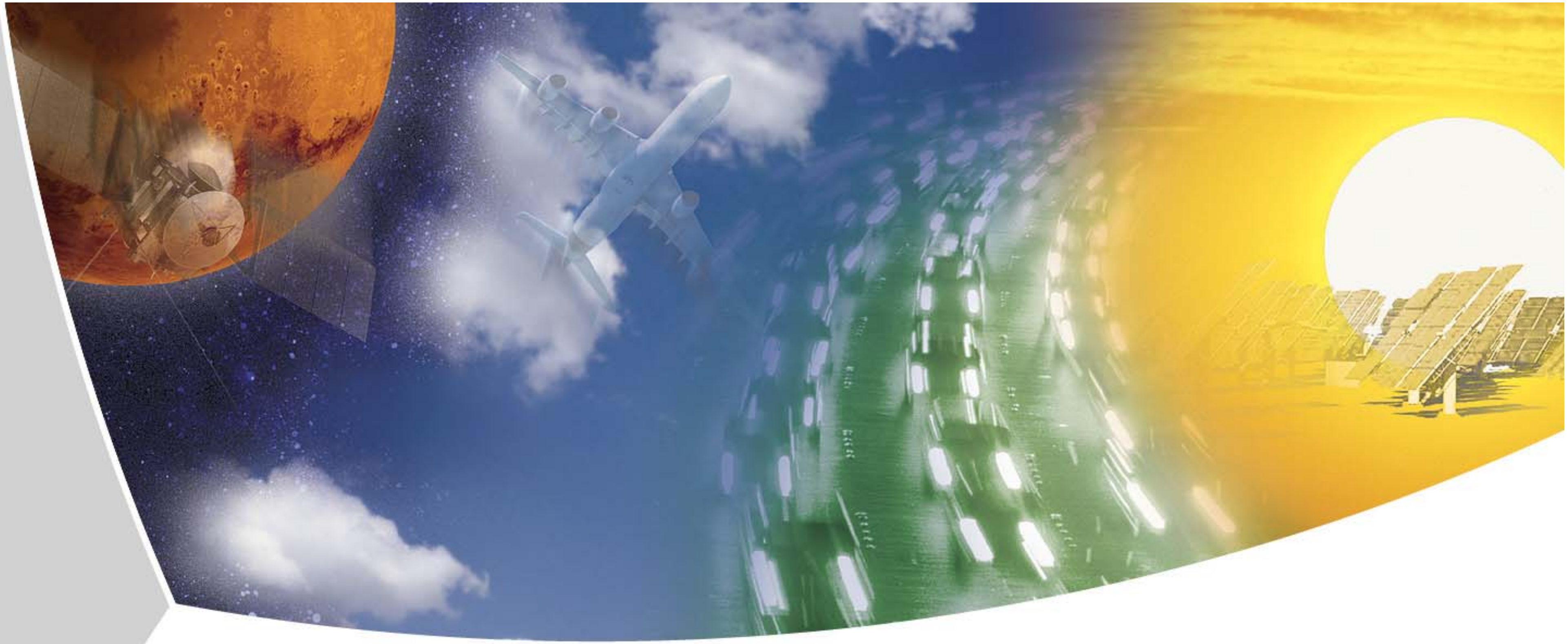

Rayleigh-Brillouin Scattering in N_2, O_2, and Air

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Institut für Physik der Atmosphäre

A SPONTANEOUS RAYLEIGH-BRILLOUIN SCATTERING EXPERIMENT FOR THE CHARACTERIZATION OF ATMOSPHERIC LIDAR BACKSCATTER

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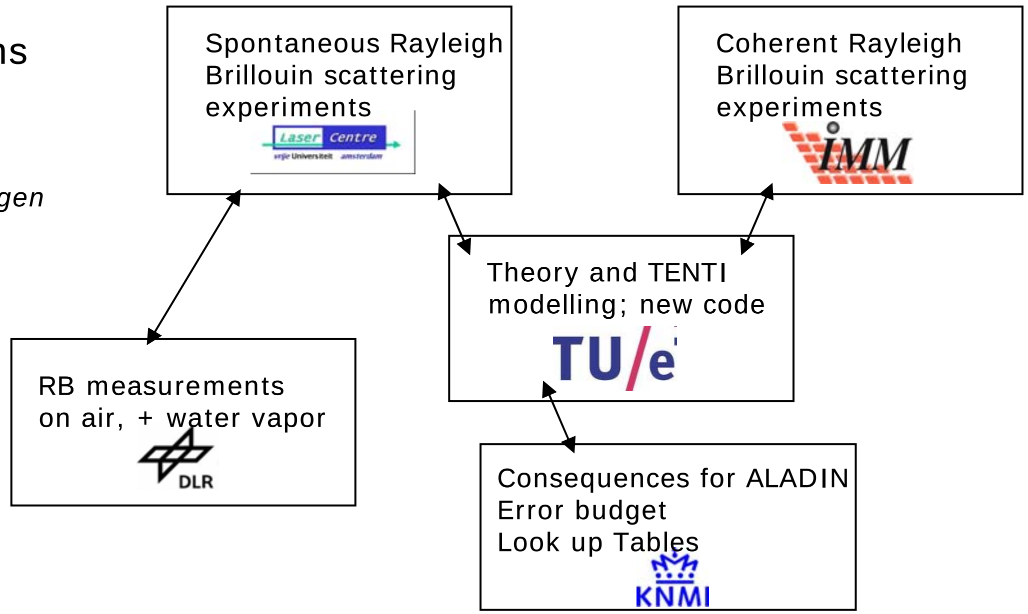

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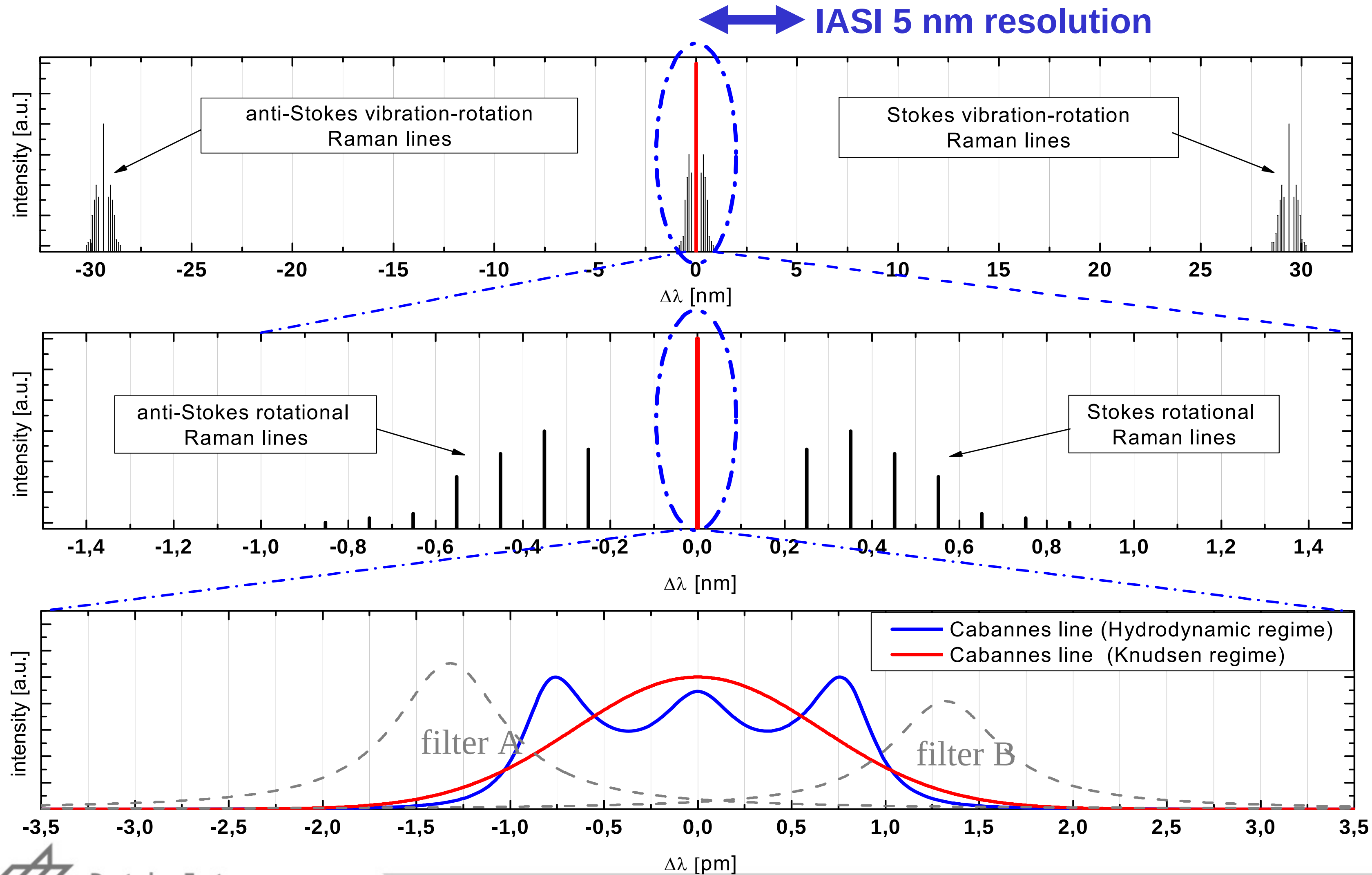
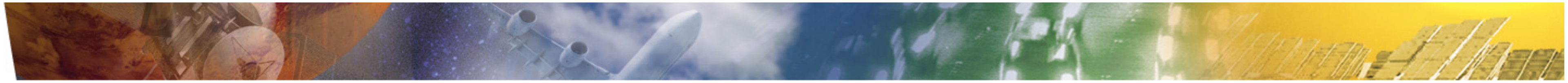
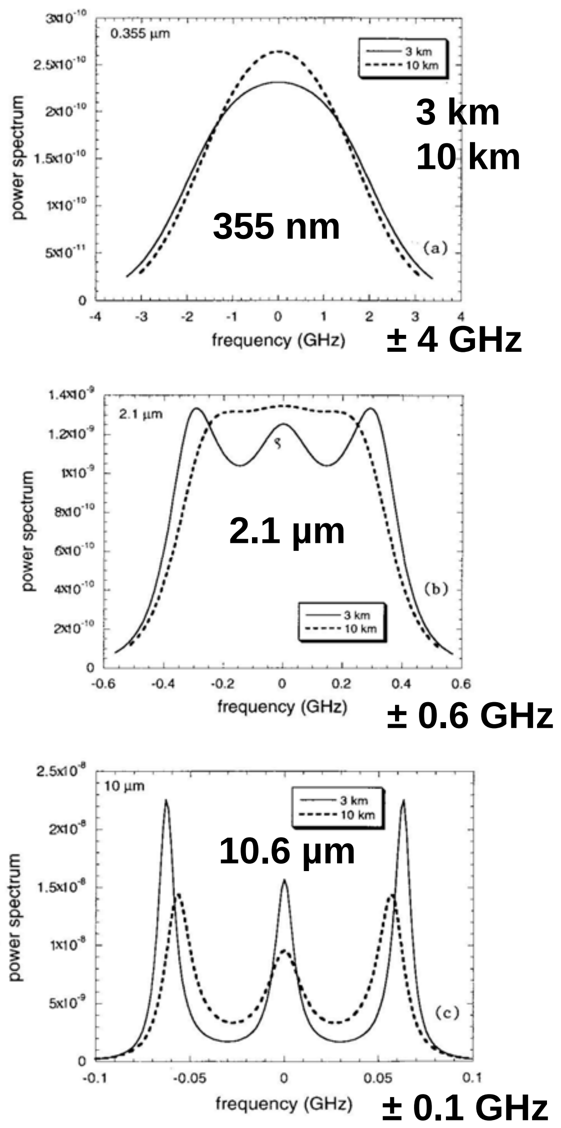
Research stay of Witschas at VU Amsterdam was funded by EU FP7/2007-2013

Molecular scattering in air - even more than 100 years after Rayleigh still some open issue





What is the exact lineshape in air?



B. Rye (1998), Appl. Opt., 6321-6328

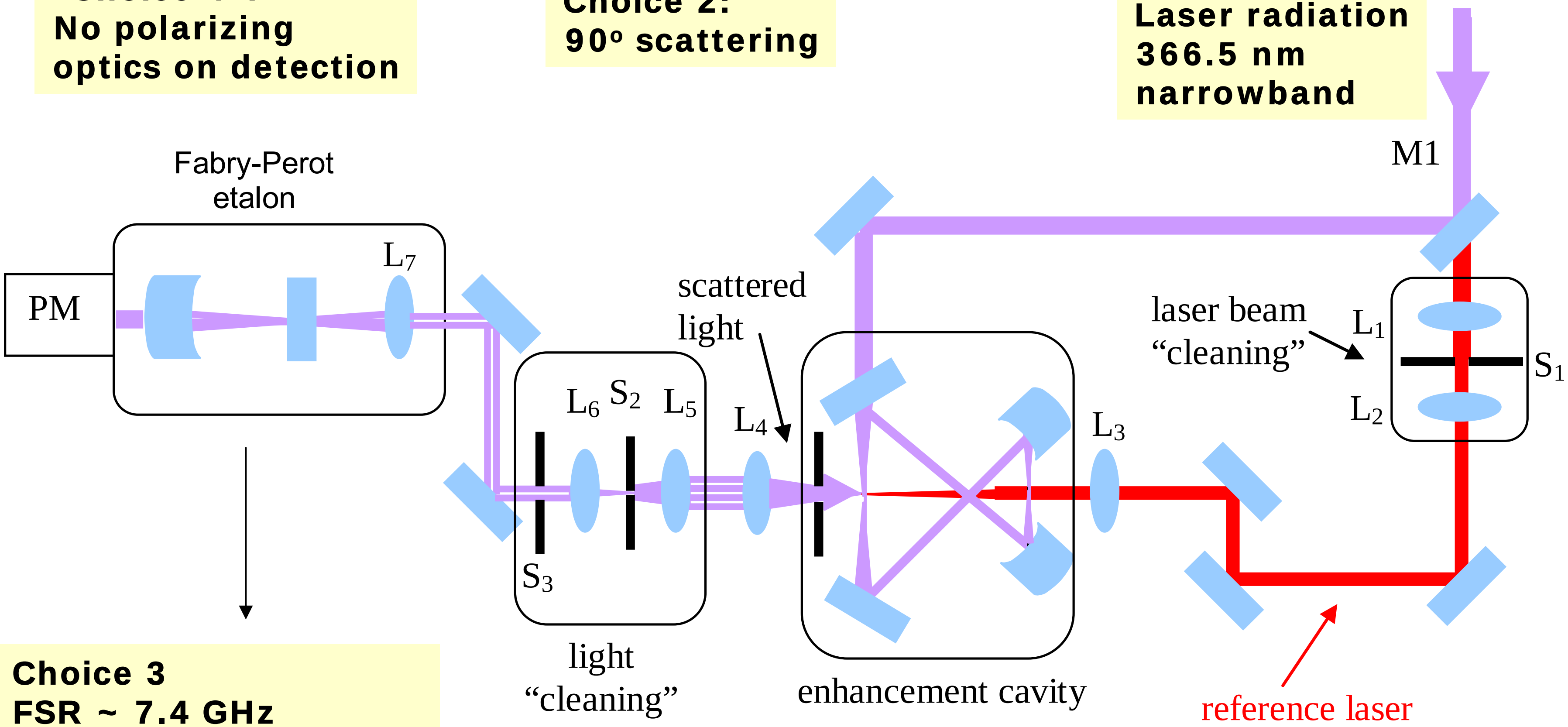
- Fiocco and DeWolf (1968) pointed out the difference of Gaussian to Rayleigh-Brillouin lineshape to lidar community
- Lidar techniques using molecular backscatter and narrow instrumental bandwidths are affected, e.g. wind, T, HSRL
- Errors for wind retrievals of ADM-Aeolus would be 3% (10 km) to 10% (ground) if Gaussian is used (Dabas et al. 2008) and thus exceeding specification of 0.7%
- Widely used models for lineshape from Boley et al. (1972) and Tenti et al. (1974) - the Tenti S6 model - are valid for single species, but not for mixtures like air (N_2+O_2)
- No experimental validation of Tenti S6 model for air; even Tenti S6 was not compared to N_2 for atmospheric pressures
- Most (or probably all) use Tenti S6 with N_2 gas parameters => Is there a difference between N_2 and air lineshape?
- What is the influence of the water vapour molecule (up to 4% in atmosphere)?

Setup for spontaneous Rayleigh-Brillouin scattering experiment at VU Amsterdam

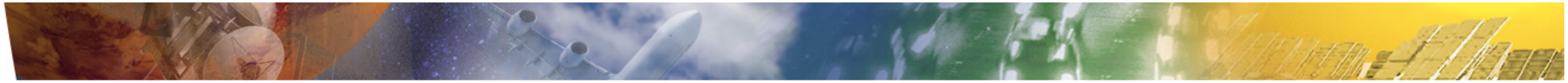
"Choice 4": No polarizing optics on detection

Choice 2: 90º scattering

Choice 1 Laser radiation 366.5 nm narrowband

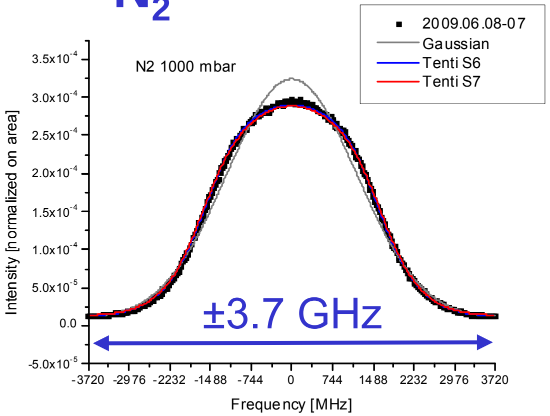


Choice 3 FSR ~ 7.4 GHz Resolution ~ 0.23 GHz

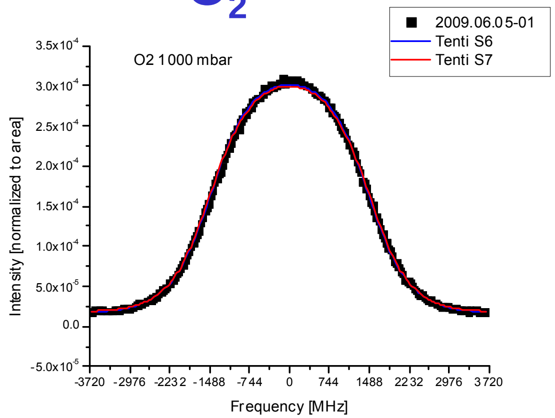


Measurements and Tenti models at 1000 hPa

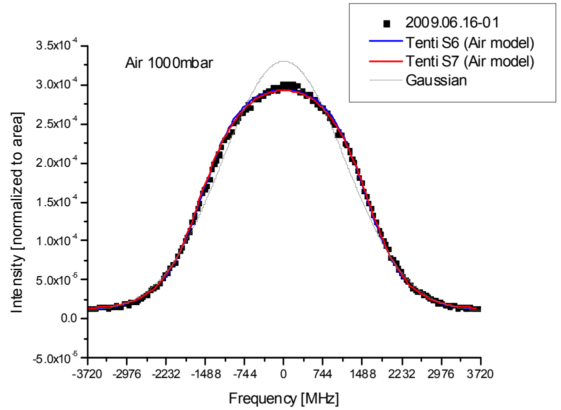
N_2

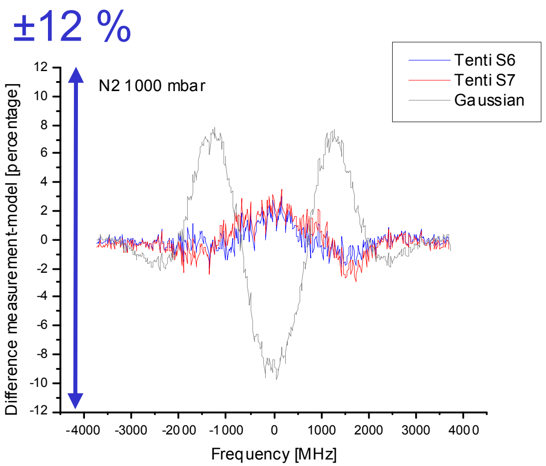


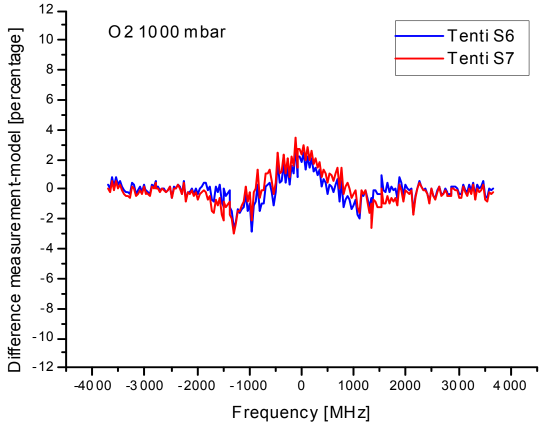
O_2

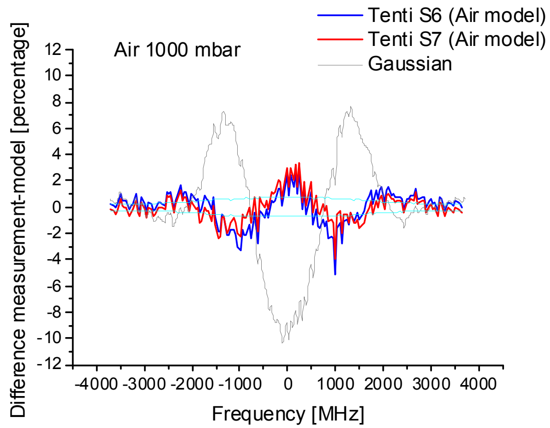


Air

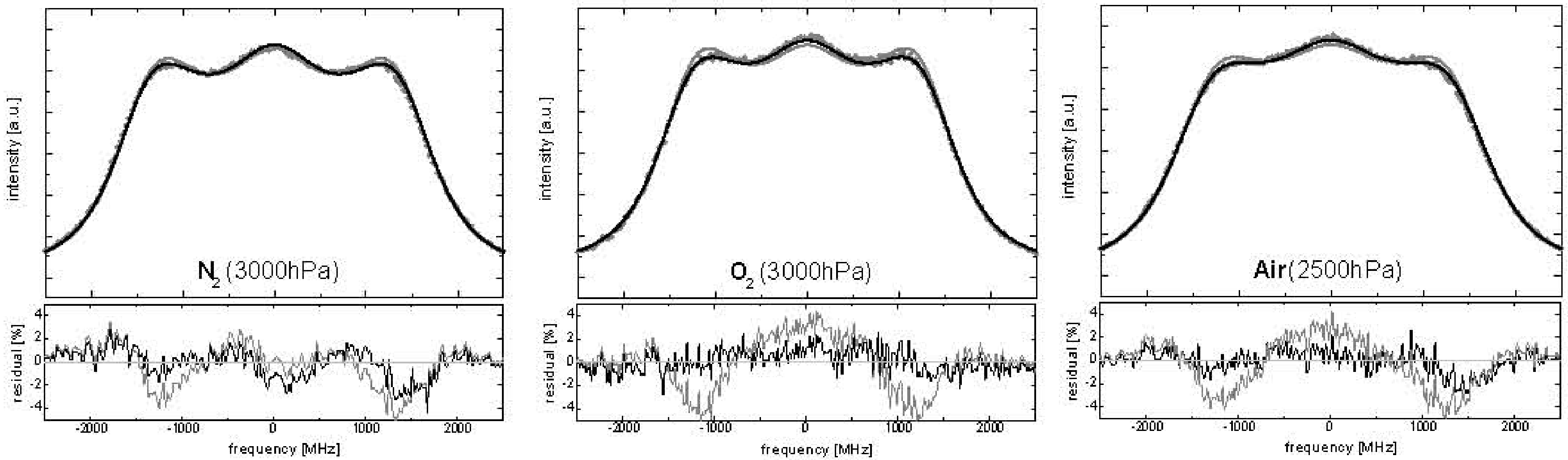






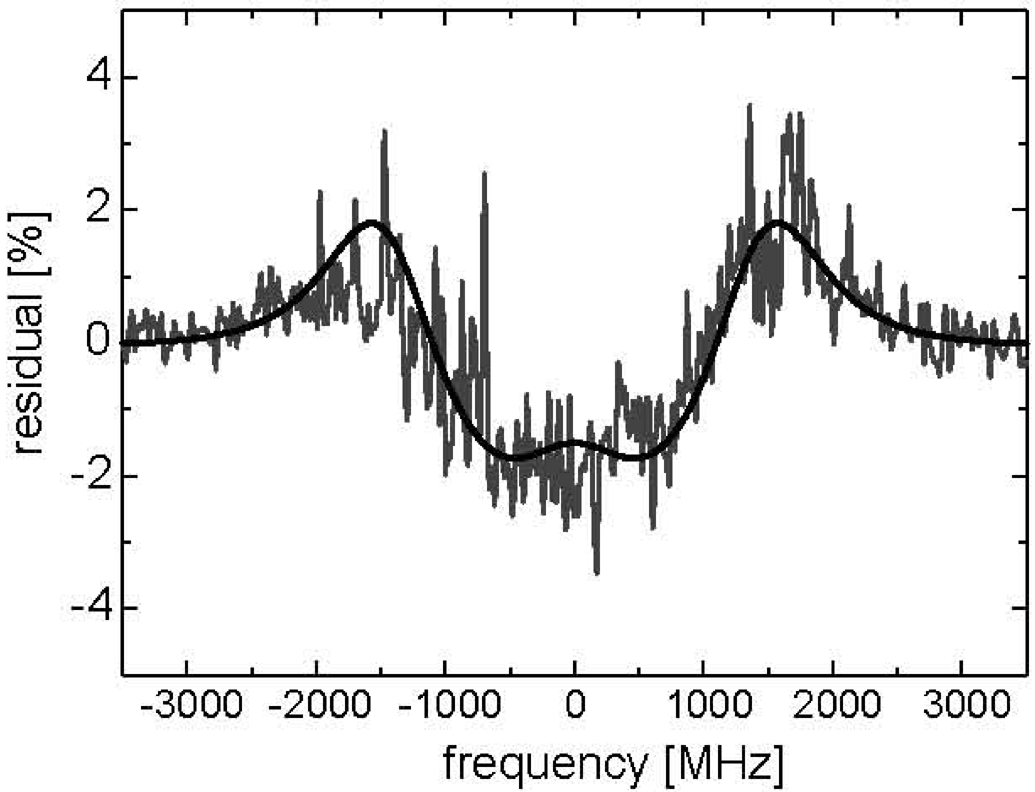


Measurements and Tenti S6 model at higher pressures



- For higher pressure 3 spectral features become visible: the central Gross line and the Brillouin doublet
- Tenti S6 is able to resolve these features
- Gas parameter with highest uncertainty within Tenti model is bulk viscosity, which is obtained from sound absorption measurements (grey curve)
- Bulk viscosity was used as fit-parameter to minimize measurement-model difference in this study (black curve)

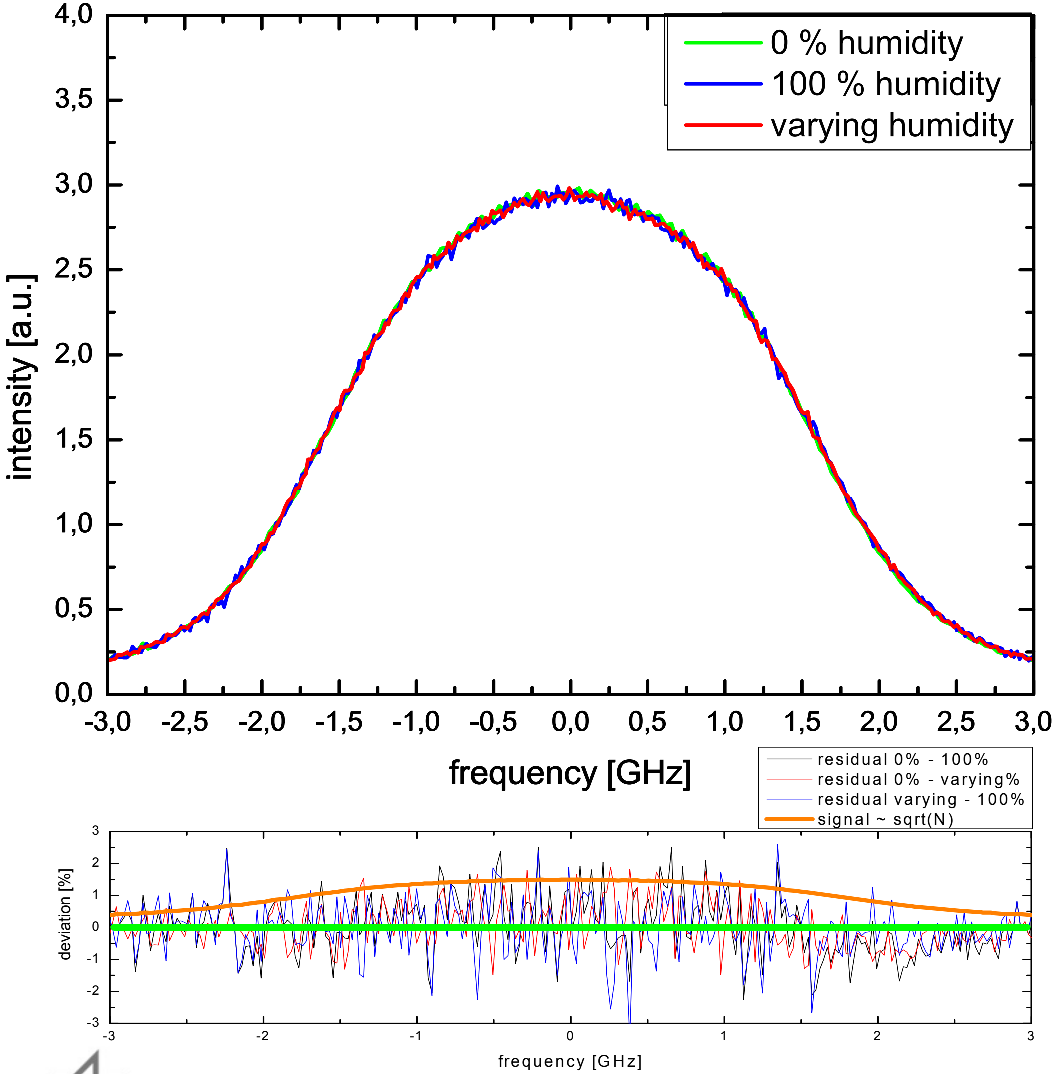
Is there a difference between lineshape of N_2 and air?



Rel. difference between lineshape for N_2 and air from measurements and Tenti S6 model at 2000 hPa, 297 K, normalized to maximum of lineshape.

- Most (or all) use Tenti S6 model with N_2 parameters
- No measurements of line-shape were performed up to now for air (79% N_2, 21% O_2)
- There is a measurable difference between N_2 and air
- The difference can be modeled with Tenti S6 using appropriate gas parameters as input for
  - molar mass
  - shear viscosity
  - bulk viscosity
  - thermal conductivity

Is there an effect of humidity?



- Atmosphere can contain up to 4 % water vapor (100 % rel. humidity at 37 °C)
- Measurements showed no significant difference between lineshape of dry and humid air up to 2.6% water vapor
- No need to consider water vapor within lineshape model for atmospheric conditions

Summary

- Spontaneous Rayleigh-Brillouin scattering was measured at 366.5 nm, at a scattering angle of 90°, at ambient temperature (≈300 K), and for pressures of 0.3 bar to 3 bar for N_2, O_2, and air by a setup at VU Amsterdam with a narrowband laser, a scattering cell within an enhancement cavity, and a confocal Fabry-Perot interferometer.
- For the first time the Cabannes lineshape was measured for dry air (N_2+O_2) and for humid air with up to 2.6 % water vapor content.
- For the first time the lineshapes of N_2 and air were compared to Tenti S6 and S7 model

Conclusion

- It was confirmed that Tenti S6 is (slightly) better than Tenti S7
- Bulk viscosity parameter was varied as model input to minimize measurement to model difference => resulted in a factor of 2 higher bulk viscosity values as reported from sound absorption experiments in literature
- Deviations between Tenti S6 model and measurements are below +-2% for atmospheric pressures, if appropriate gas parameters are used as model input
- Water vapor does not influence lineshape - at least up to 2.6% content (compared to a maximum atmospheric content of 4%)