Tracking the Evolution of Galaxies

CAS/MPG Partner Group between Purple Mountain Observatory, CAS and the Max Planck Institute for Astronomy

Nanjing-Heidelberg, 2012 .1.1–2016.12.31

Dr. KANG Xi (left) and Dr. Andrea Macciò (right) at the inauguration ceremony of the partner group, which was held at the Purple Mountain Observatory, Nanjing, in October 2012.

The formation and evolution of galaxies in a universe dominated by dark matter and dark energy is one of the most fascinating questions in astrophysics and generally in physics. Moreover the origin of galaxies has also attracted a lot of attention from the general public. To better understand the formation of galaxies in such a dark universe, scientists have made extensive studies using numerical simulations and analytical models.

The partner group between the Purple Mountain Observatory (PMO), CAS, and the Max-Planck-Institute for Astronomy (MPIA) was established in 2012 to work on the formation and evolution of galaxies in an expanding Universe. The partner group, led by Dr. KANG Xi at PMO, has developed a sophisticated model to track the formation and evolution of galaxies in a cosmological context. In the recent years, the group at MPIA, led by Dr. Andrea Macciò, has developed several numerical tools to model the evolution of ordinary baryonic matter. The combined efforts from both groups have produced new and important scientific results that have helped the scientific community to understand how galaxies come to their present shapes and distributions.

Reported by Group Leader KANG Xi

Photos/Images: By courtesy of Prof. KANG Xi.

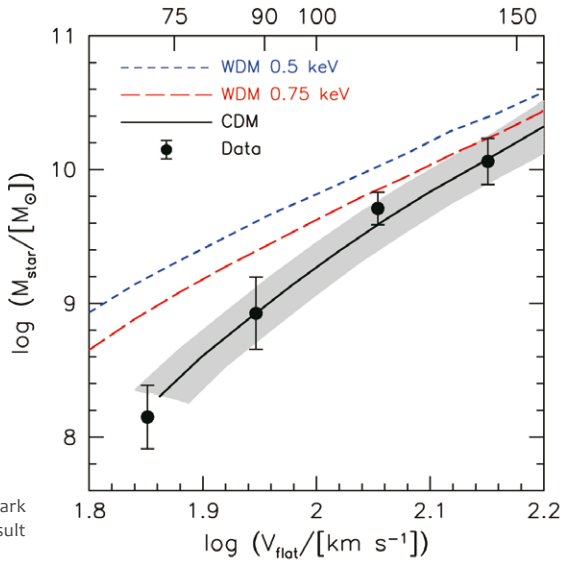

Figure 1: Relation between the stellar mass and maximum rotation velocity of galaxies. Warm dark matter with lower mass tends to over-predict the velocity of galaxy for given stellar mass. The result favors the scenario of cold dark matter.

PRESENT STATUS

After two years from its foundation, the partner group at PMO is still in its building phase. Currently, there are two research staffs and six students in the group. The The cooperative research with MPIA focuses on the following aspects, starting two years ago.

1. Numerical simulation of satellite evolution

One of the main purposes of the partner group is to foster young students. In 2011, shortly before the establishment of the partner group, CHANG Jiang a student from KANG Xi's group, visited MPIA as an exchange student. His goal was to investigate the effects of tidal forces from a massive galaxy on the mass evolution of a satellite galaxy orbiting in the host potential. Better understanding of this process will help us understand the formation of our Milky Way, as well as the whole galaxy population in a cosmological context.

The research by CHANG Jiang has shown that the efficiency of tidal stripping of stellar mass from a satellite depends on its morphology. Stars in the disk component will be rapidly stripped at a time scale of 100 Million years. However, the stars in the bulge component of the satellite will remain almost intact for more than 10 billion years. These results have important implication on the morphologic distribution of satellite galaxies in our Milky Way Galaxy. The paper has been published by the *Monthly Notices of Royal Astronomy Society* based in the UK.

2. Is dark matter warm or cold?

One of the greatest mysteries of our Universe is the nature of Dark Matter, which accounts for more than eighty percent of the total matter in the cosmos. Dark matter neither emits nor absorbs light and can be observed only through its gravitational effects. Very little is known so far on its physical nature, such as mass and cross section of interaction. With more ground- and space-based experiments, the nature of dark matter might be revealed in the next decades.

In astrophysics, the mass of dark matter is often defined in term of its "temperature". Currently, there are two competitive dark matter scenarios, namely the cold and warm scenarios of dark matter, and their imprints on the matter power spectrum are quite different. Traditionally, the temperature of dark matter is constrained by the observation of Lyman-alpha forest at early universe. Not much attention is paid to using the local observations to constrain its properties.

The research work at PMO opens a new window on the exploration of the temperature of dark matter. With the help of super-computers, Dr. KANG Xi and his collaborators at MPIA, Drs. Andrea Macciò and Aaron Dutton, have found that the mass of warm dark matter can be constrained using the local galaxies. Using the Tully-Fisher relation, KANG and collaborators have demonstrated that the mass of a possible warm dark matter candidate should be higher than 0.75 keV, consistent with the constraints from Lyman alpha observations. Actually, their results favor the "cold" scenario of dark matter.

Photos/Images: By courtesy of Prof. KANG Xi.

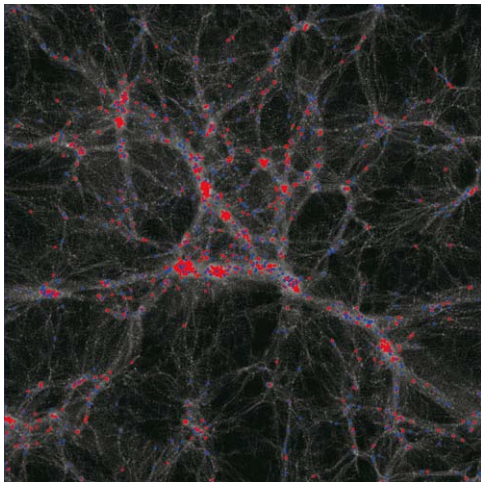

Figure 2: The team has simulated the distribution of dark matter and galaxies via super-computer simulation and semi-analytical model for galaxy formation. Shown here is the galaxy distribution in a slice of simulated universe with cosmological volume (each side of 300 Million light year).

The gray points indicate the cosmic web of cold dark matter. The points with red color show the distribution of elliptical galaxies residing in high-density regions, and blue points show the distribution of spiral galaxies in low-density regions.

FUTURE PLANS

In the next three years, the partner group will expand its team and extend its scientific research fields. The collaboration with MPIA will be further strengthened during this expansion.

1. Continuous collaboration on scientific research

The partner group treasures its fresh and productive collaboration with Dr. Andrea Macciò and his group. Future studies will continue on the formation and evolution of galaxies, the large-scale structure of the universe, the nature of dark matter, and the evolution of dwarf galaxies in the Milky Way. Agreed projects are now in good progress, such as the metal gradient of elliptical galaxies, the nature of massive satellite galaxies in the Milky Way and more constraints on the nature of dark matter. We plan to have at least four new joint publications in 2014.

2. Exchange of students and visitors

Fostering of young student is always in the priority list of the partner group. Last two years have witnessed the success of student exchange program. CHANG Jiang, the Ph.D. student mentioned above from KANG's group, came back to PMO in October 2013 to finish his doctoral studies, after having spent two years at the MPIA. A second student, WANG Liang, has just started his exchange period at the MPIA, where he plans to stay for at least twelve months. Postdoctoral researchers and Ph.D. students from the MPIA will pay shorter visits to the PMO, as already happened in October 2012 during the first joint workshop, organized in Nanjing. This exchange of people and ideas has been extremely beneficial for the both institutions.

3. Joint organization of meeting

Since late 2013, we have been preparing the 10th Sino-German workshop on galaxy formation and cosmology, which is to be held in May 2014. This workshop will focus on a wide range of topics, from our Milky Way to the large structure of the universe. This meeting will also join in the 40th anniversary of the MPG-CAS cooperation. Compared to the previous workshop, the 2014 one will be more international, with expected participants from more than 10 countries, and many distinguished scientists are invited to the meeting. We hope more fresh ideas and collaboration will soon follow the workshop. ◂

SELECTED PUBLICATIONS

Chang, J.; Macciò, A. & Kang, X. (2013) The dependence of tidal stripping efficiency on the satellite and host galaxy morphology, *Monthly Notices of the Royal Astronomical Society*, 431 (4): 3533–3542.

Kang, X.; Macciò, A. & Dutton, A. (2013) The effect of warm dark matter on galaxy properties: constraints from the stellar mass function and the Tully-Fisher relation, *The Astrophysical Journal*, 767(1):22–28.

Kang, X.; Li, M.; Lin, W. P. & Elahi, P. J. (2012) Exploring galaxy formation models and cosmologies with galaxy clustering, *Monthly Notices of the Royal Astronomical Society*, 422(1):804–11.

INFO

MPS/CAS Partner Group on Galaxy Formation and Large Scale Structure
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