Occultation limb sounders: GOMOS

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1. Background
2. Measurement principle
3. Instrument
4. Data
5. First results

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February 28, 2002, French Guiana
Perfect launch: Envisat lifetime 7-9 years

Ozone problem

- Ozone in the stratosphere:
  - Protects biosphere from solar UVB-radiation
  - Maintains stratospheric circulation
  - Central element in chemistry balance
- Stratospheric ozone is declining:
  - Almost total loss of ozone over Antarctica during October
  - Mid-latitude loss of 0.5% annually
- Reasons for ozone loss have been found
  - CFC gases+ heterogeneous chemistry
- Actions to curb CFC-gases have been taken (Montreal 1987 etc.)
- Ozone layer is expected to start a recovery

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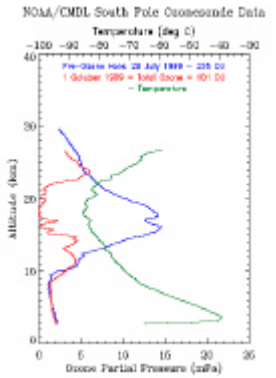
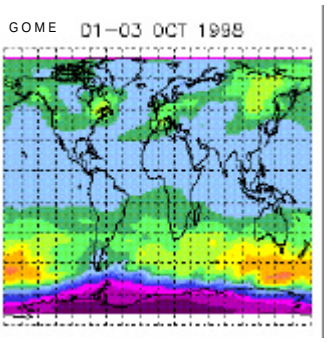
Ozone monitoring

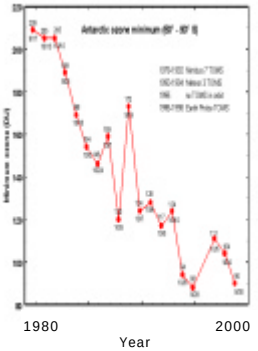
Vertical dimension



Global dimension



Time dimension



Requirements for ozone monitoring

- Monitoring of vertical profiles
- Monitoring of global distribution
- Long-term monitoring to follow trends

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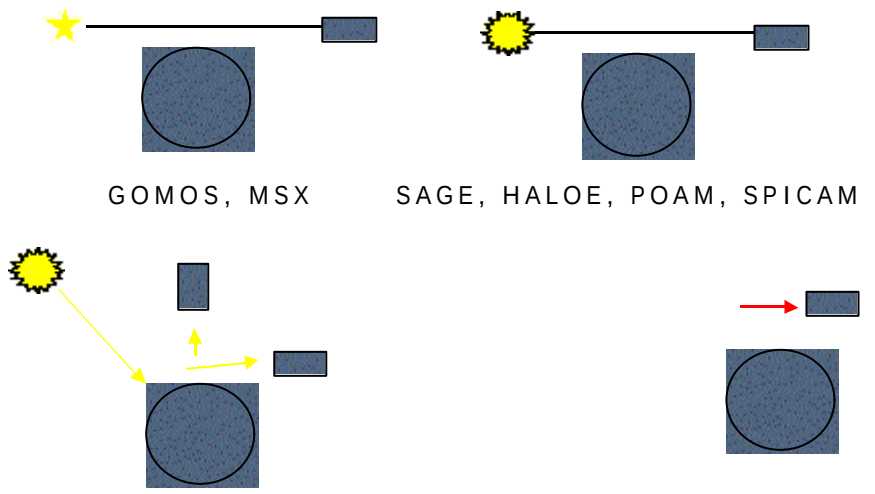
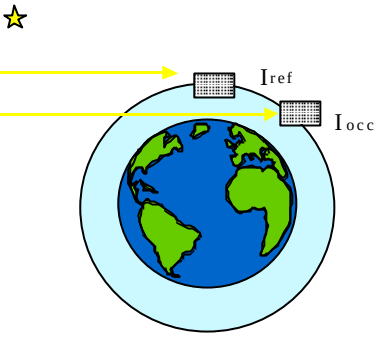


Global Ozone Monitoring by Occultations of Stars



global coverage

vertical profiles with <1.7 km sampling

$$T(\lambda) = \frac{I_{occ}(\lambda)}{I_{ref}(\lambda)}$$

self-calibration

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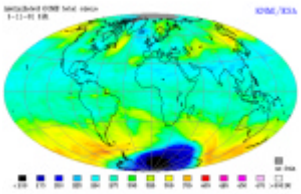
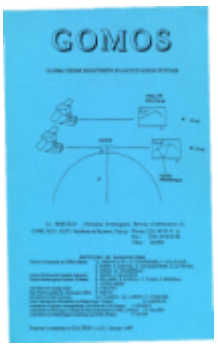


GOMOS history



1988 FMI and Service d'Aeronomie proposed GOMOS as an AO-instrument for ESA's POEM (POEM is now Envisat and Metop). Heritage: SPICAM (Mars 96)

1992 ESA gave GOMOS the EFI (ESA Funded Instrument) status. Matra (Astrium) selected to be GOMOS main contractor

1995 ESA started GOMOS GS development:
ACRI SA+FMI+Sd'A+IASB (Expert Support Laboratories)
Space Systems Finland Ltd software contract for GOMOS processor
FMI's Sodankylä observatory selected to be the GOMOS Level2 processing facility

2002 Envisat launched on February 28
GOMOS first measurement on March 20

- UVIS spectrometer (250-675 nm), IR spectrometer (756-773, 926-952 nm), star tracker, 2 fast photometers (470-520 nm and 650-700 nm)
- O3, NO2, NO3, O2, H2O, neutral density, aerosols, high resolution temperature
- Integration time 0.5 sec. Vertical resolution better than 1.7 km
- About 40 occultations per orbit, day and night, 400-600 in 24 hours

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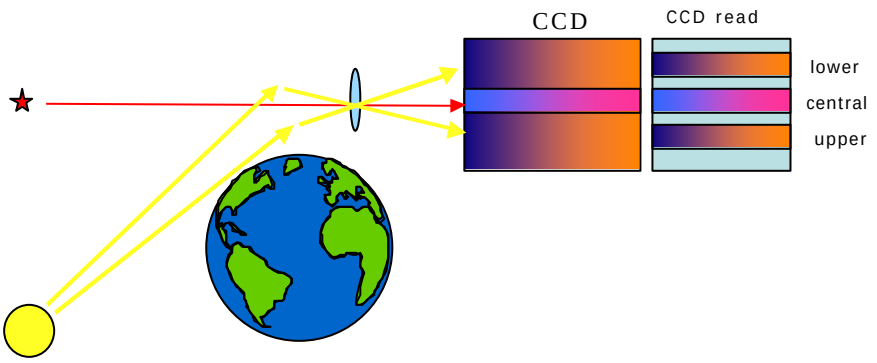
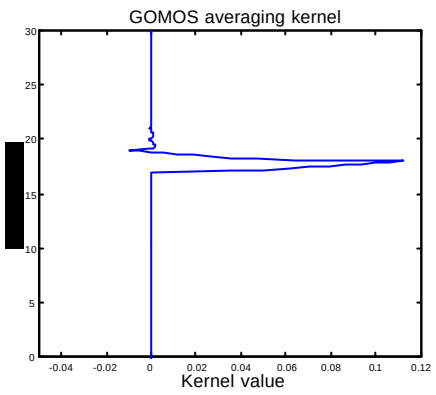
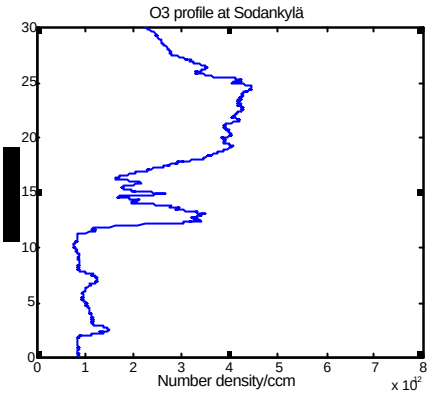
GOMOS star and limb scattering observations



GOMOS

Vertical resolution





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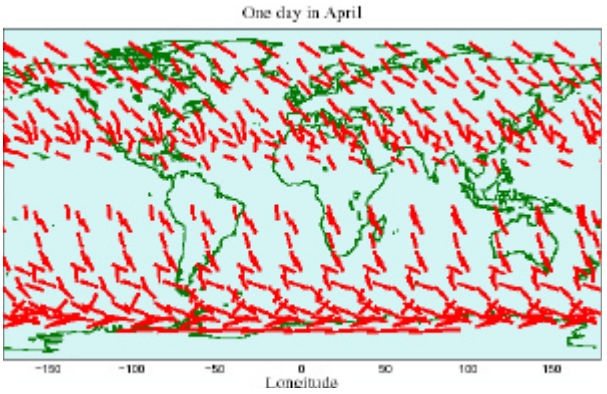
Global coverage

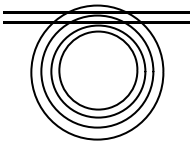


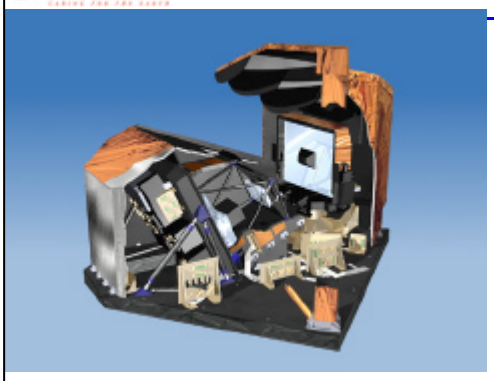
Short and long occultations. Bright and dim stars.
Cool and hot stars.

Data inversion

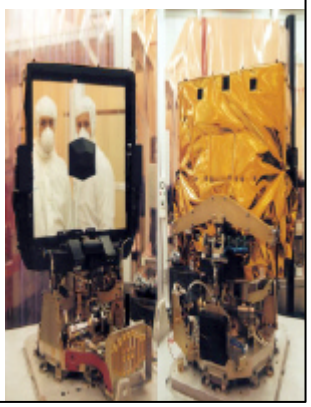
$$\frac{I_{occ}(z,\lambda)}{I_{ref}(\lambda)} = T(\lambda) = e^{-\sigma(\lambda)N(z)} \xrightarrow{\text{Spectral inversion}} N(z) = -\frac{\log(T)}{\sigma(\lambda)}$$

$$N(z) = \rho(z(s))\,ds \xrightarrow{\text{Layers}} N = G\,\rho \xrightarrow{\text{Onion peeling}} \rho = G^{-1}N$$





- 160 kg, 200 W, 226 kb/sec
- Active pointing by steering mirror
- During spring 2003 difficulties with mirror movement
- 15.7.2003: Switch to the redundant electronics: instrument works fine again!



GOMOS Observation Geometry

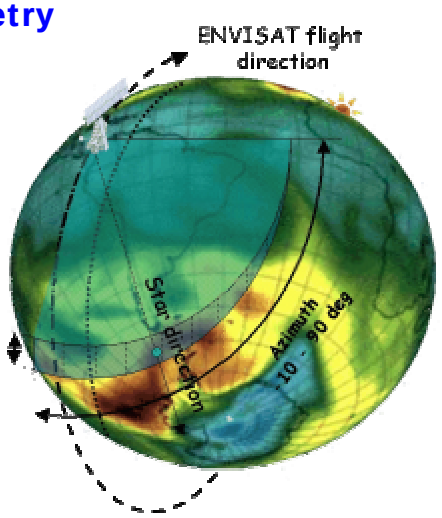
Pointing range
- Azimuth: -10 to 90 degree w.r.t anti-flight direction
- Elevation: 62 to 68 degree from nadir direction

Tracking range
- Azimuth: 7.4 degree
- Elevation: 6.5 degree

Rallying Speed
- 50 degree star separation = 24 Seconds

Max Tracking Duration
- 250 Seconds

Tracking altitude
- -15 to ~248 Km



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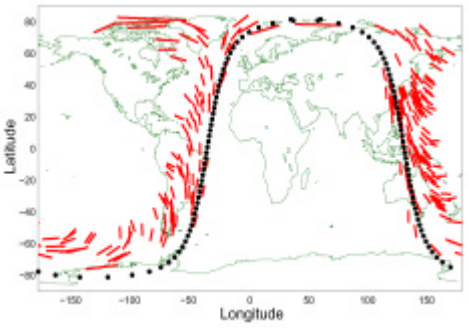
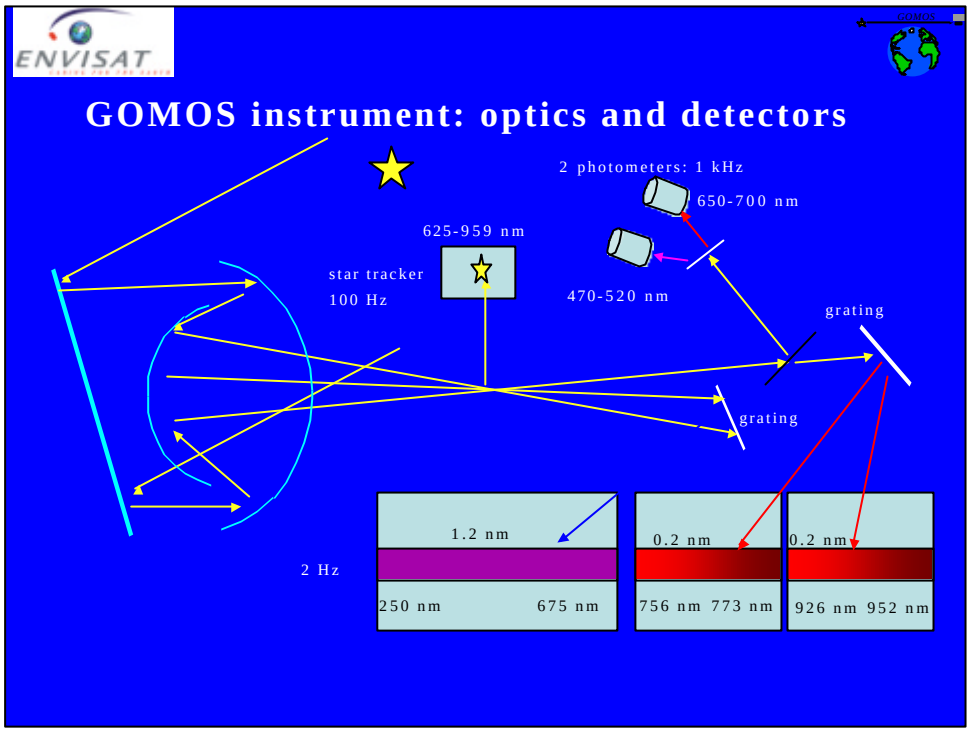
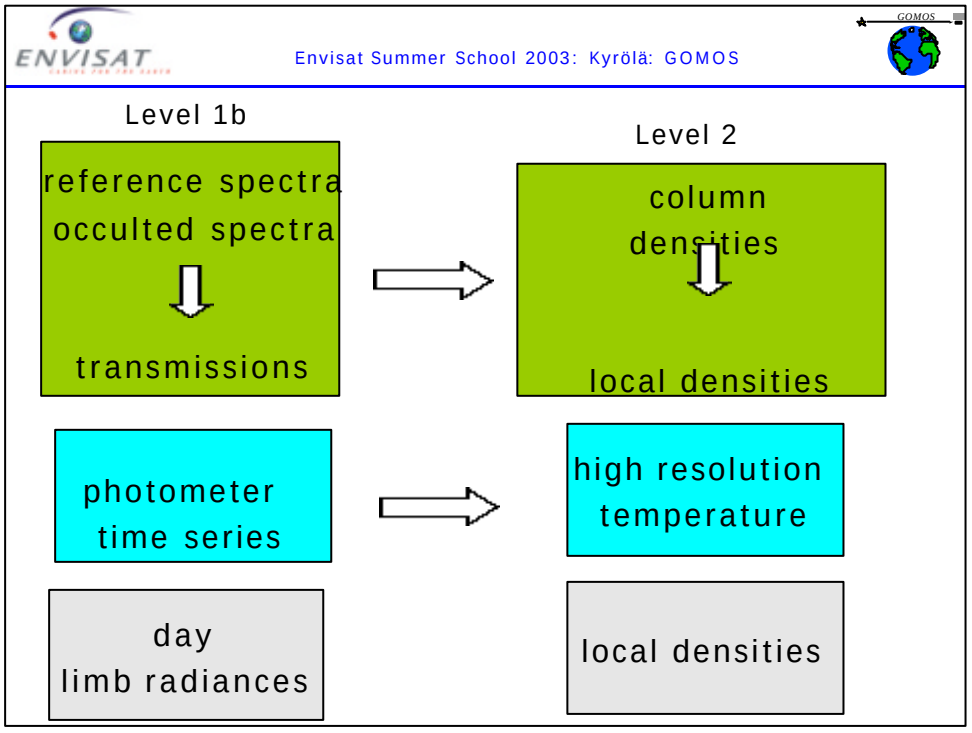
Depending on the season, there are 150 to 250 stars bright enough that they can be acquired and tracked by GOMOS. Shown is an example of one orbit with all available occultation's. But only about 40 occultations can be measured per orbit. The objective of the mission planning is to select the stars to be used in order to fulfil the mission objectives.

The mission planning considers:
- star-specific criteria
- occultation specific criteria




ENVISAT
GOMOS
GOMOS instrument: optics and detectors
2 photometers: 1 kHz
650-700 nm
625-959 nm
star tracker
100 Hz
470-520 nm
grating
grating
1.2 nm
0.2 nm
0.2 nm
2 Hz
250 nm
675 nm
756 nm 773 nm
926 nm 952 nm


ENVISAT
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GOMOS
Level 1b
reference spectra
occulted spectra
transmissions
Level 2
column densities
local densities
photometer time series
high resolution temperature
day limb radiances
local densities

Basic GOMOS data and validation: Level 1

Stellar spectra	Astronomical observations
Limb spectra	OSIRIS/Odin SCIMACHY/Envisat SOLSE/LORE
Transmissions	MSX UVISI (difficult because of scintillations)
Photometers	Unique data

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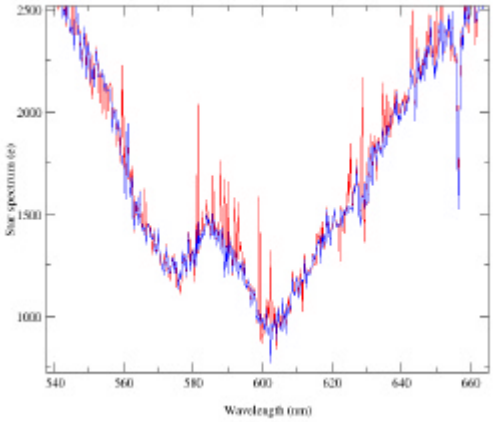
Basic GOMOS data and validation: Level 2

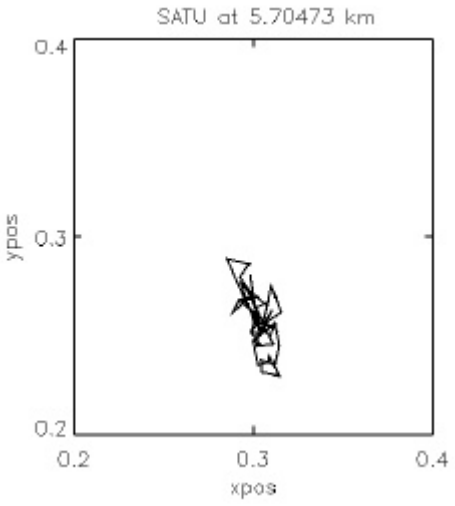
Reduced transmissions	MSX UVISI, solar occultation instruments
Column densities	MSX UVISI, solar occultation instruments
Profiles/ Ozone	Sondes, lidars, MW, balloons Satellites: Envisat, SAGE III HALOE, POAM III, Odin
Profiles/NO2	MIPAS, HALOE, SAGE III, POAM III, Odin
Density and temperature	ECMWF, lidars GOMOS internal

CCD shows more dark current noise than expected: instrument cooled down (-5 C) and various correction schemes are being applied.

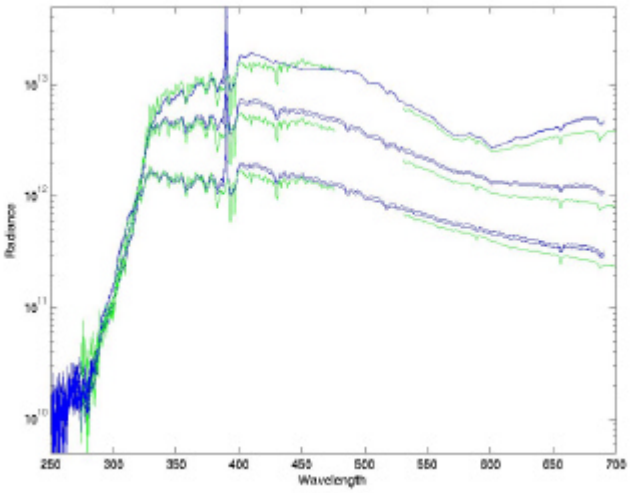
red: uncorrected
blue: corrected



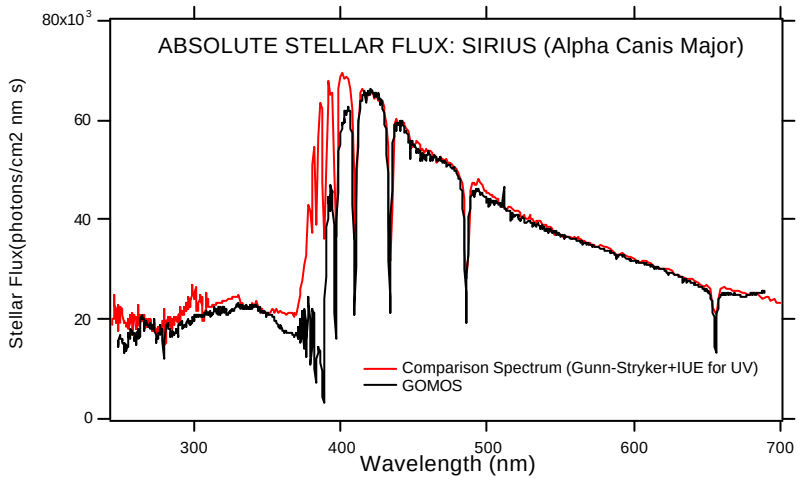
Star tracker



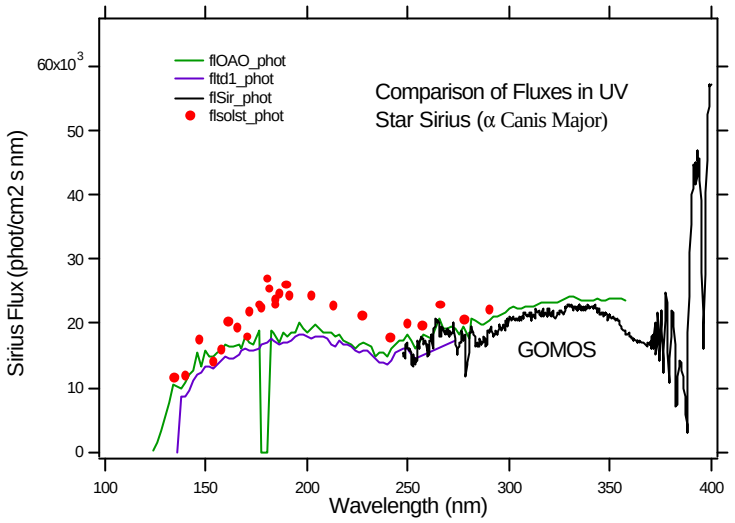
Limb radiances: GOMOS vs OSIRIS



RADIOMETRIC SENSITIVITY OF GOMOS: Comparison



ULTRA-VIOLET COMPARISON OF STELLAR FLUX



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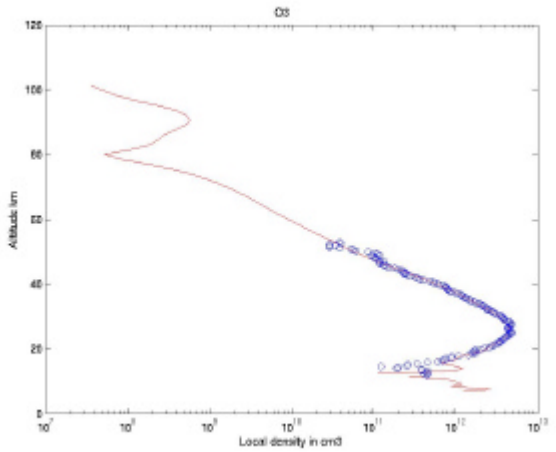
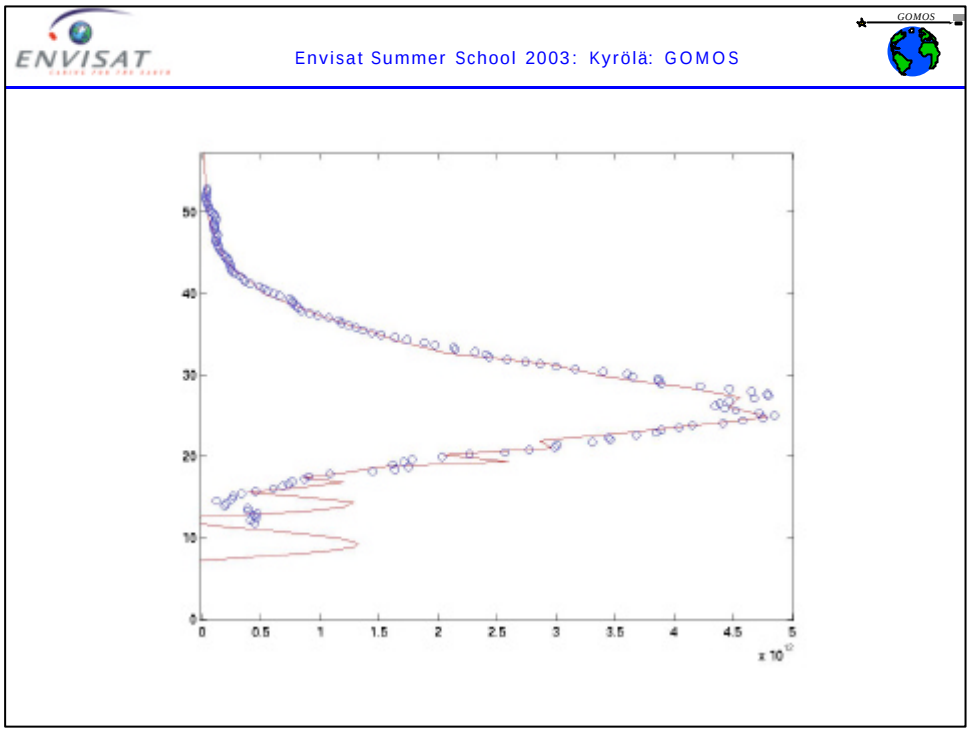
GOMOS ozone vs lidar ozone



Mauna Loa lidar data: T. Leblanc and S. McDermid at JPL/NASA,
P. Keckhut and S.Marchand at SA/CNRS-IPSL and the CALVAL NILU staff


ENVISAT
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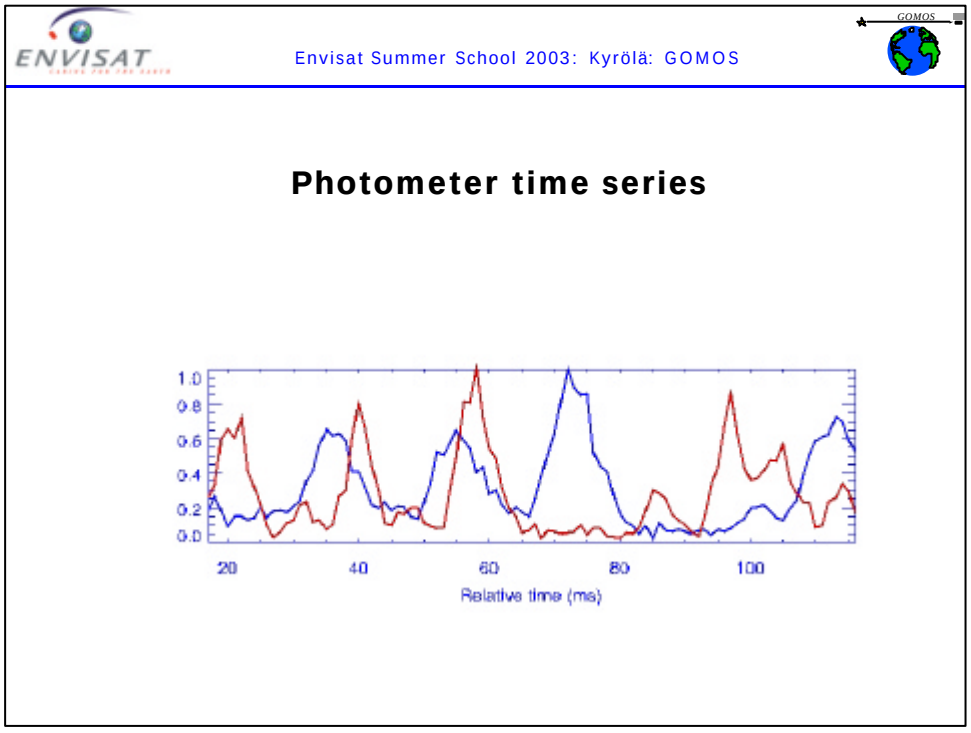
GOMOS
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
x 10^5


ENVISAT
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GOMOS
Photometer time series
1.0
0.8
0.6
0.4
0.2
0.0
20
40
60
80
100
Relative time (ms)