ESA - MOST Dragon 2 Programme

中国科技部-欧洲空间局合作 "龙计划"二期

## 2011 DRAGON 2 SYMPOSIUM

"龙计划"二期2011年学术研讨会

# Dragon 2 Project Lidar Cal/Val (ID 5291)

# Pre-launch validation of ADM-Aeolus: Experiments on Rayleigh-Brillouin scattering in air (Young Scientist contribution)

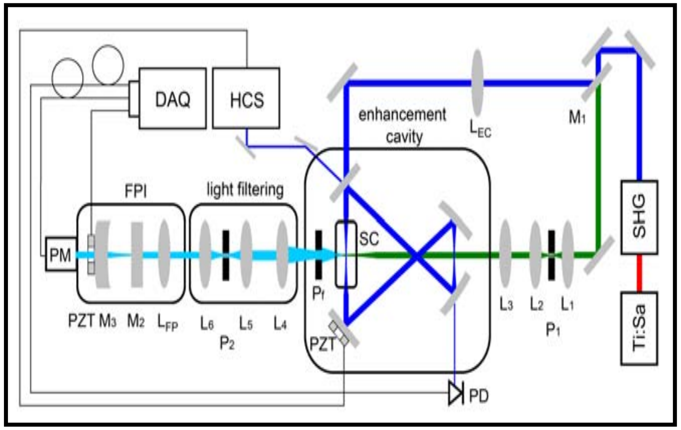
**Witschas Benjamin**, Reitebuch Oliver, Ubachs Wim, Vieitez Ofelia, van de Water Willem

20 - 24 June 2011 | Prague | Czech Republic

捷克 布拉格 2011年6月20-24日

# Overview

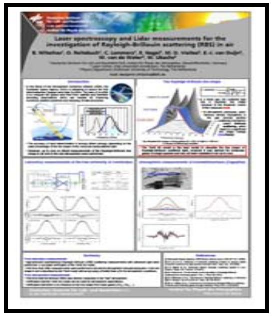
AEOLUS




- Measurements of Rayleigh-Brillouin scattering on air in the laboratory

- Measurements of Rayleigh-Brillouin scattering in the real atmosphere

# Related publications



- **Further results of the experiments on Rayleigh-Brillouin scattering in air are presented at the Young Scientist's Poster session**: "Laser spectroscopy and Lidar measurements for the investigation of Rayleigh-Brillouin scattering in air".

Experiments on spontaneous Rayleigh-Brillouin scattering in air

Dissertation

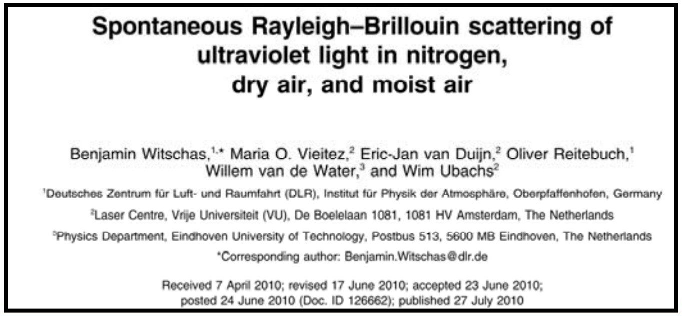
zur Erlangung des akademischen Grades doctor rerum naturalium (Dr. rer. nat.)

seit 1558

vorgelegt dem Rat der Physikalisch-Astronomischen Fakultät der Friedrich-Schiller-Universität Jena

von Dipl. Ing. (FH) Benjamin Witschas

- **Doctoral Dissertation finished and submitted** to the Friedrich-Schiller University, Jena, Germany in April 2011 (Benjamin Witschas "Experiments on spontaneous Rayleigh-Brillouin scattering in air").



**Spontaneous Rayleigh–Brillouin scattering of ultraviolet light in nitrogen, dry air, and moist air**

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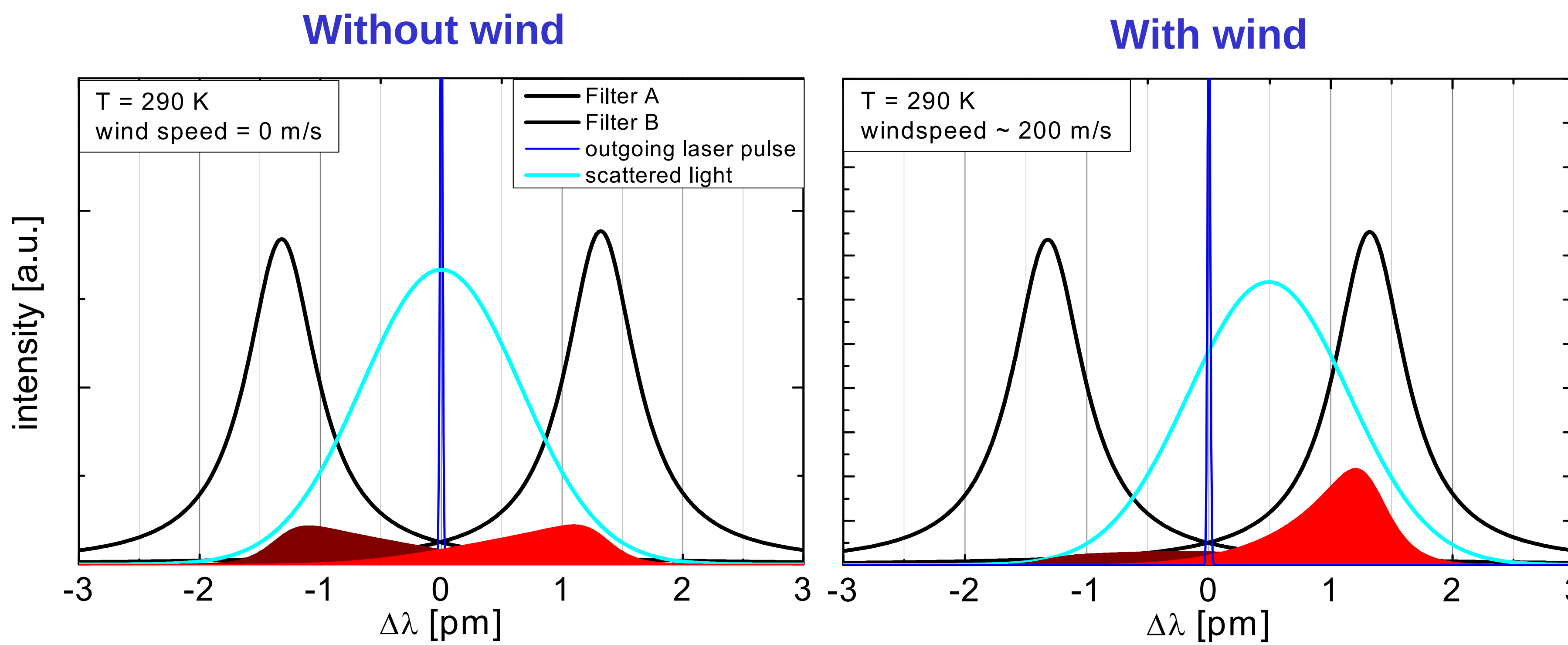
- **Paper published in Applied Optics (July 2010).**

  Witschas et al. (2010), Spontaneous Rayleigh-Brillouin scattering of ultraviolet light in nitrogen, dry air, and moist air.

# Necessity of investigating Rayleigh-Brillouin scattering in air




- The determined wind speed directly depends on the ratio A/B.
- A/B directly depends on the line shape of the scattered light

Hydrodynamic regime (dense gas):

Mean free path << scattering wavelength

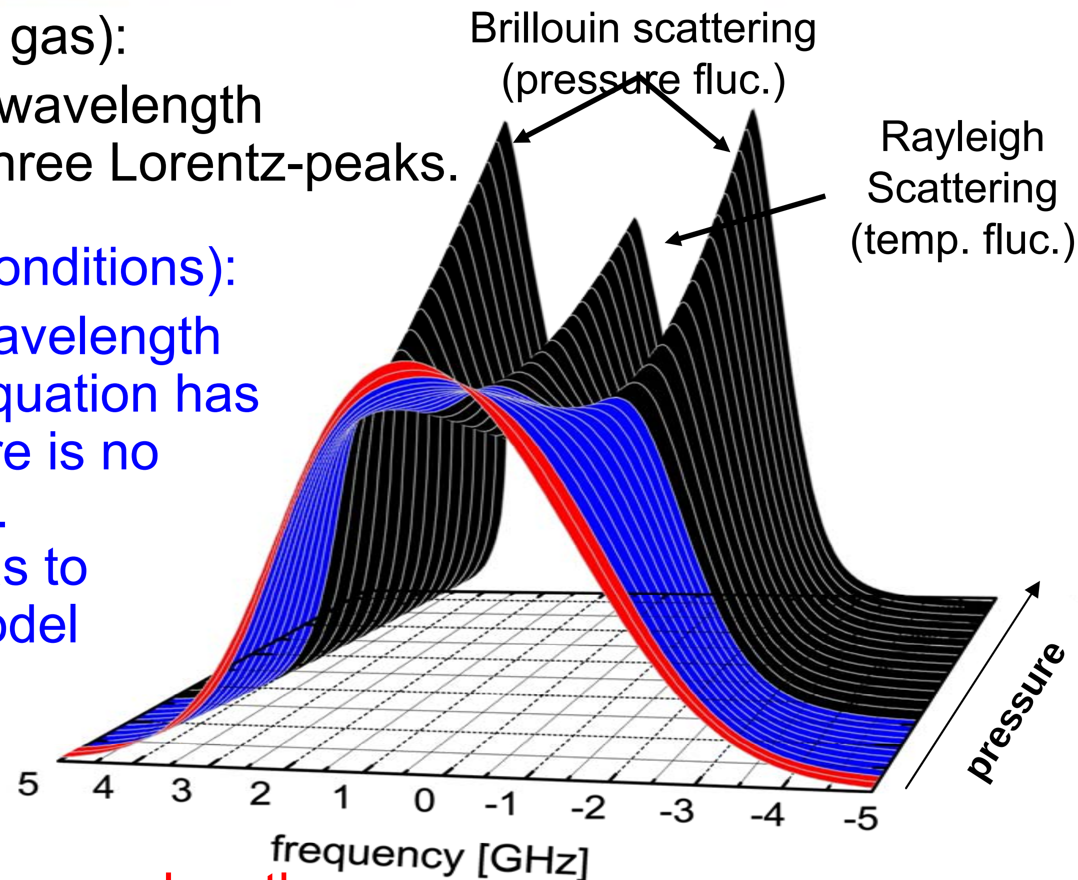
→ spectrum is composed of three Lorentz-peaks.

Kinetic regime (atmospheric conditions):

Mean free path ≈ scattering wavelength

→ The Boltzmann transport equation has to be solved, however, there is no analytical solution possible.

→ An approximative model has to be derived → TENTI-S6-model which is the best available SRB line shape model




Knudsen regime (dilute gas):

Mean free path is >> scattering wavelength

→ spectrum is described by a Gaussian function (Brownian motion)

The Rayleigh-Brillouin line shape of light scattered in air has not been investigated, yet (Neither in the lab, nor in the real atmosphere).

# Necessity of validating the Tenti S6 line shape model

- The Tenti S6 line shape model was derived for molecular gases

→ **The applicability in air (mixture of molecular gases) is questionable**

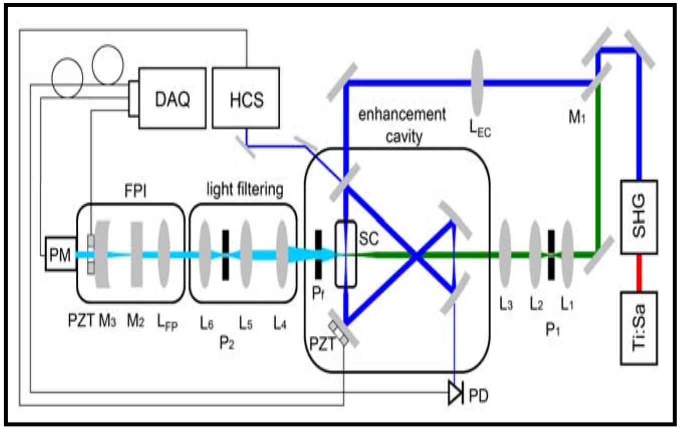
- The Tenti S6 line shape model was verified with Rayleigh-Brillouin scattering measurements in molecular gases, however:

→ **Up to now, no SRBS measurements have been performed in air or nitrogen under atmospheric conditions.**

## Scientific questions:

- **Is the description of SRB line shapes in air accurate by using the Tenti S6 model?**
- **Does water vapor influence the SRB line shape?**
- **Do any effects in the atmosphere restrict the application of the Tenti S6 model?**

# Overview



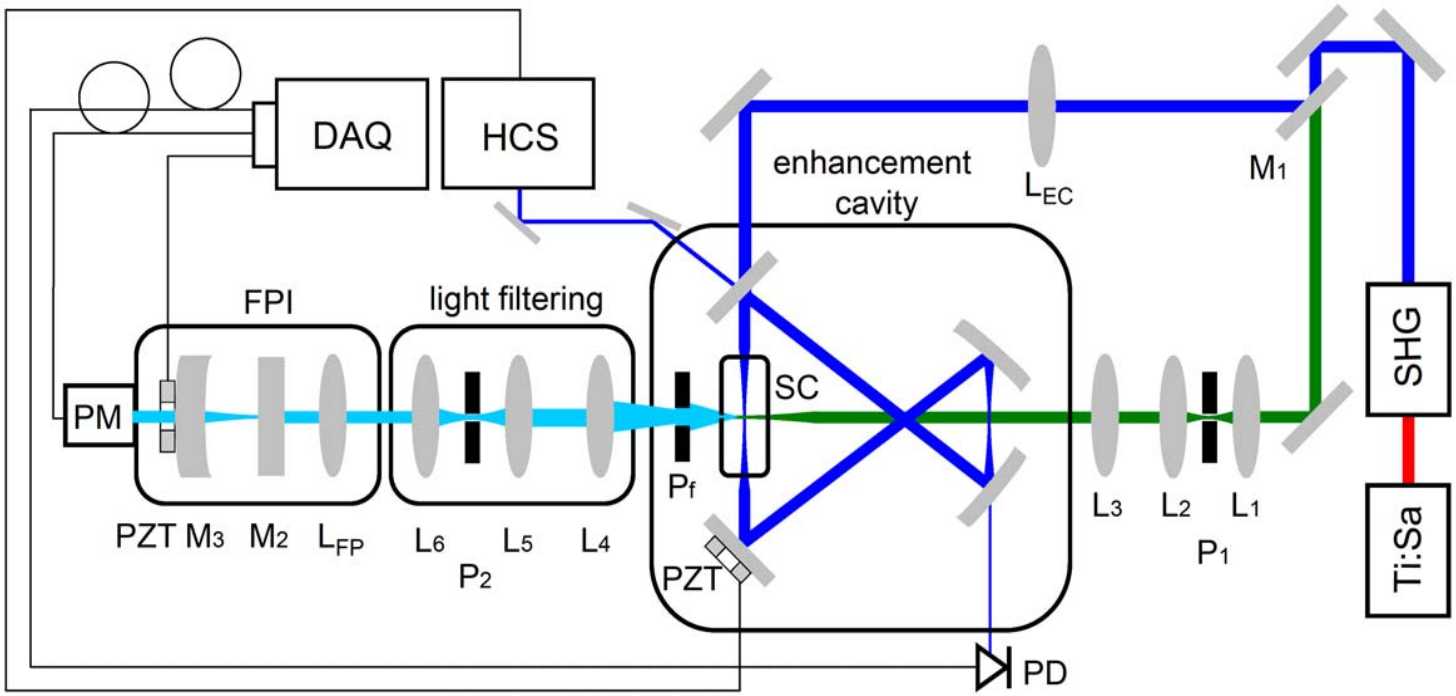

- Measurements of Rayleigh-Brillouin scattering on air in the laboratory

- Measurements of Rayleigh-Brillouin scattering in the real atmosphere

# Setup for Rayleigh-Brillouin scattering measurements in air

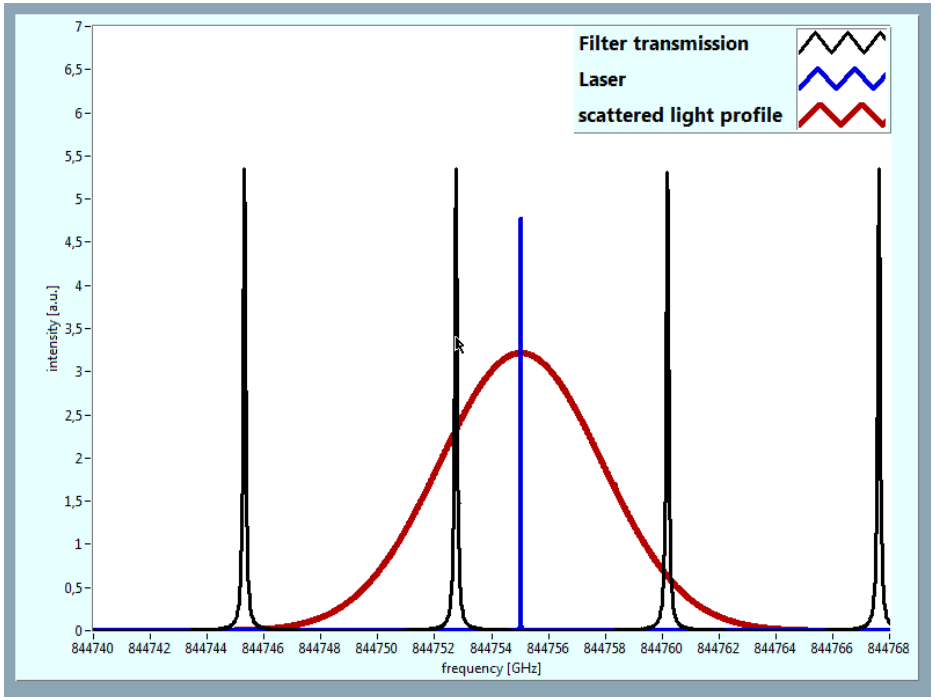
**Prof. W. Ubachs**, Prof. W. van de Water, M. O. Vieitez, E. J. van Duijn

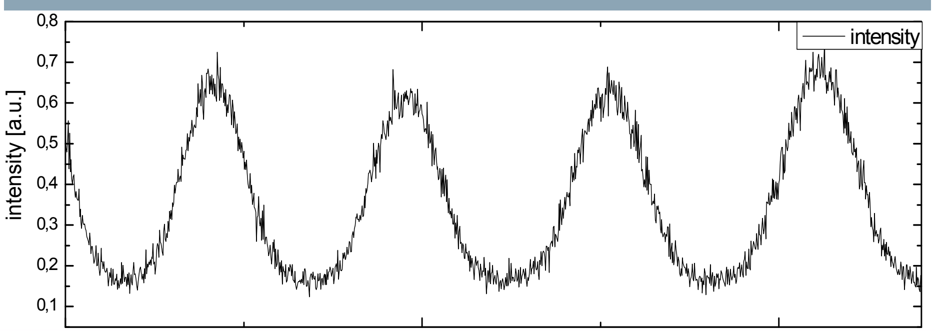
Laser Centre
vrije Universiteit amsterdam




**SC** = scattering cell, **FPI** = Fabry-Perot interferometer, **PM** = Photo multiplier

# Measurement procedure

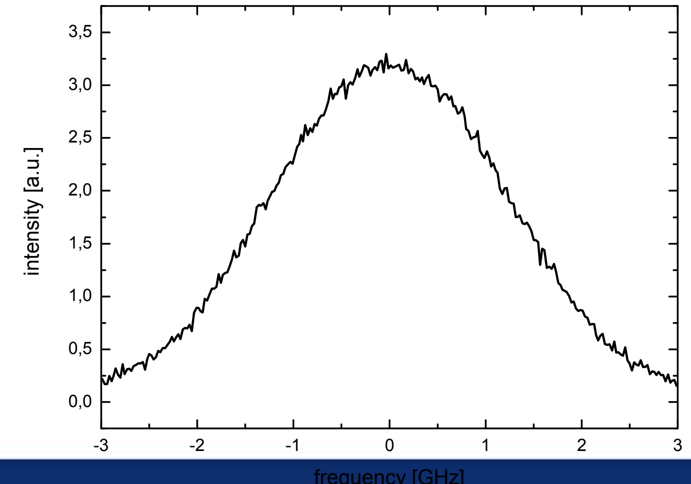


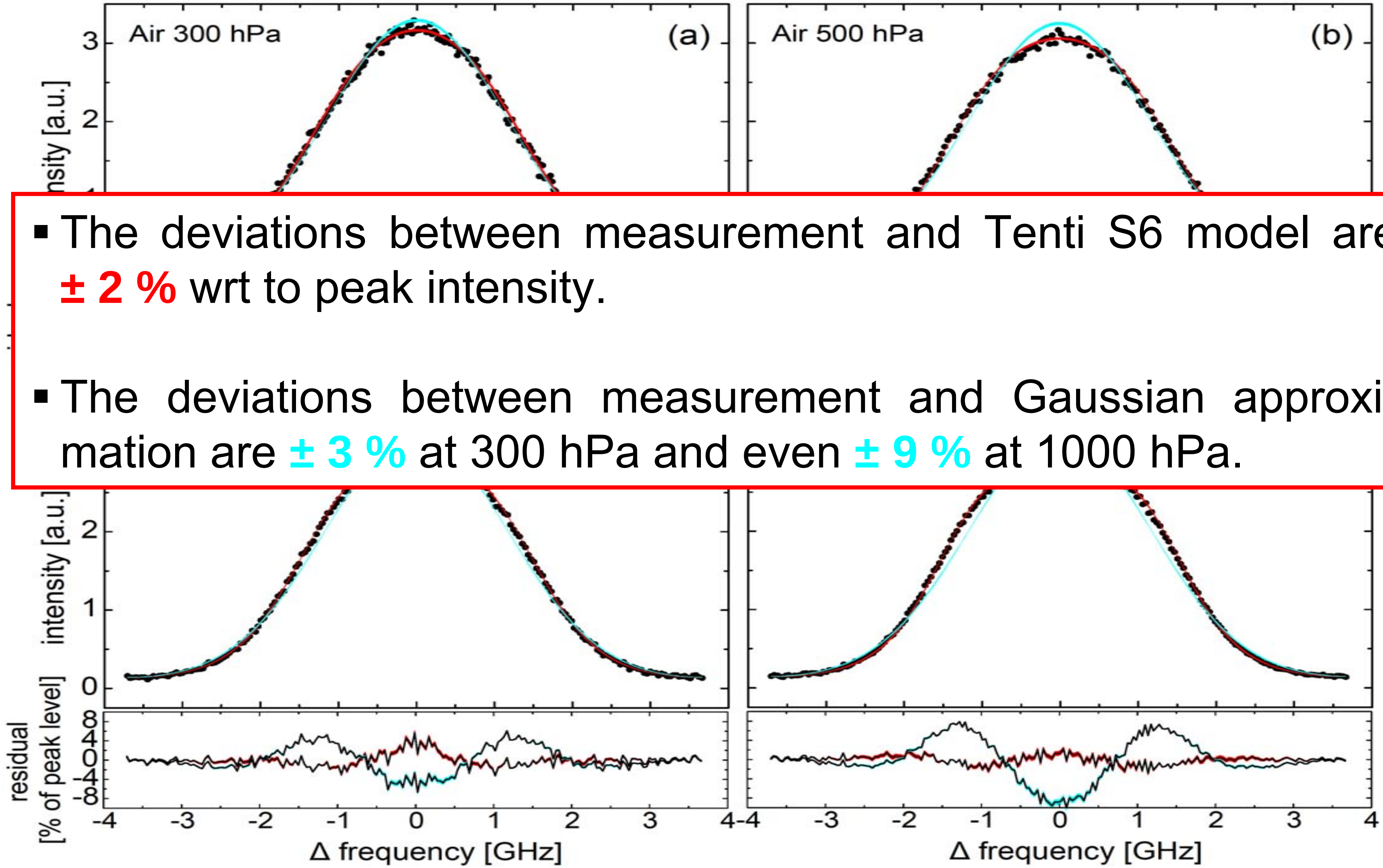

- The wavelength of the incident laser light **(blue)** is kept constant.
- The spectral position of the FPI transmission curve **(black)** is varied by changing the mirror distance

→ The line profile of the molecular scattered light **(red)** is sampled.

average




# SRB measurements in air at atmospheric conditions



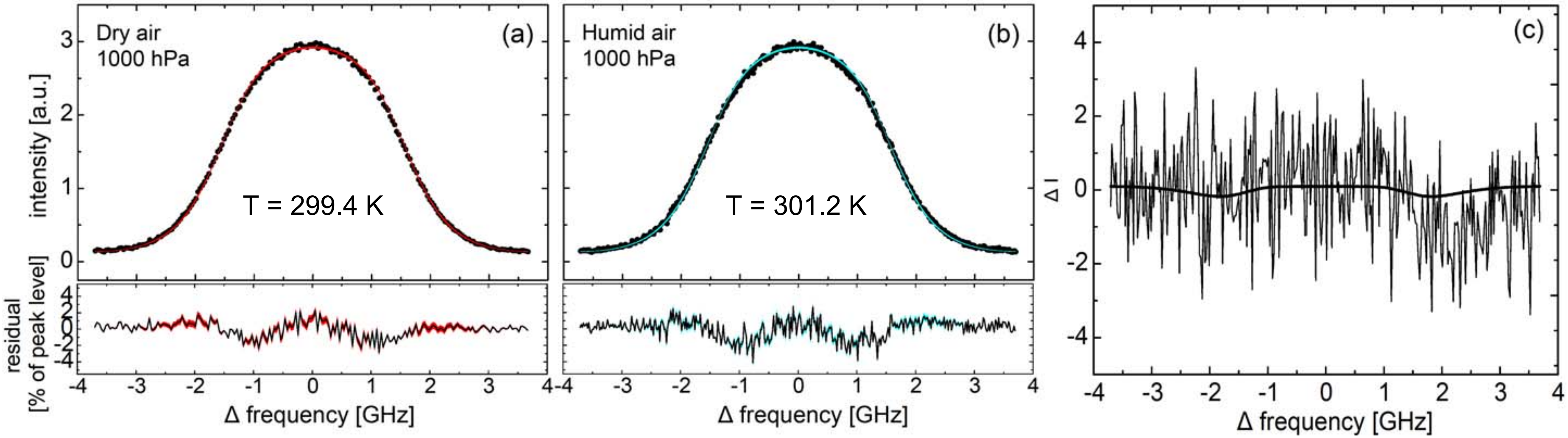

- The deviations between measurement and Tenti S6 model are **± 2 %** wrt to peak intensity.

- The deviations between measurement and Gaussian approximation are **± 3 %** at 300 hPa and even **± 9 %** at 1000 hPa.

# Influence of water vapor to the SRB  line shape

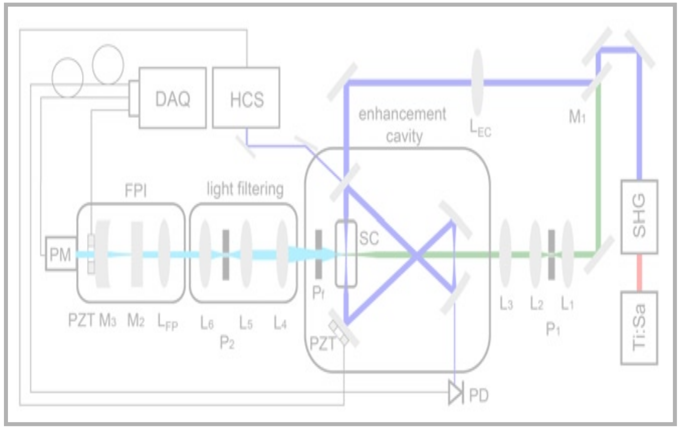
• In the atmosphere, air can contain up to 4 vol. % water vapor (e.g., tropical conditions with water vapor saturated air, p = 1013 hPa, T = 30 °C), and thus, water vapor might be the largest contributor to air after $N_2$ and $O_2$.

• Water vapor in air accelerates the relaxation process of O2 and N2 molecules between translational and rotational degrees of freedom. **It is a question if this influence also affects the SRB line shape.**




→ Humidity has no significant influence on the SRB line shape (up to a content of 3.6 vol. %). → Atmospheric moisture content does not have to be considered for SRB line shape calculation within atmospheric applications.

# Overview

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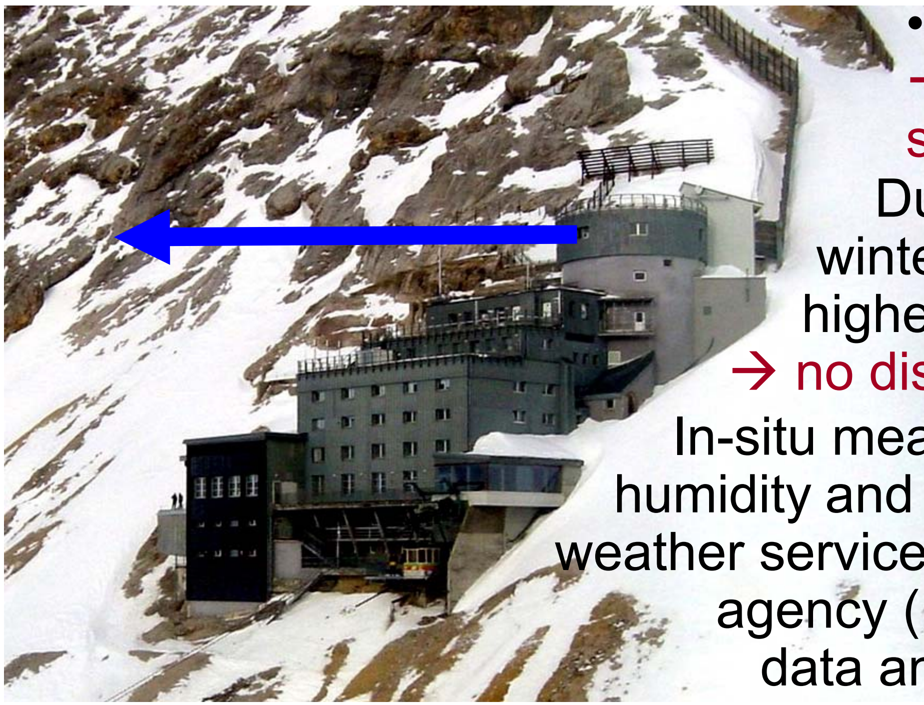
# BRAINS (BRillouin scattering – Atmospheric INvestigation on Schneefernerhaus)

## The measurement location Schneefernerhaus UFS (2650 m asl.)



- The ambient pressure is 700 – 730 hPa
→ remarkable influence due to Brillouin scattering is expected.

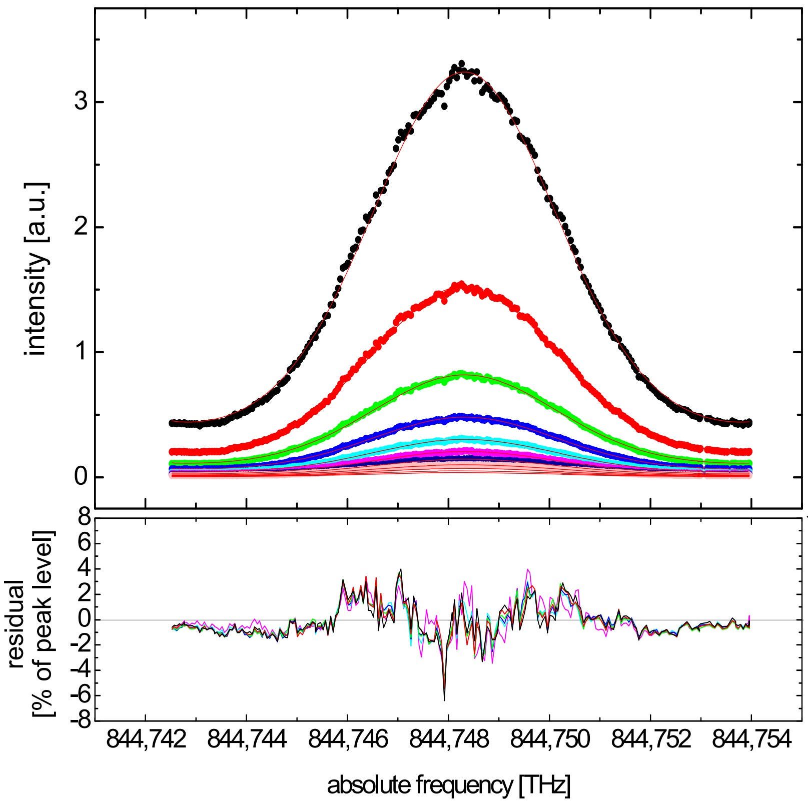
During high-pressure weather conditions in winter, the altitude of the UFS is usually higher than the atmospheric boundary layer
→ no disturbance due to scattering on aerosols.

In-situ measurement data of temperature, pressure, humidity and aerosol content, provided by the German weather service (DWD) and the federal environmental agency (UBA) is available and can be used for data analysis

- Daily radiosonde launches from Innsbruck airport (~ 30 km from UFS)
- Possibility of performing horizontal lidar measurements
→ signal averaging over several kilometers → improvement of the SNR
- Despite the extraordinary location, the UFS offers a very good laboratory infrastructure (power supply, cog railway)

# BRAINS

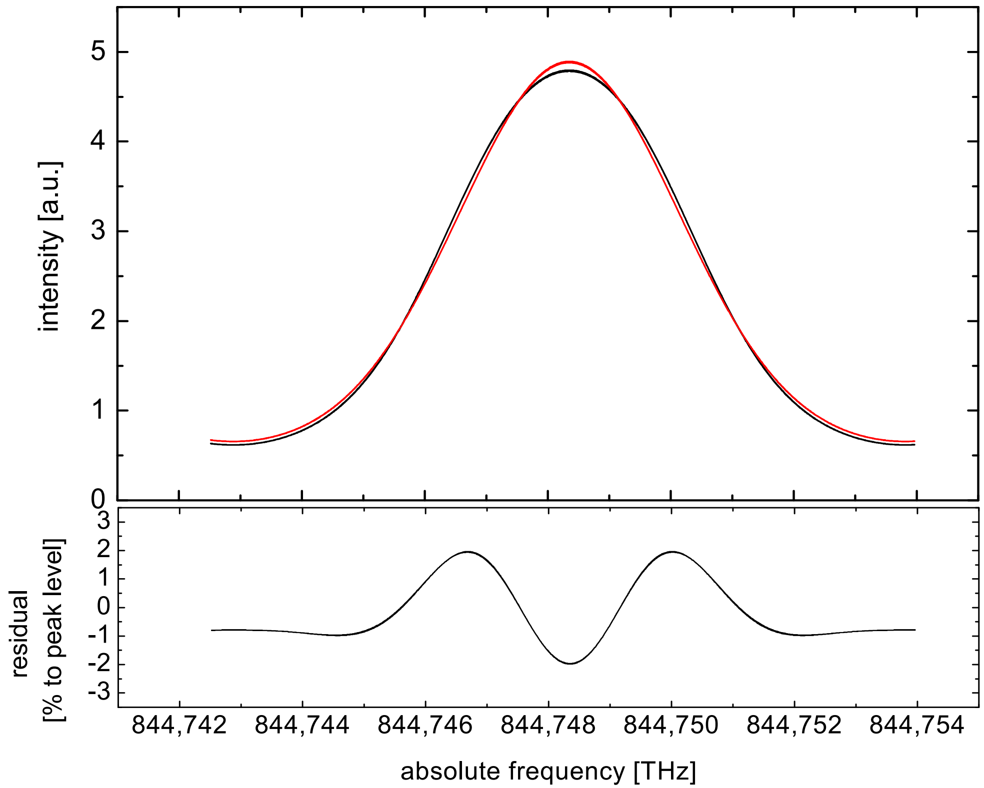
# Atmospheric measurement (31.01.2009)




- First of all, the FPI filter parameters are determined (not shown).
- Thereafter, the measured SRB line shapes are analyzed with the developed fit-function (Convolution of the Airy-function incl. defects with a Gaussian line shape).
- A characteristic deviation between measurement and best fit is expected due to the effect of Brillouin scattering.

**Characteristic “fingerprint” due to Brillouin scattering**

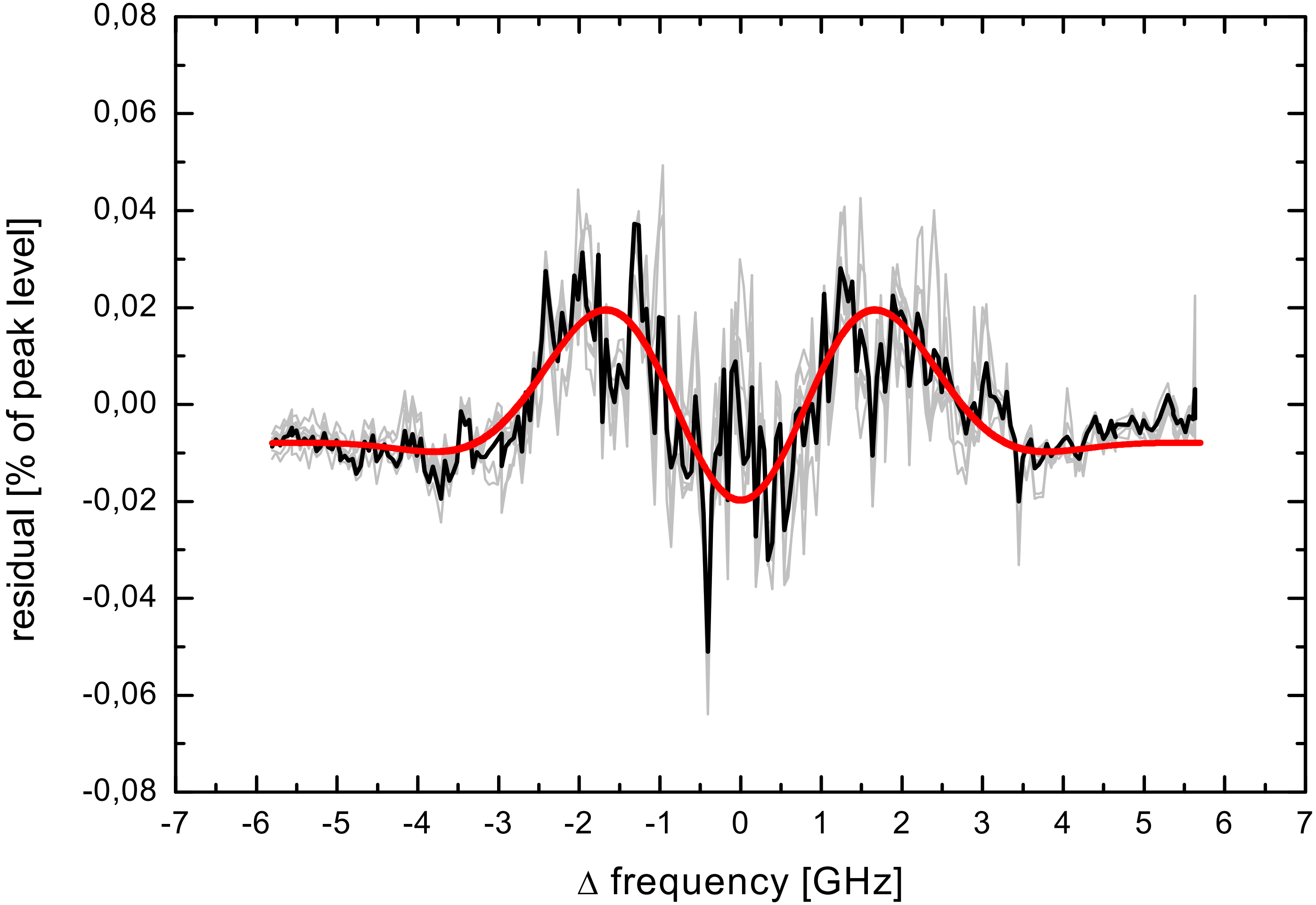
# Simulated atmospheric measurement (31.01.2009)

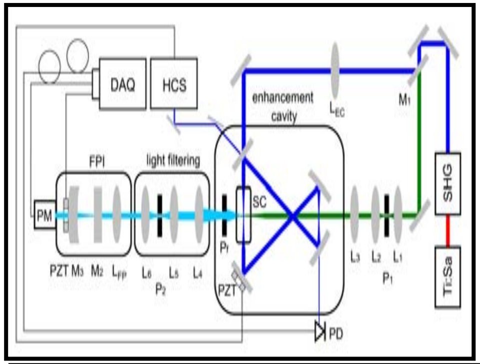



- Numerical simulation of an atmospheric signal **(black)** using:
  - FPI filter parameter from internal measurement
  - Atmospheric temperature and pressure from DWD
  - Gas transport coefficients from air (lab. experiments)
- Simulated signal is analyzed with the developed fit-function (red)

**• Characteristic deviation (fingerprint) between measurement and best fit due to the effect of Brillouin scattering.**

# Comparison of fingerprints (meas. / simu.)






# Summary and Conclusion

- The exact knowledge of the Rayleigh-Brillouin line shape in air is important to avoid systematic errors in the wind retrieval for the ADM-Aeolus mission.
- For the first time, the Rayleigh-Brillouin line shape of light scattered on air was measured in laboratory.
- It is shown that for atmospheric relevant pressures, the deviation between measured SRB line shapes in air and the Tenti S6 model is less than ± 2% wrt peak intensity (appropriate gas transport parameters has to be used).
- It is verified that water vapor has no remarkable influence to the SRB line shape, and therefore has not to be considered in data analysis.
- For the first time, the effect of Brillouin scattering was measured in the real atmosphere.
- SRB line shapes in air are accurately described by the Tenti S6 model in backscatter geometry and real air composition.

# Thank you for your attention

# 谢谢