnitude $m(1500$ Å$) \approx 24.^m0$ for 30 min exposure time and $S/N = 10$. In the case of the maximum possible exposure times in one orbit this corresponds to about 26^m in V for unreddened OB stars.

Figure 2 shows the limiting sensitivity of the ASCHOT telescope compared to other ground-based and extraterrestrial surveys.

6 The Parameters of ASCHOT

Diameter of the main mirror	1.2 m
Diameter of the correcting mirror	0.8 m
Focal ratio	3:1
Field of view — of which for scientific observations	5° 2.5°
Scale: 1 arc sec =	12 μm
Accuracy of stabilization (made by stars brighter than $8.^m5$ in B)	$\pm 0.3''$
Angular diameter of a point source (80% of energy) including errors of guidance	$2''$
Limiting stellar magnitude ($\lambda = 1500$ Å, $\Delta\lambda = 300$ Å, exposure 5 min)	24^m
Low dispersion spectra	1500 Å/mm
Limiting stellar magnitude in the case of low dispersion spectral observations	$21.^m5$

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