THE CORONAL HELIUM ABUNDANCE EXPERIMENT ON SPACELAB 2*

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Abstract. The Coronal Helium Abundance Spacelab Experiment, (CHASE), basically consists of a grazing incidence telescope and spectrometer sensitive over the range 150–1335 Å. Whilst aimed primarily at deriving the solar helium abundance from measurements of coronal resonance scattering, its specification has been extended in order to provide a more general purpose solar XUV facility. The instrument will be flown on the Spacelab 2 Mission, currently scheduled for launch in November 1984.

1. Scientific Objectives

Helium constitutes around 10% of all atoms in the Universe. However, its abundance in the Sun and other astronomical objects is known only approximately. The element is important in relation to a number of physical processes in the Sun: to nuclear processes in the core, opacities in the photosphere, and radiative energy transport in the chromosphere.

Current cosmological theories indicate that most of the helium in the Universe must be of primeval origin, with only a negligible fraction resulting from stellar nucleosynthesis. In this case one expects the relative helium abundance to be everywhere the same. An accurate value of this abundance is important in all aspects of stellar evolution and modelling; furthermore, it is a key parameter in cosmological calculations. Clearly, an accurate value obtained for the best studied of all stars would be of considerable value.

Nevertheless, an accurate derivation of the solar helium abundance has proved difficult to perform. Because of their high excitation potential, He I lines are formed in the Sun at high temperatures in the chromosphere, and in regions where the situation is complicated by inhomogeneities associated with the chromospheric network and spicules. However, the proposed experiment will observe the hydrogen (1216 Å) and ionised helium (304 Å) resonance lines formed by photo excitation of the coronal material. Here the hydrogen and helium line emission is due mainly to the resonance scattering of the intense chromospheric emissions at these wavelengths. The experiment will look at the light source (disc) and the scattering region (corona above the limb) and, because the two principal lines are common in both cases, the results are independent of instrument intensity calibration. Second order effects in the calculation are due to electron density and temperature which

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can be adequately measured by line ratio methods. It is anticipated that the relative helium abundance will be established to better than 5%, and in a manner which is independent of most of the assumptions regarding atmospheric models.

2. The Instrument

The proposed investigation requires a telescope and spectrometer working in the XUV spectral range. Several experiments, for example the Harvard experiments on OSO-4 and 6 (Noyes, 1971), have carried out solar XUV observations, however relatively few have extended their coverage into the grazing incidence region below 300 Å (Firth *et al.*, 1974; Reeves *et al.*, 1972). Clearly then there is some advantage in enhancing the instrument specification to provide a facility capable of more general solar XUV studies.

The scientific requirements of the instrument can be summarised as follows:

(1) Adequate sensitivity and dynamic range to record emission lines on the disc and above the limb. These lines to include 1216 Å, 304 Å and temperature and density sensitive pairs.

(2) Pointing capability (to better than 5 arc sec).

(3) Spatial resolution of ~15 arc sec.

(4) Spectral resolution ≤0.5 Å.

(5) Ability to provide 1 and 2 dimensional scans.

To accomplish these objectives the instrument (shown schematically in Figure 1) utilises a 1 m grazing-incidence spectrometer using a 1200 lines mm^{-1} concave grating. The image of the Sun is focused on to the entrance slit plane by means of a 28 cm focal length grazing incidence telescope of Wolter type I section design.

Eleven Channel Electron Multipliers are placed behind individual exit slits that are positioned on the Rowland Circle. In addition, a Channel Multiplier array will be incorporated allowing several close emission lines to be monitored simultaneously. The selected line list is shown in Table I.

The experiment is mounted on the ESA Instrument Pointing System (IPS) which is capable of providing sufficient pointing control. However, there are three other solar experiments on the IPS, and some independent pointing is desirable on two accounts: (a) to fully utilise that time allocated to the other experiments, and (b) to ensure co-alignment during joint observing programmes. This requirement is fulfilled by the construction of scan platforms for both the mirror and the slit. Both motions are mutually perpendicular and allow two dimensional raster scans to be performed. The total offsets involved are ±20 arc min for the mirror and ±15 arc min for the slit, both having a step resolution of 10 arc sec. The slit mechanism fulfills the dual purpose of pointing control and slit selection (slit sizes are listed in Table II), the choice of slit is decided by a trade off between adequate spatial resolution and counting statistics for any given observation.

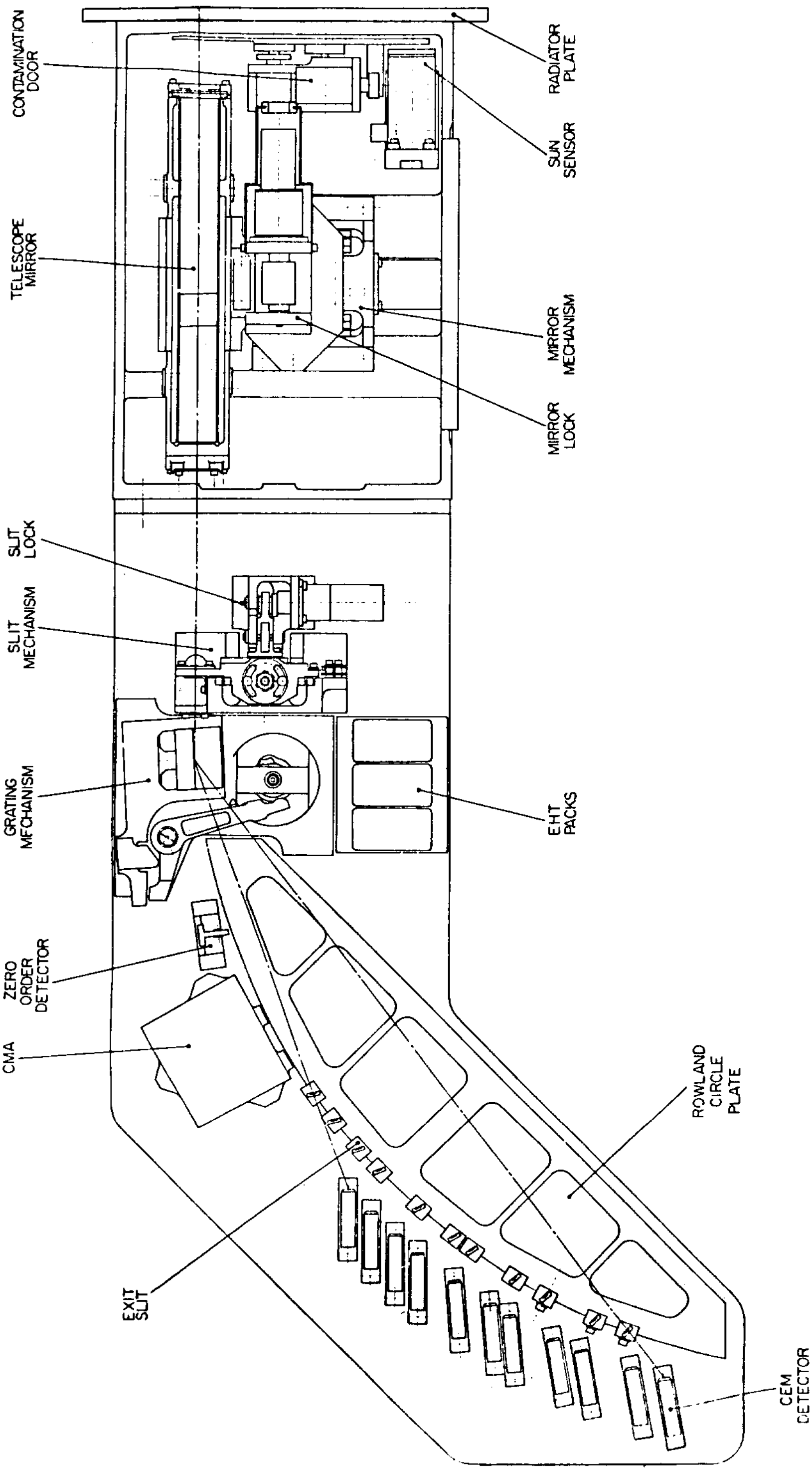


Fig. 1. Schematical outline of Coronal Helium Abundance Spacelab Experiment (CHASE).

TABLE I

CHASE line list

Ion	λ (Å)	Order	Detector*	Comments
O VI	150.09	1	CMA	T_e from ratio 150/1032
Fe IX	171.08	1	CMA	Fe ionisation sequence
Fe X	174.53	1	CMA	Fe ionisation sequence
Fe XIV	219.13	1	CMA	ρ from ratio 211/219
Fe XV	284.15	1	CEM	Fe ionisation sequence
Fe X	174.13	2	CEM	Check on CMA performance
Fe XIV	211.33	2	CEM	ρ from ratio 211/219
Fe XIII	246.21	2	CEM	Fe ionisation sequence
He II	303.77	2	CEM	He/H abundance
Fe XVI	360.80	2	CEM	Fe ionisation sequence
S V	786.46	1	CEM	Sulphur abundance
S VI	933.40	1	CEM	Sulphur abundance
O VI	1031.92	1	CEM	T_e from ratio 150/1032
H I	1215.67	1	CEM	He/H abundance
C II	1335.68	1	CEM	Scatter monitor

* CMA – Channel Multiplier Array plate.
CEM – Channel Electron multiplier.

It is necessary in the helium abundance experiment to measure the intensity on either side of the emission line, contributions to which could arise from a true solar continuum or from scattered light. In order to achieve this, a small wavelength scan is effected by rocking the grating. In this way, the wavelength range is increased at moderate cost to resolution, with the additional bonus of access to more emission lines. Total scan is ±400 arc sec with a 5 arc sec step, this range being equivalent to ~ ±10 Å at hydrogen Lα.

A further refinement to the instrument is the provision of a sun sensor. This will be aligned to the instrument's optical axis prior to flight, and will serve to monitor any misalignments occurring between the instrument and the IPS pointing direction. A static misalignment could easily occur at launch, but more serious would be varible offsets resulting from thermal drifts occurring on-orbit.

The final mechanism takes the form of a closeout shutter for the apertures associated with the mirror and sun sensor. The Spacelab environment is not

TABLE II

Entrance slit sizes

Dimensions (μm)	Effective aperture (arc sec)
20×20	15×15
40×40	30×30
80×80	60×60
40×240	30×180
80×240	60×180

particularly clean and provision is made to prevent line-of-sight particles from contaminating the optics during experiment shut-down periods.

The operational flexibility of the instrument is maximised by the incorporation of a dedicated experiment microprocessor utilising a Motorola 6800 CPU and 28k bytes of memory. Pre-programmed sequences initiated from either the crew station or the ground control centre will be used for mechanism control and data processing prior to transmission. During the mission the sequences may be modified or, if necessary, replaced. The serial transactions with the Spacelab data handling system will be variable format to suit the current investigation and the total downlinked data rate is approximately 8.5 k bits s^{-1}.

The experiment is presently at the intergration phase, and an engineering mock-up is shown in Figure 2. The grid structure on which it is mounted represents the 'cruciform' which in turn is mounted to the pointing system. The boxes to the side of the instrument house the microprocessor and analogue circuitry; these are physically isolated from the instrument for reasons of thermal control.

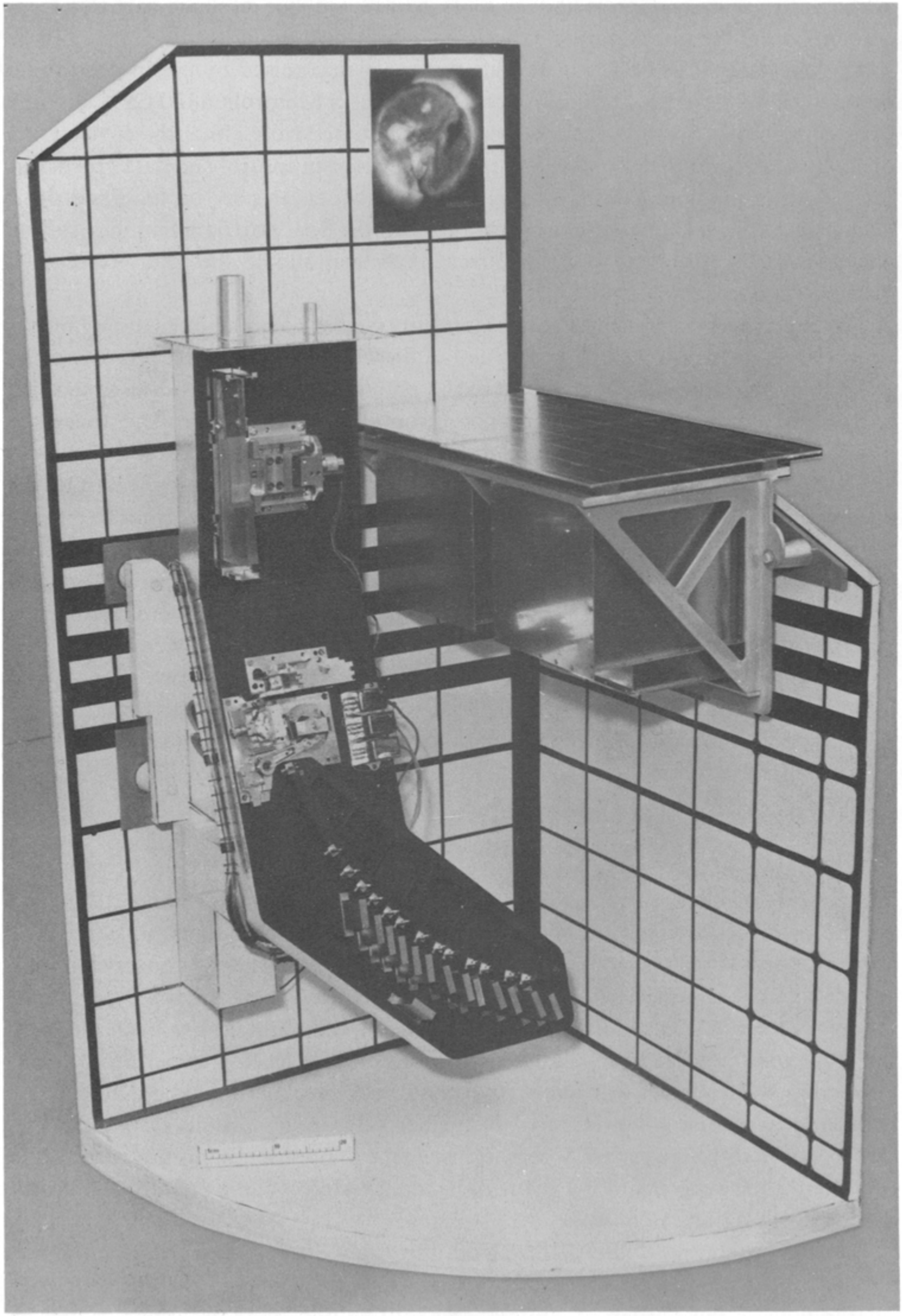
The thermal analysis of Spacelab experiments is in any case complicated by the variety of Shuttle orientations, and the problem is made considerably more difficult for IPS mounted experiments. It was decided to isolate the electronics and to radiate experiment and electronics waste heat directly to space via separate forward-facing radiators, the remaining surfaces of the experiment being covered with many layers of thermal blanket material. This method was found to provide the cleanest thermal interface by minimising thermal paths to the shuttle surfaces.

Both instrument and electronics will contain separate heaters, both for the colder shuttle orientations and for initial warm-up, with active heaters in the instrument for more precise thermal control.

3. Mission Operations

The Spacelab 2 Mission is currently scheduled for launch in November 1983, and will be in orbit for a period of seven days. With 13 experiments on board it is inevitable that some restrictions are imposed on each experiment's observing time. The detailed observing schedules now being constructed show the IPS experiments to have a total of approx. 75 hr solar pointing. A commitment has been made by the IPS experimenters to maximise this allocation by agreeing to periods of Joint Observing. Such periods will involve two or more of the experiments simultaneously observing a chosen solar feature. A further allocation of time is termed Co-Observing. This refers to any observations where joint observing is not worthwhile but where each experiment, by virtue of its independent pointing control, can carry out its own programme of work.

Experiment control will be either from the Crew Station or the Payload Operations Control Centre (POCC) at Houston. The experiment microprocessor considerably eases the burden of control, and routine observing programmes will be initiated normally by the Payload Specialist. At the POCC a PDP 11/34 computer



with 112k byte memory and graphics processor will be devoted to analysis of CHASE data in near real time.

4. Conclusion

This experiment is aimed at deriving an accurate measure of the solar helium abundance, and at the same time performing useful studies of the XUV emission from coronal and active regions. With careful pre-mission planning, the science return should also be considerably enhanced by the joint observing programmes being proposed.

CHASE, despite its smaller size, will provide a proving ground for the larger solar XUV packages now at the proposal stage. In particular the complexity of its operation and position on the IPS, will test both the Spacelab system and the Payload Specialist concept of operations.

References

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