Why are there no 14.5 GHz formaldehyde masers?

Level: MSc
Supervisor: Prof. Johan van der Walt
Co-supervisor: Dr. Fanie van den Heever
Institution: NWU
Contact: johan.vanderwalt@nwu.ac.za

Project Background and Aim

It is well known that most young, high mass star forming regions have associated maser emission by a variety of molecules such as H_2O, OH, CH_3OH, H_2CO, CS and NH_3. Maser emission from CH_3OH and H_2CO have been shown to be exclusively associated with high mass star forming regions. Although the interpretation of maser emission is not as straightforward as is the case for "normal" thermal emission, astrophysical masers reveal aspects of the kinematics and physics of the regions where they operate that cannot be extracted from the thermal emission. Examples of this is the proper motions of masers, which carry information about gas motions, and the periodic CH_3OH masers, which reveal the presence of periodic phenomena in high mass star forming regions not manifested in the thermal emission.

Perhaps the most basic aspect of masers that must be understood for their interpretation is how they are 'pumped.' Understanding the pumping mechanism is typically achieved by numerically solving the rate equations to determine the conditions under which population inversion of the masing transition occurs. For the 4.8 GHz ortho-formaldehyde masers, this was first done in 1981 by Boland and De Jong. Apart from the scarcity of H_2CO masers, it also became apparent that, from an observational standpoint, the predictions of the Boland and De Jong model did not fully explain these masers. One aspect that our own numerical calculations indicate is that the 4.8 GHz masers must also have associated 14.5 GHz masers, consistent with the predictions made by the calculations of Boland and De Jong. However, observationally these masers are not detected. They are either too faint or it might be that the 14.5 GHz transition is not inverted at all. **Thus the question: Why are there no 14.5 GHz formaldehyde masers?**

The aim of this project is to investigate the inversion of the 14.5 GHz transition of ortho-formaldehyde by implementing and/or adapting an existing Monte Carlo code (RATRAN) to calculate the level populations, enabling a more realistic treatment of the spatial variation of the free-free radiation field responsible for pumping the masers.

Project description and requirements

A shortcoming of our current calculations is that, within the framework of the escape probability method, the basic assumption is that there are no spatial gradients in the physical conditions, such as density, temperature and the energy density of the radiation field. RATRAN (written in FORTRAN77) is an existing Monte Carlo code to calculate level populations under more realistic assumptions regarding the spatial variation of the physical conditions. Of particular importance is the incorporation of the gradient in the energy density of the radiation field in a more realistic manner.

The student will be expected to understand how RATRAN works, adapt it to the current problem or write a corresponding implementation in C, implement a radial-dependent free-free radiation field, and explore to what extent this might explain the weakness or absence of 14.5 GHz masers in known 4.8 GHz maser sources. This project is best suited for a student who already has some competence in scientific coding (preferably in C or C++). Learning about the application of the Monte Carlo method will also benefit the student in applying it to other real-world problems.