



## Congratulations to New ICFO PhD graduate

Dr. Julio Sanz graduated with a thesis entitled *Two-Component Bose-Einstein Condensates with Competing Interactions*

February 10, 2020

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Dr. Julio Sanz received his Master degree in Photonics from the joint program between the UPC, UAB, UB and ICFO before joining the Ultracold Quantum Gases research group led by Prof. Dr. Leticia Tarruell where he studied Bose-Einstein condensates. Dr. Sanz's thesis, entitled *Two-Component Bose-Einstein Condensates with Competing Interactions*, was supervised by Prof. Leticia Tarruell.

### ABSTRACT:

This thesis reports the experimental study of two-component Bose-Einstein condensates with tunable interactions, which are exploited as a platform to perform quantum simulation of many-body quantum systems.

To perform this experiments, we have implemented an atomic source consisting on a glass

cell 2D MOT vacuum chamber and a high resolution optical system to image and manipulate the atoms. Furthermore, we develop and characterize a polarization phase contrast technique which is able to probe optically dense atomic mixtures at intermediate and high magnetic fields in open transitions. This technique has been used to either probe the total column density of a two-component atomic cloud or the difference in column density between both components.

We report on the first observation of composite quantum liquid droplets in an incoherent mixture with residual mean field attraction. Strikingly, this novel phase is stabilized due to the repulsive beyond mean field corrections in a weakly interacting system. Moreover, we have characterized the liquid to gas phase transition which occurs for small atom numbers.

Additionally, we have compared two different self-bound states in a quasi-1D geometry with incoherent mixtures: quantum droplets and bright solitons. Depending on the atom number and interaction strengths both states can be smoothly connected through a crossover or be distinct entities separated by a transition. We have measured its composition, its phase diagram and mapped out the soliton to droplet transition.

Finally, we report on a technique to modify the elastic and inelastic interactions in a two-component Bose-Einstein condensate with very unequal and competing interactions under the presence of strong coherent coupling. This technique provides a wide flexibility and has allowed us to observe bright solitons in quasi-1D in a coherently coupled dressed state.

We exploit the fast temporal control of the effective interactions to quench them into the attractive regime and study the resulting modulational instability which develops into a bright soliton train.

**THESIS COMMITTEE:**

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Dr Julio Sanz