Retrieval of O, O2, O3 and N2 mesospheric and thermospheric distributions from PROBA2 LYRA occultation data

AUTHORS

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ABSTRACT

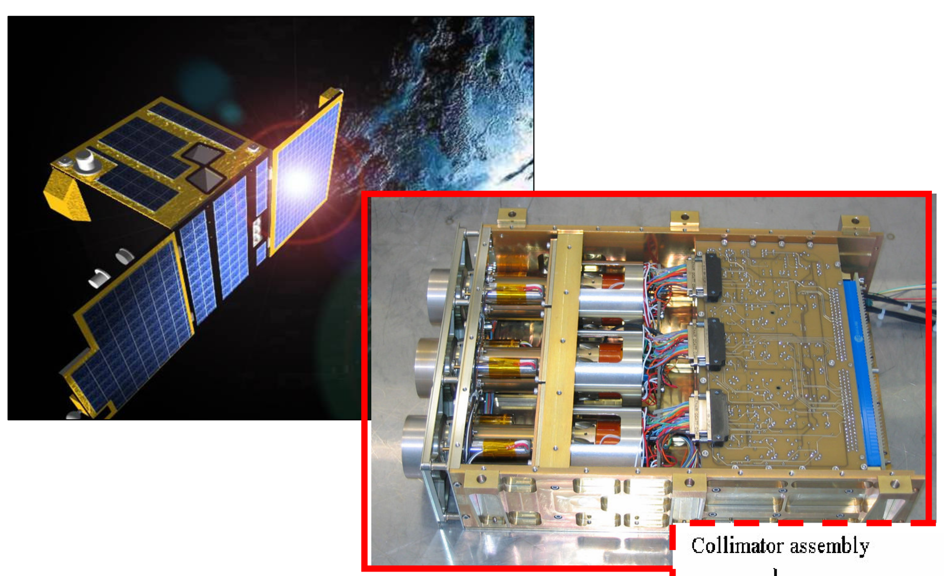
LYRA is a solar EUV/VUV radiometer that will embark in 2008 on-board **PROBA2**, an ESA micro-mission. It has been designed by the Royal Observatory of Belgium, with Dr J.-F. Hochedez as PI, and build by Physikalisch-Meteorologisches Observatorium Davos (PMOD), with Dr W. Schmutz as lead co-I. LYRA will monitor the solar irradiance in **four passbands**:

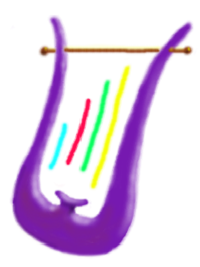
- Lyman-alpha **(Ly)** : **115-125 nm**
- Herzberg continuum **(Hz)** : **200-220 nm**
- Aluminium filter **(Al)** : **17-80 nm**
- Zirconium filter **(Zr)** : **1-20 nm**, where solar variability is highest.

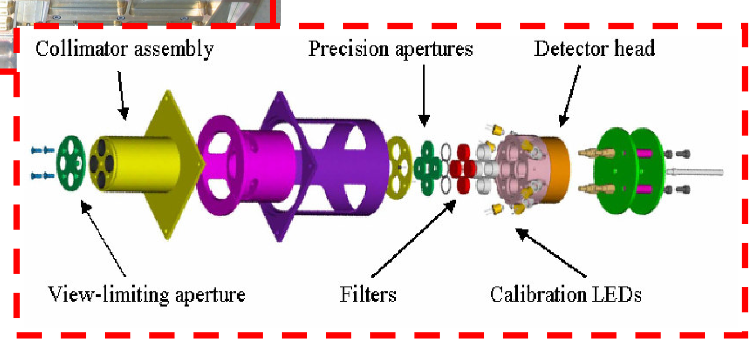
LYRA will benefit from pioneering **wide bandgap detectors** based on diamond. These sensors make the instruments **radiation hard and solarblind**: they minimize the use of additional filters to block the unwanted visible light, but which also attenuate seriously the desired UV radiation. This enhances the detectors effective area, and therefore increases the accuracy, the cadence, or an optimal combination of both.

The PROBA2 heliosynchronous orbit generates brief eclipses three months per year. These allow studying the high atmosphere composition by the **solar occultation method**. Chemical species addressed are **thermospheric N2, O, O2** and **mesospheric O2 and O3** in the winter hemisphere. LYRA's **high cadence (up to 100 Hz) and signal to noise ratio** offer the possibility to reach a very favourable vertical sampling, unfortunately counterbalanced by the extent and inhomogeneity of solar source. The chosen inversion method takes these hurdles into account by dividing the sun surface into parcels and **analyzing the contribution of each parcel independently.**

LYRA – A LARGE YIELD RADIOMETER







Lyra benefits for:

1. Calibration LEDs
2. Diamond detectors
3. Full sun field of view

CONCLUSION

We have implemented a method able to retrieve the extinction coefficient as a function of altitude for each Lyra channel, in the altitude interval where each optical thickness vary from 0.01 to 10. We have simulated noisy transmission data and used it to test this method.

The next step would be the separation of the different constituents participating to the extinction. Nevertheless, this would require additional information in channels Al, Zr and Hz.

From Ly channel, the O_2 density can be retrieved for altitudes in the 115-220 km range.

(*) Ref: **Lumpe et al.** Atmospheric Constituent density profiles from full disk solar occultation experiments, *J. Quant. Spectrosc. Radiat. Transfer*, Vol 46, No 6, 1991

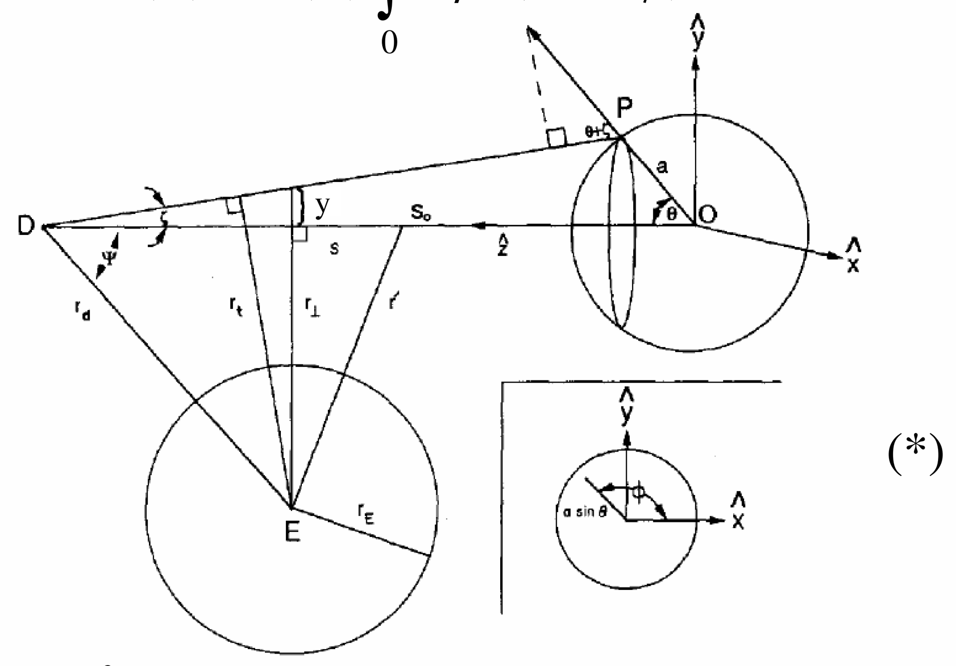
FORWARD MODEL

Forward Model of the channel c transmission (T_C) :

$$T_C(r_\perp) = \frac{\int_{\lambda 1}^{\lambda 2} d\lambda Q(\lambda) \int_0^{\pi/2} d\theta \sin(\theta)\cos(\theta) \int_0^{2\pi} d\psi I(\lambda,\theta,\phi) \exp\left[-\sum_i^{components} \sigma_i(\lambda) N_i(\theta,\phi,r_\perp)\right]}{\int_{\lambda 1}^{\lambda 2} d\lambda Q(\lambda) \int_0^{\pi/2} d\theta \sin(\theta)\cos(\theta) \int_0^{2\pi} d\psi I(\lambda,\theta,\phi)}$$

with :

- Q = instrument response
- N = slant column density
- I = unattenuated solar flux
- σ = extinction cross-section
- $r_\perp$ = tangential altitude



(*)

Hypothesis:

- $\sigma_c^{\ *}$ = mean of σ on channel c
- $I(\lambda,\theta,\phi) \approx I_1(\lambda) I_2(\theta,\phi) = I_1(\lambda) I_2(\theta,\pi-\phi)$

Variable change : $\begin{cases} \mu = \cos\theta \\ y = \beta \sin\theta \cos\phi \end{cases}$

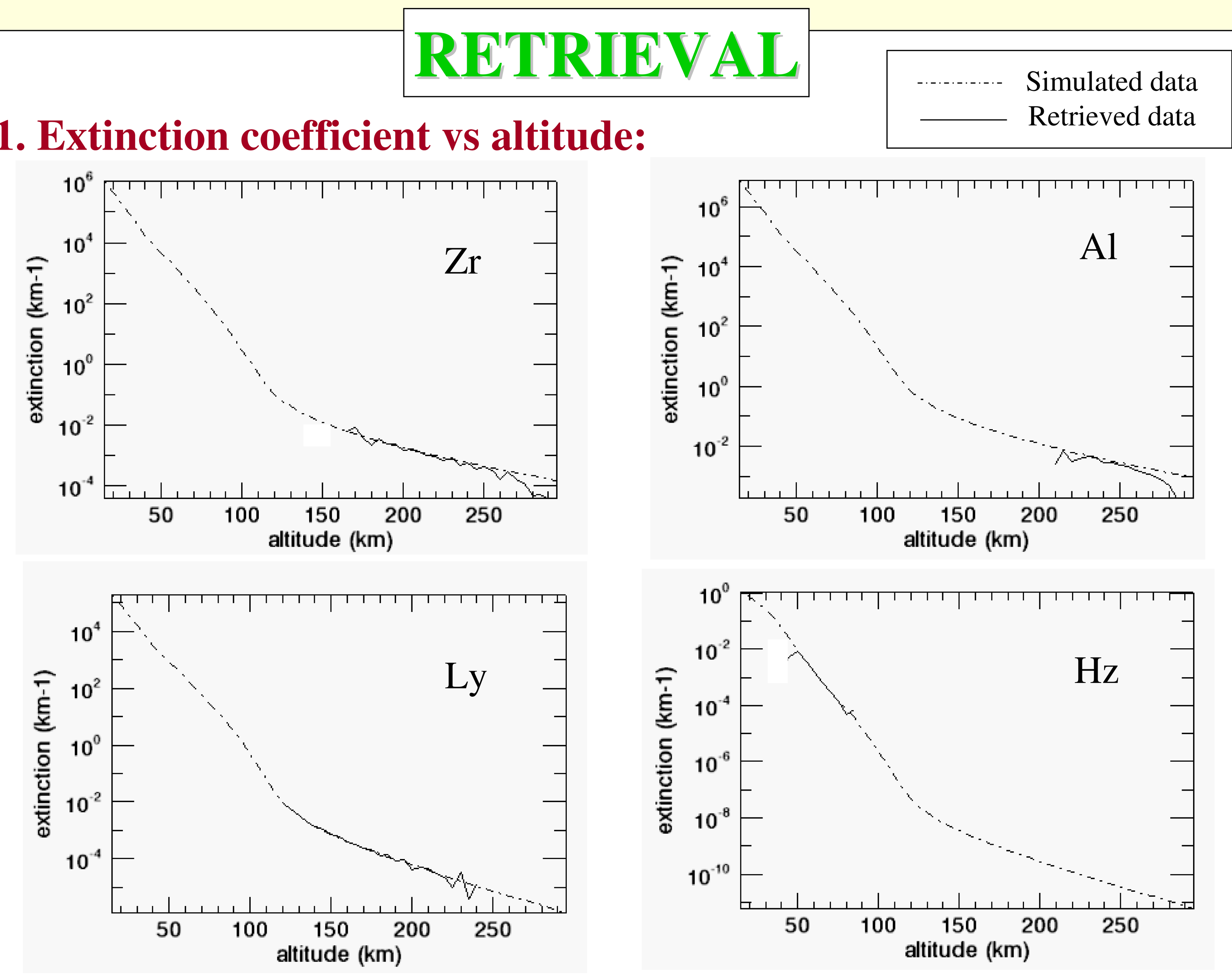
$$T = \frac{\int_{-\beta}^{\beta} dy \exp\left[-\sum_i \sigma_i^{\ *} N_i(y)\right] \int_{-\sqrt{1-\frac{y^2}{\beta^2}}}^{\sqrt{1-\frac{y^2}{\beta^2}}} d\mu M(\mu)}{\int_{-\beta}^{\beta} dy \int_{-\sqrt{1-\frac{y^2}{\beta^2}}}^{\sqrt{1-\frac{y^2}{\beta^2}}} d\mu M(\mu)}, \quad \text{with } M(\mu) = \frac{\mu I_2(y,\mu)}{\beta\sqrt{1-\mu^2-\frac{y^2}{\beta^2}}}$$

Simulated T_C:

- Initial slant column densities based on MSISE-90
- No scattering
- No active region or coronal hole
  1. first attempt with uniform irradiance: $I_2(y, \mu)$ = constant
  2. second attempt with
     - limb brightening for Al, Zr and Ly channels : $I_2(y, \mu) = I_2(0, 1) / \mu$
     - limb darkening for Herzberg channel : $I_2(y, \mu) = I_2(0, 1) * \mu$
- Noise/signal ~1E-4 for Zr channel and 1E-5 elsewhere

RETRIEVAL

1. Extinction coefficient vs altitude:



2. Separation of the constituents

Channel	Components
1-20 nm	O, O_2, N_2
17-80 nm	O, O_2, N_2
115-225 nm	O_2
200-220 nm	O_2, O_3

Problem: In each channel, the extinction coefficient is only retrieved for optical thicknesses in the 0.01 to 10 interval.

→ **We miss information to retrieve the four constituents densities at each altitude**