LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

FAKULTÄT FÜR PHYSIK
METEOROLOGIE

Temperature effects on the molecular Raman backscatter cross-sections due to narrow-band interference filters

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Introduction

When electromagnetic radiation interacts with molecules, elastic and inelastic scattering processes occur. In contrast to elastic scattering, the wavelength and the state of polarization of scattered photons may change when they are scattered inelastically. In this abstract we will focus on the inelastic scattering processes, the so-called Raman scattering. In particular, we investigate the effect of atmospheric temperature on the molecular rotational-vibrational (ro-vibrational) Raman backscatter cross-section which may occur after transmission of the backscattered radiation through narrow-band interference filters (IF). To analyze the consequence of the **changing temperature** we apply the equations published by M. Adam [1] to calculate the **temperature dependent ro-vibrational Raman backscatter cross-section for the N_2 molecule at 387 nm (laser wavelength of 355 nm)**. These equations have been implemented and evaluated as part of the Algorithm for Rayleigh and Raman calculations (ARC) that has been developed within ACTRIS [5].

Here, we show how the central wavelength and bandwidth of the IF affects the molecular Raman backscattering cross-section of N_2 for different temperature conditions.

Methodology

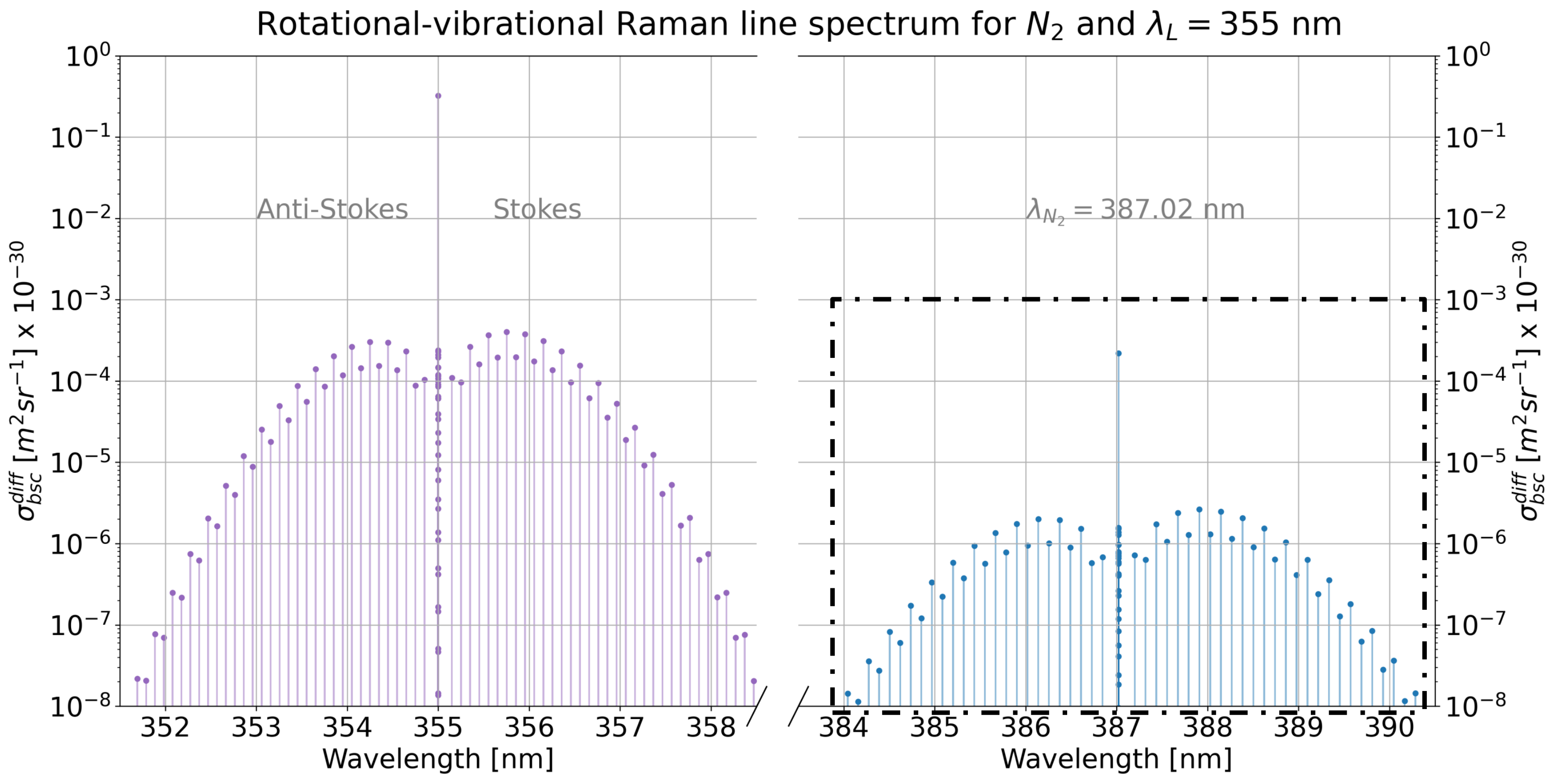

Figure 1. Pure rotational Raman backscatter spectrum of N_2 (left) and respective ro-vibrational Raman spectral lines for N_2 (right) in a dry standard atmosphere.

Filtering

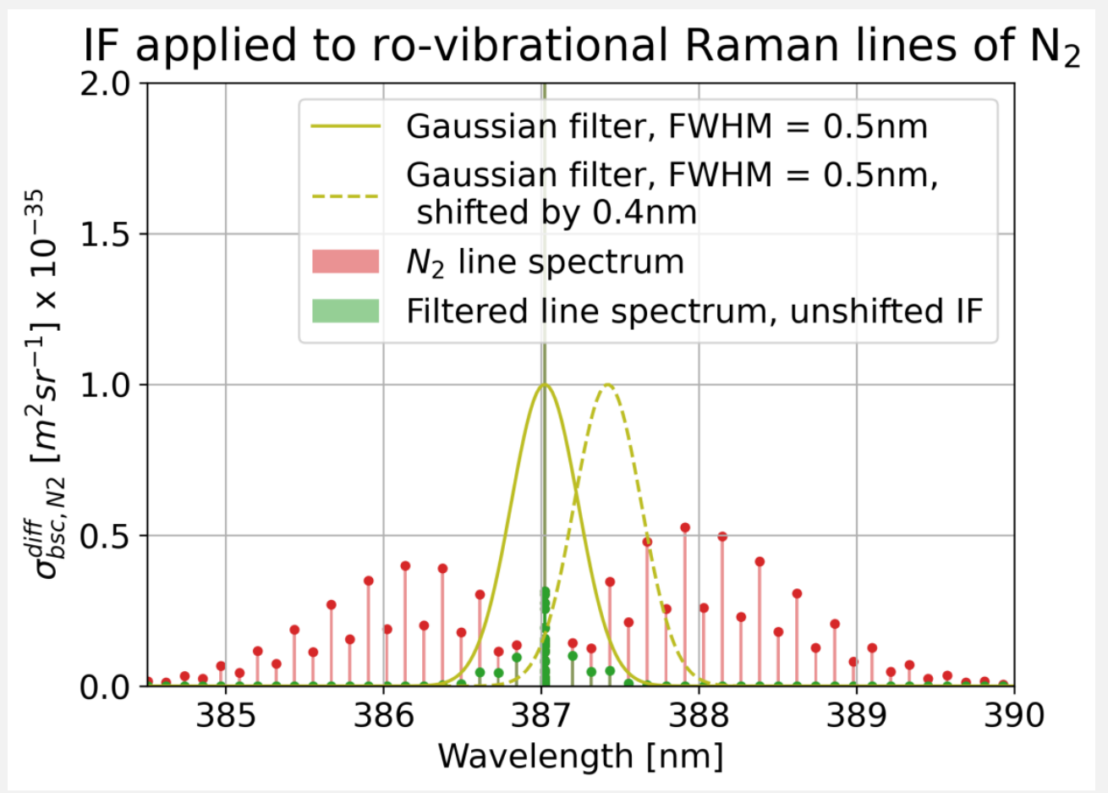

Figure 2. Application of a centered and a shifted Gaussian shaped IF.

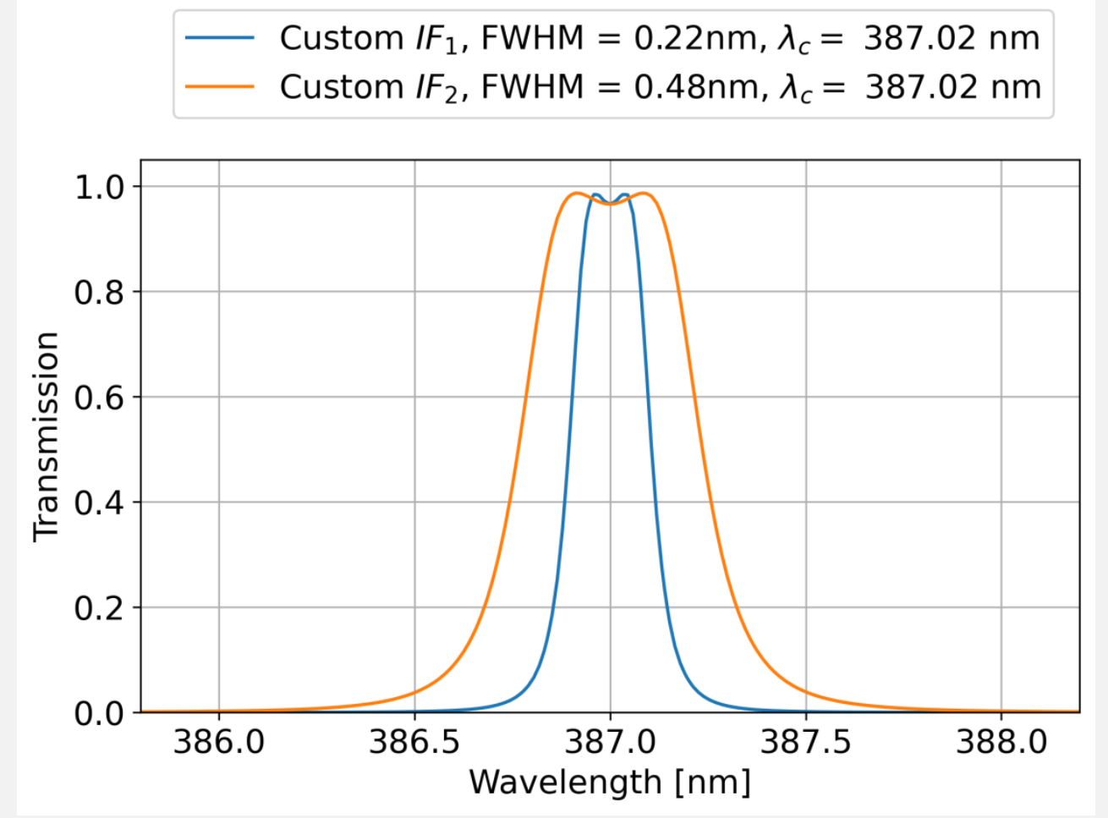

Figure 3. Custom double cavity IF.

Initial equations

1. Differential backscatter cross section (SI-units)

$$\left(\frac{\partial\sigma}{\partial\Omega}\right)_{T,J} = \frac{\pi^2}{\epsilon_0^2} \cdot \left(\nu_0 - \nu_{vib} + \Delta\nu_J\right)^4 \cdot F_{MB}(T,J)\Phi_J'$$

2. Total backscatter cross section

$$\sigma_{bsc,i} = c_{N_2} \cdot \sum_J \left(\frac{\partial\sigma}{\partial\Omega}\right)_{T,J}$$

T:	Temperature
J:	Rotational quantum number
c_{N_2}:	Atmospheric molar fraction of N_2
$\nu_{0,vib,J}$:	Relevant wavenumbers (laser, rotational and vibrational transistions)
F_{MB}:	Maxwell-Boltzmann distribution
Φ':	Platzek-Teller coefficent for ro-vibrational Raman scattering

Apply filter to ro-vibrational spectrum (highlighted in Fig. 1 with the dashed square)

$$\sigma_{bsc,i}^{eff} = \sigma_{bsc,i} \cdot T_{IF}\left(\nu_0 - \nu_{vib} + \Delta\nu_J\right)$$

Calculate relative deviation of effective backscatter cross–section due to temperature variation. Compared are the effective backscatter cross-section values at the two most extreme temperatures.

$$\chi\,[\%] = \frac{\sigma_{bsc,N_2}^{eff}(15\mathrm{km}) - \sigma_{bsc,N_2}^{eff}(0\mathrm{km})}{\sigma_{bsc,N_2}^{eff}(0\mathrm{km})} \cdot 100$$

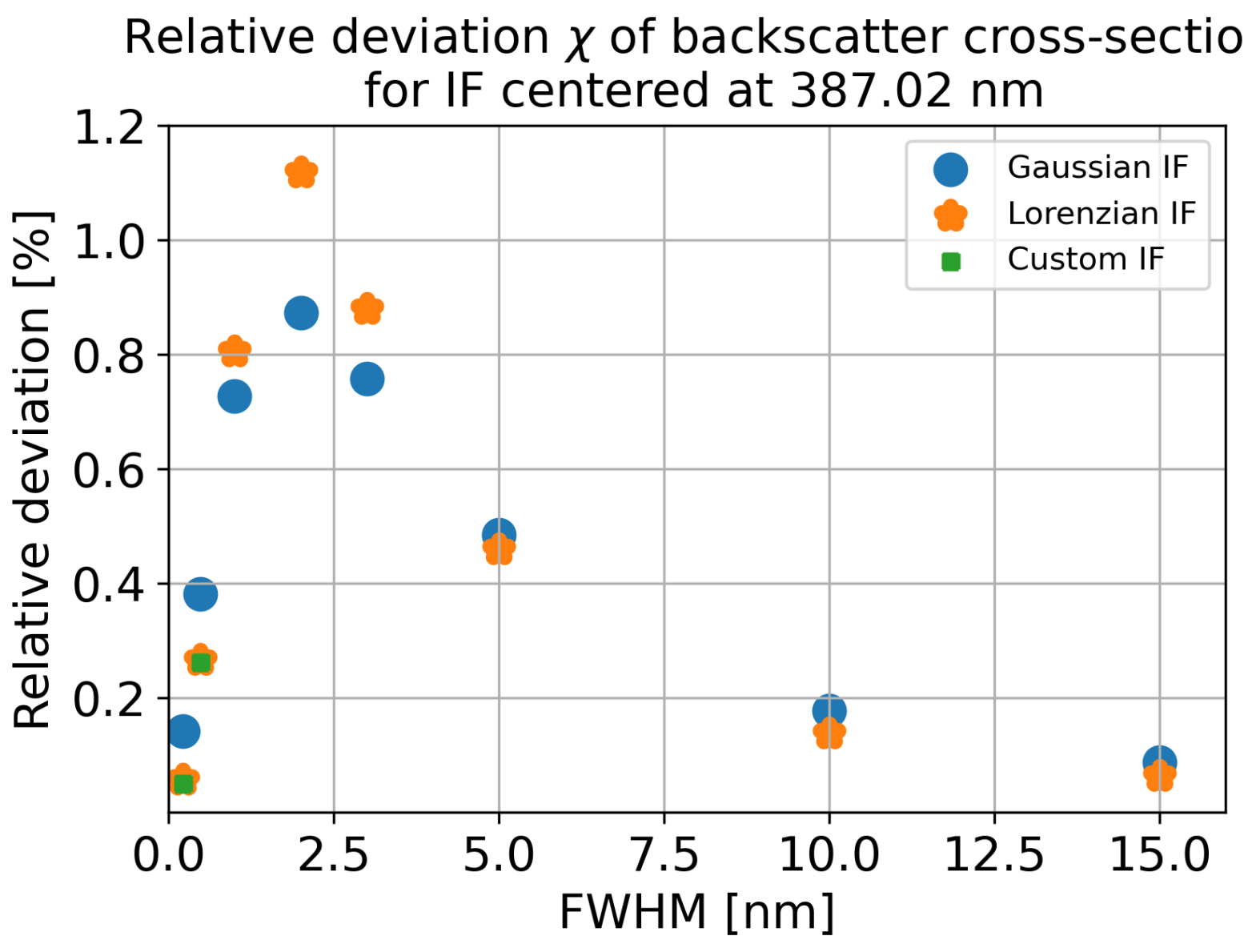

Figure 5. Relative deviation χ of the effective total backscatter cross-section due to temperature differences.

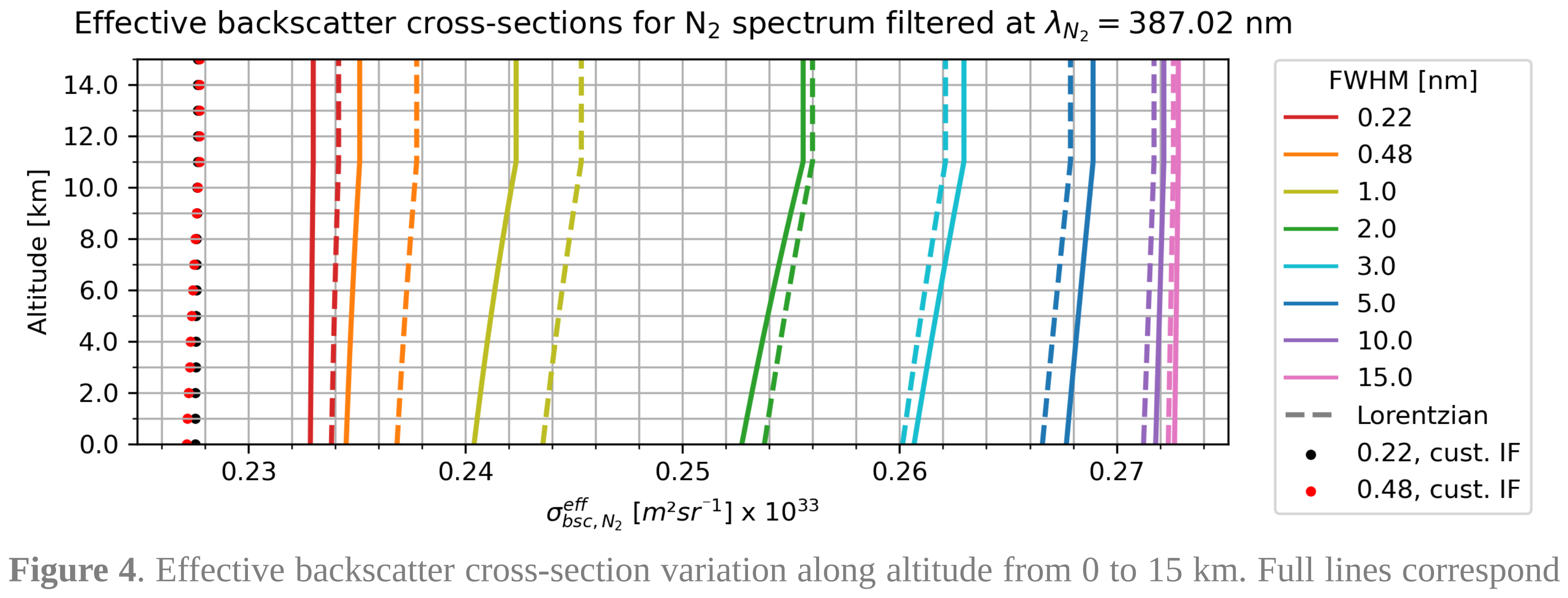

Figure 4. Effective backscatter cross-section variation along altitude from 0 to 15 km. Full lines correspond to Gaussian shaped filters, dashed lines to Lorentzian shaped filters and dotted lines to double cavity IF.

Summarizing plot

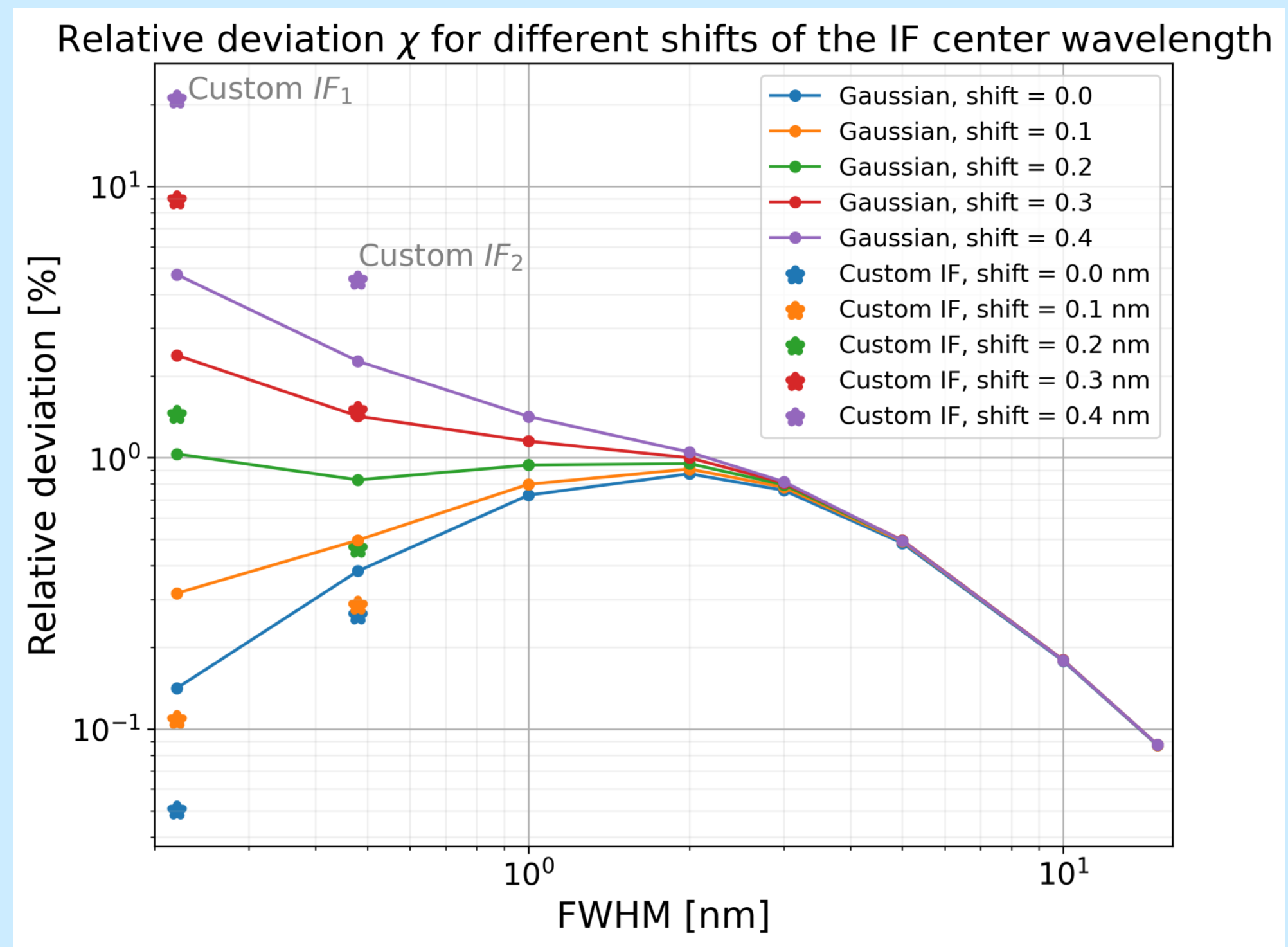

Figure 6. Relative deviation χ of the effective backscatter cross-section for two different double-cavity IF and different Gaussian shaped IF of different bandwidth shifted with respect to the central line of the ro-vibrational spectrum of N_2. Lorentzian shaped IF show a very similar behavior as the Gaussian ones. Consequently, they are spared here.

Conclusion

- Temperature dependence of the effective backscatter cross-section when using narrow-band IF applied to the N_2 Stokes ro-vibrational Raman spectrum
- For filters with narrow bandwidth ($\leq$ 1 nm) or broad bandwidth ($\geq$ 5 nm) the effective ro-vibrational backscatter cross-section is affected by less then 0.5% due to temperature changes from the atmosphere (temperature range: 288.15 K (0 km) – 216.65 K (15 km)
- Wavelength shifted IF (see Fig. 2 and Fig. 6): The IF shift can lead to temperature variations of the backscatter cross-section up to 11% for very narrow IF. The temperature variations are small ($\chi <$ 0.5%) for IF with bandwidths broader than 5 nm
- The transmission curve of the IF leads to temperature variations less than 0.2% of the backscatter cross-section

Future work

- Include more real IF bandwidths
- Use all three common lidar wavelengths
- Consider effect on the systematic error on lidar products (aerosol extinction and lidar ratio)
- ➢ **Conclude to recommendations for IF usage**

Acknowledgements, References

This project receives funding from the European Union's Horizon research and innovation program under grant agreement No. 871115. ACTRIS-D is funded by the German Federal Ministry for Education and Research (BMBF) under grant agreements 01LK2001A-K &01LK2002A-G.

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