Modeling and Retrieval of Cometary Gas Spectral Lines for Rosetta-MIRO Observations of Comet 67P/Churyumov-Gerasimenko.

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Introduction: The Microwave Instrument for the Rosetta Orbiter (MIRO), on board the ESA Rosetta spacecraft, will observe spectral lines of water, carbon monoxide, ammonia, and methanol at submillimeter wavelengths from the coma of Comet 67P Churyumov-Gerasimenko [1,2]. Realistic modeling of observations of the cometary gas spectral lines is critical in preparation and interpretation of the MIRO observations. In addition, a reliable and efficient inverse method to retrieve cometary parameters from the observed lines is needed to interprete the observation results and refine the future observation planning.

Approach: A Direct-Simulation Monte Carlo (DSMC) technique [3] is applied to model the gas kinetics in the cometary coma. The DSMC model takes the outgassing rate and the molecular velocity distribution at the surface as the boundary condition and calculates the gas density, temperature, and mean velocity profiles in the coma. Over most of its extent, the coma is not in thermodynamic equilibrium. Therefore, the population distribution in the molecular rotational levels associated with the MIRO spectral lines must be calculated by directly solving the rate equations and radiative transfer equations that are coupled through an average radiation intensity at a given line frequency in the coma. The coupled equations are solved using the accelerated Monte Carlo method [4]. The outcome of the accelerated Monte Carlo method is a profile throughout the coma of the non local thermal equilibrium distribution of molecular level populations. Finally, the MIRO measurements of the cometary gas spectral lines are simulated with a radiative transfer model using the calculated coma profile and molecular level population distribution. The MIRO antenna power pattern is approximated with a Gaussian function.

We combine these models to create a complete coma forward model. Conditions at the nucleus/coma interface are specified by a nucleus thermophysical model described in [5]. The DSMC extrapolates this to a coma temperature, density and velocity profile. The accelerated Mont Carlo method (which allows for non-LTE conditions) then determines molecular level distributions throughout the coma. Our radiative transfer code then uses the gas density, velocity, and energy level information to model the MIRO spectral lines.

The retrieval problem that we face with MIRO observations is (1) to retrieve coma profiles from the MIRO spectral lines and (2) to retrieve nucleus and coma surface conditions (jets, outgassing rate, outgassing velocity distribution) from the MIRO retrieved coma profile. We use optimal estimation theory [6] to invert the MIRO data. This method takes a Bayesian approach to maximize the conditional probability of finding a state (model parameter) vector for a given measurement vector. It takes into account the errors in the measurements, *a priori* knowledge about the state vector and the uncertainty of the knowledge. The final outcome of the retrieval method is not only the retrieved state vector but also the uncertainty/error of the retrieved vector and the contribution of the measurement and *a priori* knowledge to the retrieved vector.

Results: By using the forward models in combination, we studied the effect of the physical conditions of the comet nucleus and coma on the observations by MIRO at various observational conditions. We also studied the behavior and performance of the retrieval method for various observational data and *a priori* knowledge. The study results are used to prepare the MIRO observations and refine the forward model and the retrieval scheme. Figure 1 illustrates the use of the forward model to estimate the expected line spectrum strength and shape for coma observations spanning from the nadir direction to the zenith direction.

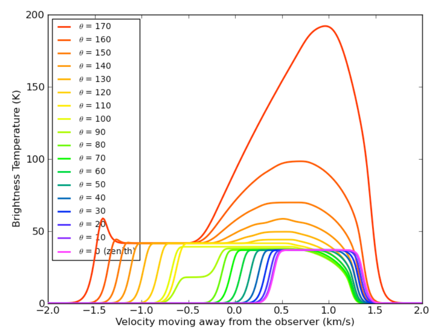

Figure 1. Simulated MIRO line spectra at the heliocentric distance of 1.3 AU and cometocentric distance of 100 km.

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