# The Physics of Atmospheric Gas Measurements
# The 2009 Noble Lectures, University of Toronto
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## 1. Introduction to quantitative spectroscopy applied to the Earth's atmosphere

**Basic atmospheric properties**
- Hydrostatic equilibrium
- Adiabatic lapse rate
- Basic structure and variability

**Wavelengths and frequencies**

**Blackbody radiation, Boltzmann statistics, temperature, and equilibrium**
- Blackbody radiation
- Radiance and radiancy
- Rayleigh-Jeans limit:
- Bi-Directional Reflectance Distribution Function (BRDF)

**Basic solar properties**
- The Sun's structure
- The photosphere
- Solar versus Earth emission

**Basic spectroscopy**
- Spectroscopic preliminaries: Einstein A and B coefficients
- Introduction to rotational spectroscopy
- The standard definition of intensity, *S*
- Ultraviolet/visible (electronic) spectroscopy

**Introduction to radiative transfer**
- Basic relationships
- Emission and absorption
- Line shapes
    - Doppler
    - Lorentzian: Lifetime broadening
    - Lorentzian: Pressure (or collision) broadening
    - The Voigt Function
    - Line broadening in the atmosphere

## 2. Atmospheric physics as applied to data analysis algorithms

**Elements**
- Spherical geometry ⇒ cones ⇒ étendue

**Atmospheric Scattering**
- Rayleigh scattering with depolarization
  - The Ring effect
- Phase function expansion
- Mie scattering

**Atmospheric physics details**
- High resolution solar reference spectra
- Wavelength calibration
- Undersampling

**A bit more radiative transfer**
- 0-layer atmosphere
- 1-layer atmosphere

## 3. Atmospheres and Instruments

**Preliminaries**

**various:**
- platforms (ground-based, airplane, balloon, satellite);
- geometries (zenith, limb, nadir);
- modes (emission, absorption, scattering);
- wavelengths (microwave, infrared, visible, ultraviolet).

**Fourier transform spectrometers**

**Grating instruments**

**Overview of measurement programs (with a prejudice for mine).**

## 4. Data fitting, analysis, and satellite results

**Spectrum (and other data) fitting**
- Linear fitting
- A bit of nonlinear fitting
  - Aside on correlated parameters
- The Levenberg-Marquardt method
- Weighting functions, averaging kernels, and contribution functions
- Other methods

**Fitting UV/visible atmospheric spectra**

- Introduction and motivation
- Historical note
- THE RULES
- Slant column fitting details
- Air mass factors
- Ozone profiles and tropospheric ozone

**Results from GOME, SCIAMACHY, and OMI**

## 5. Symposium "Ultraviolet and visible measurements of the Earth's atmosphere: Toward continuous pollution monitoring from space"