Scientific report of my visit to Povo (19/09 to 07/10)

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This visit occurred in the framework of a collaboration between Alain Aspect's group in Institut d'Optique in Orsay (France) and Sandro Stringari's group in Trento University in Povo (Italy). The theme of this project is the study of ultracold dilute atomic gases placed in a rotating toroidal trap.

An optical tweezer experiment is currently setting up in Orsay, with a view to creating an all-optical toroidal atomic trap containing a Rubidium Bose-Einstein condensate. This trap will be realized by rapidly moving the focus point of a detuned laser beam along a circular path, using for this vibrating mirrors (galvanometers). In comparison with other techniques of generating toroidal traps, this one would present the advantage of being easily able to change the shape of the torus, going from a circle to an ellipse, the axis of this ellipse being possibly rotated. It also potentially offers a strong transverse confinement, which allows, at least in a first approach, for a 1D treatment of the trapped gas along the torus. It finally offers the possibility of making very small toroidal traps (with radii of about 50 μm), which would allow for a 'reasonable' atomic density all along the torus.

The aim of the collaboration with the Povo group is to study theoretically such a system (ultracold dilute gas in a 1D rotating toroidal trap). In particular, the question of wether it will be possible or not to nucleate vortices by rotating the axes of the trap is of special importance. Numerical simulations of the 1D toroidal Gross-Pitaevskii equation with a periodic potential in a rotating frame are being developed for the circular case in Povo at the moment.

In order to contribute in connecting the Orsay experiment and the Povo simulations, we worked on the reduction of the problem to the 1D case, when the transverse dimensions can be assumed to be much smaller than the longitudinal one. Defining a system of coordinates adapted to a trapping potential of the 'waveguide' type (ie strong confinement in two dimensions, along a 1D curve), we used them to re-write the Schrödinger equation. Following a method inspired from the Born-Oppenheimer approximation, we solved (perturbatively) the ground state transverse energy and used the result as a potential for the longitudinal equation. We obtained with this method a 1D Schrödinger equation for various situations, including rotation of the wave-guide, which is our main result, but also presence of gravity, longitudinal dependance of the transverse confinement, atomic interactions...

The future collaboration between our two groups on this project will consist in checking numerically our analytical predictions, and adapt the parameters to a possible experimental configuration. Links with Povo simulations about vortices nucleations could also be made in the near future. Simultaneously, the theoretical work is under progress to adapt our planar-waveguide model to potentially non-planar configurations. We hope to be able to submit a publication on this work in the months to come.