HIPPARCOS AS INPUT CATALOGUE FOR THE GOMOS ENVISAT INSTRUMENT

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ABSTRACT

GOMOS is being developed as one of the ESA instruments to be flown on-board the ENVISAT environmental satellite. This instrument is based on the star occultation principle. Using a medium resolution spectrometer, GOMOS will measure the concentration profiles of, and monitor the trends in, Ozone and other trace gases. The input catalogue of GOMOS, which could include some 1000 stars, is currently being prepared using the Hipparcos and Tycho Catalogues as reference.

Key words: guide star catalogues.

1. THE GOMOS MISSION

In response to the growing concern about the ozone equilibrium in the stratosphere, the GOMOS instrument (Global Ozone Monitoring by Occultation of Stars) has been included in the ENVISAT-1 mission of the European Space Agency.

In order to ensure a highly accurate and stable measurement over the 4 years of the ENVISAT mission (which is a must for a fine analysis of the trends in stratospheric ozone), a method based on star occultations (Figure 1) has been proposed by a team of European Scientists led by Service d'Aéronomie (CNRS) and the Finnish Meteorological Institute (Bertaux et al. 1991).

From its polar orbit, GOMOS is pointing at various stars whose lines-of-sight are tangential to the Earth limb (Figure 1). For each individual star, the spectrum measured outside the atmosphere is compared to the spectrum seen through the atmosphere when the star approaches the limb. The wide spectral range of the instrument (250 – 952 nm) allows absorption lines of a number of trace gases, such as O_3, NO_2, NO_3, to be recorded as well as the water vapour content. In addition GOMOS will provide information on aerosols and temperature distributions in the stratosphere as well as an analysis of the atmospheric turbulence (scintillation).

The main feature of GOMOS is that it is a self-calibrated instrument, as it allows to derive an absolute concentration of atmospheric molecules from relative measurements and is therefore protected against instrumental radiometric drifts. The method has been already demonstrated in space using the Sun as light source; but the specific advantage of GOMOS, related to the large number of observable stars, is that it combines the advantages of high vertical resolution in the atmosphere (1.7 km) and good Earth coverage.

2. THE INSTRUMENT DESIGN

The GOMOS block diagram is shown in Figure 2. It is based on a 20 × 30 cm Cassegrain telescope which simultaneously feeds, through an optical beam dispatcher placed at its focal plane, a UV–Visible medium resolution spectrometer—for signal measurements in the Huggins and Chappuis bands (250 – 675 nm), a near infrared high resolution spectrometer—for O_2 (around 760 nm) and H_2O (around 930 nm), and two fast photometers operating in the spectral bands [470 – 520 nm] and [650 – 750 nm], with a 1 kHz sampling rate, for scintillation characterisation.

Using a large steerable flat mirror (30 × 40 cm) in front of the telescope, GOMOS is able to acquire and track stars down to magnitude 5 within a very large angular range (100 degrees in azimuth). A complex star tracking system—using two redundant star trackers—allows the star position to be maintained within 20 μrd during the 50 seconds of a typical measurement period. These star trackers are able to operate in both day or night conditions, i.e. when the instrument is looking at a bright or a dark limb.

With a mass of 163 kg and a power consumption of 146 W, GOMOS is part of the ENVISAT–1 payload which will be integrated on the Polar Platform to be launched by the end of this century. During the four years of the nominal mission, GOMOS will provide data at a constant rate of 222 kbits/s during nominal operation. Further details could be found in Popescu et al. (1997).

Figure 1. The GOMOS measurement principle.

Figure 2. GOMOS functional block diagram.

3. HIPPARCOS AND TYCHO AS INPUT CATALOGUES

As was the case for the Hipparcos satellite, it will be necessary to up-link periodically to GOMOS the file of stars to be observed. The selection of these stars, extracted from the GOMOS input catalogue (the so-called 'NOVA' catalogue in its preliminary form), will be automatically achieved on-ground by algorithms which are currently elaborated in the frame of the GOMOS Mission Planning (E. Kyrölä et al. 1997). In order to optimize the scientific return of the instrument, these algorithms are using a number of criteria which are addressing both astrometric and spectrophotometric parameters as well as some operational ones:

1. The astrometric parameters: The star positions have to be known in order to drive the steering front mechanism and to allow acquisition by the star tracker. Obviously, mas accuracies are not required to operate GOMOS and the use of the Hipparcos Catalogue may be considered at first glance as a consolidated but somewhat luxurious input data base; it is however essential to detect and reject double or multiple systems which could corrupt the retrieval of ozone concentrations. (GOMOS is in essence a 'slit-less' spectrometer in which the spectral line shape is directly dependant on the tracking accuracy and also on the input star profile). Information provided by the Hipparcos Catalogue on multiplicity of stars (as well as some proximity charts) is therefore essential.

2. The spectro-photometric parameters: A number of stellar parameters have a direct influence on the retrieval accuracy of the trace gases concentration:

   - the star magnitude which has a direct link with the noise affecting the recorded stellar spectra. On the other side, due to the concept of the instrument, the slow variability of the magnitude (variable stars) is not considered as a critical parameter. However, to avoid second order effects, variable stars will not be favoured;
   - the stellar temperature which will affect unequally the retrieval of the various species: As an example, it has been shown (E. Kyrölä et al. 1997, Korpela 1991) that for ozone measurements the optimum stellar temperature is above 8000 K, when for NO3, colder stars are preferred. Figure 3 shows a selection of stars within the temperature range 3000 K − 30 000 K. Considering typical performance data of the instrument, it appears that up to 1000 stars could be used during dark limb conditions, when only 160 are appropriate in bright limb occultation, if one considers the star magnitude criteria alone;
   - the spectral type and the colour index (B-V) or $(B_T - V_T)$ will be used to determine together with the star magnitude a predicted accuracy. It is acknowledged that these parameters are only a crude way to predict 'outside of the atmosphere' stellar spectra. Another approach could be to use the limited number of spectra recorded already in space (e.g. by IUE) to try to reconstruct a data base. An attempt made in this direction by CNRS (in the framework of the 'NOVA' catalogue) has clearly demonstrated that the scaling of these spectra is hampered by the heterogeneity of spectro-photometric references. The Hipparcos and Tycho Catalogues will undoubtedly help in this respect.

3. The operational parameters: Obviously, at a given time of the year and during a given orbit, only a subset of the observable stars will be occulted by the Earth and are potential candidates for GOMOS observation. Accessible altitude ranges, accuracies and global coverage are optimum on the night side (dark limb), but useful measurements will also be obtained on the day side (bright limb) when observing the brightest stars. Figure 4 shows the coverage of the northern hemisphere achieved in one day using the stars given in the 'NOVA' catalogue. This figure is slightly seasonal dependant but shows very good coverage including the high northern latitudes. It will therefore be possible to optimize the star selection to improve accuracy and spatial resolution of trace gases fields.

4. CONCLUSIONS

The operation of GOMOS is based on a dedicated input star catalogue. *A priori* knowledge of some astrometric and spectro-photometric parameters is needed to optimize the scientific return of the instrument. The Hipparcos and Tycho data base will provide a consolidated basis for the selection algorithms.

In fact, as for Hipparcos, it is likely that the star selection criteria will be tuned after the review of the first months of operation, and that simulated stellar spectra will be replaced by real ones. As a natural spin-off, GOMOS will also generate medium to high resolution spectra of stars outside the atmosphere in the range 250 − 950 nm during the 4 years of the mission.

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Figure 3. Stars selected from the Hipparcos Catalogue (magnitude versus stellar temperature).

Figure 4. Northern hemisphere coverage by occultations available over 1 day.