USES OF THE ENVISAT PAYLOAD FOR MESOSPHERIC AND THERMOSPHERIC INVESTIGATIONS: THE AALIM PROPOSAL.

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ABSTRACT

The ENVISAT satellite, due to be launched in 2000, crosses the auroral ovals which are the location of important spectral emissions. The variety of sensors, especially the limb sounders SCIAMACHY (UV-visible and near IR), MIPAS (infrared) and GOMOS (UV-visible and near IR) is superior to any previous payload for their study. Also, as polar troposphere and lower stratosphere studies demand the knowledge of the emissions from the upper atmosphere, these must be eliminated by a combination of their detection in the signal itself and their theoretical modelling. Outside the auroral regions, high altitude emissions exist too and are worth studying. A dedicated proposal: AALIM, addresses the observation by MIPAS and SCIAMACHY at the auroral oval crossings, night-side, twilight and daytime. An analysis of the possible observation modes will be made. Collocated data of GOMOS in stellar occultation mode or background mode are also considered.

1. INTRODUCTION

The ENVISAT programme places high priority on polar lower atmospheric chemistry, this specific observation occurs precisely in the auroral zones and the understanding of the signal will require to eliminate all upper atmospheric perturbations and thus to model them with the highest accuracy. The determination of these perturbations requires data of the existing MIPAS high altitude mode together with collocated SCIAMACHY limb data and similar GOMOS background or occultation data. Despite 70 years of auroral and ionospheric research, the mechanisms leading to aurora and airglow are far from being understood and thus the observation data will be fundamental to derive the necessary correction terms, in particular, the fact that night-time auroras are stronger and more frequent than daytime auroras constitutes a strong perturbation for the GOMOS signal and their rapid variations in space and time might perturb the built in background suppression of this instrument. The AALIM proposal intends to study these effects during the commissioning phase so that the derived results can be used to correct the data processors and that it becomes possible of assessing the viability of specific observation modes as the SCIAMACHY eclipse programme and ask for its extension on the night side. During the mission, long term phenomena could be studied and statistical studies of the observed emissions could provide the link with solar activity, meteoric showers or even falling mini-comets as observed on controversial Dynamics Explorer 1 images. These early single pixel observations were recently confirmed by a detailed study of the images of the POLAR far-ultraviolet dayglow camera showing the extent of the clouds formed and even the tracks of the mini-comets (Frank and Sigwarth, 1999).

2. DETAILED DESCRIPTION.

The observations of airglow and auroral emissions should be repeated several time during the mission in order to check the effects of solar activity. Co-located data of GOMOS in stellar occultation mode and background mode will also be requested as they contain the same signal as in the SCIAMACHY limb result. This mode should be tested in priority in the begin of the mission during the eclipse and twilight phase of SCIAMACHY. In the case where variations are observed more frequent observations could be requested in this time slot occupied now, for SCIAMACHY, by only a monthly moon occultation and instrument maintenance, essentially dark current monitoring. The most recent SCIAMACHY observation schemes include several night nadir observation as well as limb observation in the part which is closest to the sunrise terminator, allowing thus for twilight observations.
The final result of the AALIM proposal will be the understanding of the molecular, energetic and possible meteoritic structure of the mesosphere. Molecular systems such as NO, CO, CO2 ,O3, H2O, OH, long-lived excited species as O(1S), N(2D), N2* may be determined including their latitudinal variation much better than they are now. Finally, after more than ten years of controversy, these four year series would permit to confirm or infirm the influx of a large number of pure ice comets on the earth's upper atmosphere.

AALIM observes airglow and auroral emissions simultaneously with SCIAMACHY and MIPAS, infrared NO and O3 enhancements at the time of auroral crossings and similar UV phenomena in the SCIAMACHY range. This mode could be also active during the eclipse phase of SCIAMACHY for high altitude background studies. The understanding of auroral emissions might be also essential to the interpretation of the MIPAS stratospheric data in the polar regions. The GOMOS occultation and background modes are permanently measured as the specific analysis of the GOMOS data necessary to obtain atmospheric transmission data requires the measurement of the stellar source and of the background effects for all the range of altitudes, on the contrary, MIPAS and SCIAMACHY have modes which are specific of the lower atmosphere and in which upper atmospheric perturbations are minimised and thus difficult to study.

A sample of known auroral lines in the UV and visible can be given in the following (see for example Chamberlain and Hunten, 1987): atomic oxygen: 557.7 nm, emitted around 100 km, triplet of atomic oxygen: 630.0, 636.4, 639.2 nm; auroral low latitude emission: ionized molecular nitrogen: 391.4 nm, Balmer emissions from atomic hydrogen: 656.3 nm., 486.1 nm; oxygen ionic lines at 732 nm, atomic sodium at 589 nm; hydroxyl radical: Meinel bands between 900 and 1000 nm, bands between 305 and 315 nm. All of these are located in the SCIAMACHY range, only the Meinel bands are not accessible to GOMOS. The infrared aurora covers the entire range of MIPAS with ozone excitation processes in the 9-10 micrometer range, NO excitation processes in the fundamental 5.3 micrometer band are also observable at the MIPAS spectral resolution allowing to have access to the temperature of the emission process, especially the very clean NO line at 1914.99 cm-1, frequently used in vertical distribution determinations, should be enhanced in the auroral process. The intensity enhancements are not only due to changes in the emission processes but also to higher molecule productions during the energetic events related to the auroras, in particular, NO can be affected by different phenomena like the sub-auroral ion drifts (De Keyser et al, 1998) taking place around 65° of latitude and happening at very specific longitudes (Muller et al, 1998). NO is extremely important as its radiation at 63 μm is the dominating cooling mechanism of the thermosphere. The energetic aspects of the apparition of auroras in terms of solar activity are not even fully understood, in particular, the daytime auroras have been recently found to be statistically weaker to the night-time auroras (Newell et al, 1998).

Apart from these well-known emission features, many emission lines have not been interpreted. Laboratory experiments are planned to characterise the emission properties of the highly excited gerade states of molecular nitrogen, which may be present in the emission data. A recent suggestion of absorption around 4.47 micrometer in the N4+ ion can be a start to look for this all nitrogen ion.

The effects of the small comets are even more difficult to assess, the recent findings of Frank and Sigwarth (1999) show that they can quench or absorb the emissions of atomic oxygen at 130.4 and 135.6 nm on circles of around 100 km of diameters. These authors estimate the number of these comets to 10 million per year, pure water ice seems to be the only possible composition compatible with the fact that they never were detected before. The absence of consequences to previous atmospheric measurements might be traced to the isolated character of previous observations or as in the case of several global experiments to their treatment as zonal longitudinal averages, this was normal as previous modelling efforts were limited to two-dimensional computations. In the ENVISAT case, higher spatial resolution and signal quality as well as progress in the three-dimensional understanding of the lower atmosphere will encourage full use of the data set to track local effects.

MIPAS, as an infrared emission instrument, shows sensitivity to warm upper atmospheric emissions of NO, O3, H2O, OH, CO2 and NO+. These are present in both the quiescent and the aurorally disturbed atmosphere. The mechanisms of emission are essentially vibration-rotation bands and thus subject to emissions outside the local thermodynamic equilibrium hypothesis. This situation has already been observed and interpreted using the results of the shuttle-borne CIRRIS instrument from the Air Force Research Laboratory, these results are used in the Air Force Research Laboratory SHARC (Strategic High Altitude Radiance Code) software which will be used as a first forward model for the comparison between observation and results (Sharma et al, 1996). The non-LTE situation introduces the parameters of vibrational and to a lesser extent, rotational temperatures in the retrieval process and thus creates the need for a different algorithm. It should of course not be forgotten that the kinetic temperature is highly variable as it depends from the solar activity and energy transfers from the exosphere and thus requires careful modelling. The relevant MIPAS studies have been presented at this symposium (Lopez-Puertas et al, 1999).

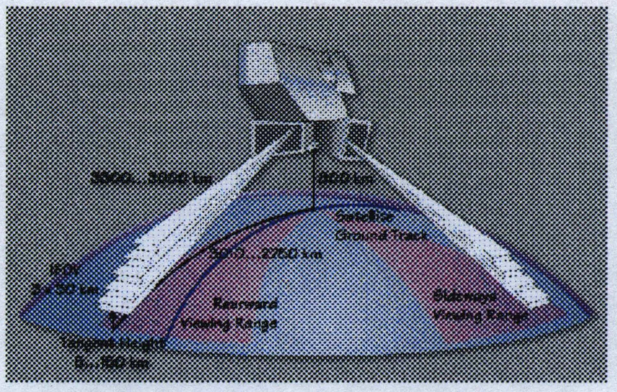

Fig. 1: The MIPAS observation geometry, the rearward port is the best adapted to polar observations

The MIPAS Science Advisory Group identifies five upper atmospheric observational scenarios (MIPAS SAG,1998):

1: validation of non-LTE effects on the retrieval of p-T and some of the main target species still optically active in the mesosphere or affected by non-LTE emissions at higher altitudes: CO2, O3, H2O, CH4, N2O and HNO3 between the altitudes of 10 and 100 km.

2: polar vortex dynamics and stratosphere mesosphere exchange: CO2, NO, H2O, O3 between the altitudes of 10 to 90 km.

3: budgets of the mesosphere and thermosphere: energy and hydrogen, nitrogen and carbon: CO_2, CO, NO, NO_2, N_2O, H_2O, CH_4, OH from 40 to 120 km.
4: non LTE studies: NO between 70 and 160 km.
5: auroral effects: NO, NO^+, CO_2, O_3, OH between 40 and 160 km.

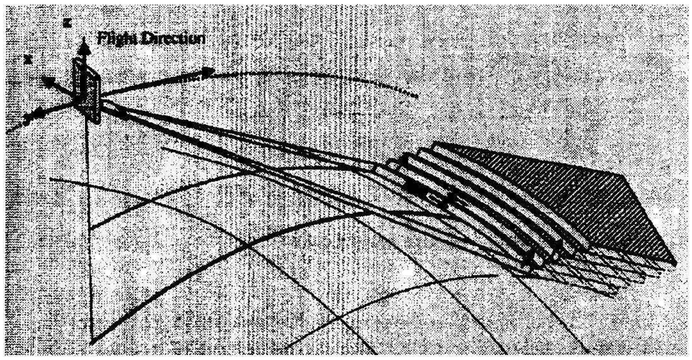

Fig. 2: The SCIAMACHY observation geometry, as the SCIAMACHY limb mode is performed in the forward direction, SCIAMACHY and MIPAS do not observe the same air-masses simultaneously.

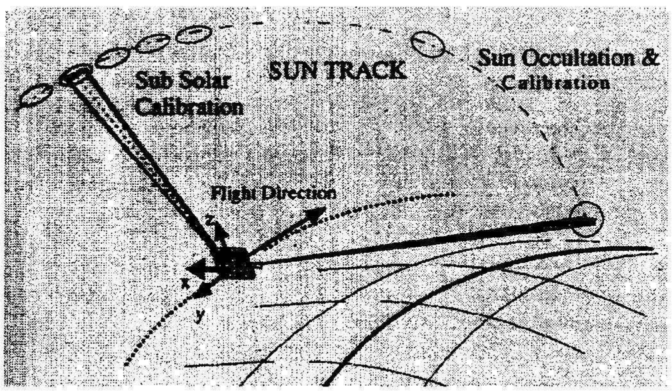

Fig. 3: The SCIAMACHY solar occultation mode, the GOMOS stellar occultation uses a similar geometry, absorption spectra are important as they are less sensitive to NLTE effects than emission spectra. During the GOMOS occultation operations, a background mode is also observed which would allow to separate the absorptions and emissions of the quasi-identical air-masses.

The AALIM proposal would request these data and the level 2 treatments performed at these occasions, as the level of studies done on the MIPAS side is by far the most advanced, we propose that the parallel SCIAMACHY and GOMOS observations follow the MIPAS schedule. In brief, MIPAS requests regular global surveys with insistence on equinoxes and solstices, it requires also periodic auroral observation with emphasis on the Winter aurora. The softwares used for the direct modelling will be a combination of AFRL proven products: MOSART for the UV-visible and SHARC for the infrared.

The consistency of the two spectral ranges in terms of retrieved atmospheric properties will constitute an important verification of the models for which no complete multi-spectral check was ever performed. Finally, discrepancies between both models and observations might reveal overlooked phenomena, the most obvious being the influx of small pure ices comets recently detected by the quenching of airglow emissions in UV observations.

3. SYNERGIES WITH OTHER MISSIONS.

The evident synergy is with the NASA Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) mission which was designed to study the physical and chemical processes acting within and upon the coupled mesosphere, lower-thermosphere, ionosphere system between about 60 and 180 km.. Originally proposed as a two-spacecraft mission, TIMED was downsized to a core mission of four experiments and six interdisciplinary investigations. The instruments include the Solar EUV Experiment (SEE) provided by the University of Colorado, the TIMED Doppler Interferometer (TIDI) provided by the University of Michigan, the Global Ultraviolet Imager (GUVI) provided by the Aerospace Corp., and the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) provided by NASA's Langley Research Center. As the first of the science missions in the Solar Connection Program, TIMED is scheduled for launch in early 2000. The similarities of objectives between the AALIM proposal and the TIMED mission are exemplified by the following table giving the SABER objectives:

Table 1:TIMED-SABER scientific objectives.

Parameter	Wavelength (μm)	Application	Altitude Range (km)
CO_2	14.9 & 15.2	T, density, IR cooling rates, P(Z), non-LTE	10 - 130
O_3	9.6	O_3 conc., cooling rates, solar heating, chemistry and dynamics studies	15 -100
$O_2(^1\Delta)$	1.27	O_3 conc.(day), inferred [O] at night, energy loss for solar heating efficiency	50 - 105
CO_2	4.3	CO_2 conc.; mesosphere solar heating; tracer	85 -150
OH (υ)	2.0 & 1.6	HO_x chem., chemical heat source, dynamics, inference of [O] and [H], PMC studies	80 - 100
NO	5.3	Thermosphere cooling, NO_x chemistry	90 - 180
H_2O	6.9	HO_x source gas, dynamical tracer	15 - 80

4. CONCLUSIONS

The AALIM proposal will request limb data of MIPAS, SCIAMACHY and GOMOS for the periods allocated for the planned MIPAS high altitude observations and for specific SCIAMACHY evaluation periods during the commissioning phase. After testing of the scientific value of the SCIAMACHY night-side and twilight limb results obtained at these occasions, more SCIAMACHY data could be requested. The high quality of the ENVISAT payload can transform this project in an invaluable complement of dedicated mesosphere thermosphere projects as NASA TIMED.

The analysis method will be straightforward in its first stage: MIPAS, SCIAMACHY and GOMOS data will be compared with direct radiative spectral models and checked for consistency, atmospheric composition and temperatures will be retrieved by simple techniques and compared with the results obtained by the 1 to 2 processors of the three instruments. In a second stage, a development of the assimilation techniques now introduced in the troposphere and stratosphere could be envisaged.

The deliverables will be first the upper atmospheric composition, which will be compared with the existing models of the mesosphere-thermosphere and second the role of non-LTE species such as electronically excited N2*, and metastable atoms and further refinement of emission data. This project will be supported by the necessary laboratory and theoretical studies of the fundamental aspects of molecular physics involved.

This proposal will have reached success if a global radiative model of the upper-atmosphere for the equinoxes, solstices day-time and night-time polar aurora is delivered at the end of the mission. Apart from improved dynamic and energetic knowledge of the upper atmosphere, an unambiguous answer concerning the presence of small pure-ice comets and their chemical effects is expected.

5. REFERENCES

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