A holistic view of stellar feedback and galaxy evolution

Feedback from massive stars drives the secular evolution in galaxies up to the mass of the Milky Way. The energy and momentum generated during the lives and deaths of stars above 8 solar masses enriches the interstellar medium, drives the expansion of star-forming regions and the disruption of molecular clouds, regulates the formation of star clusters, controls the baryon cycle in star-forming galaxies, reshapes the dark matter distributions in dwarf galaxies, and facilitates the dissipation of proto-planetary disks. Yet, despite a qualitative theoretical understanding of feedback mechanisms (e.g., protostellar jets, stellar winds, ionizing radiation, supernovae), our quantitative knowledge is severely lacking.

Indeed, one of the fundamental problems in modern astrophysics is constraining how galaxies turn their gas into stars, how feedback from these stars regulates the growth of galaxies, and how these processes may have changed with galactic environment and across cosmic time. The physics of star formation and the (re)distribution of mass, energy, and metals by stellar feedback are the missing ingredients required to connect the observed galaxy population to ΛCDM cosmology. Outstanding questions include: what are the dominant stellar feedback mechanisms as a function of stellar properties (e.g., mass, chemical composition, rotation rate, binarity, evolutionary phase)? How does feedback change with environment (e.g., metallicity, ambient gas density, location within a galaxy)? How does our knowledge of feedback change with physical scale, from small (clouds) to large (galaxies) scales? And how does stellar feedback change across cosmic time?

Until recently, it was not possible to observationally quantify stellar feedback outside of the limited sample of star-forming regions in the Milky Way. Nowadays, thanks to the development of novel astronomical instruments (e.g., so-called integral field spectrographs like MUSE on the Very Large Telescope) and new flagship observatories (e.g., the James Webb Space Telescope), we can now quantify stellar feedback for large samples of star-forming regions across entire galaxies. These observations are complemented by a new generation of numerical models that include many more physical processes than earlier work, including cosmological zoom-in simulations that allow us to probe star formation and galaxy evolution over an unprecedented range of scales and environments.

Progress in the field requires: (1) an observational census of the quantities describing the effects of stellar feedback across entire galaxies; (2) a corresponding census from theoretical models of star formation and galaxy evolution; and (3) meaningful methods of comparing observations and simulations. Efforts towards these are being carried out by both the “nearby” and “high-redshift” Universe communities, but there is little to no interaction between them. This Ascona meeting will bridge the gap between the various groups of researchers (observers, theorists, nearby, and distant Universe): we will define the most important issues, compare analysis methods, and define strategies to connect stellar feedback on all scales and across cosmic time.

Focus and objectives

The meeting will bring together researchers working on stellar feedback and galaxy evolution from four backgrounds, namely: (i) observations in the nearby Universe; (ii) observations in high-redshift galaxies; (iii) molecular cloud- and galaxy-scale simulations; and (iv) cosmological simulations. This meeting intentionally wants to connect otherwise disconnected communities to make progress in the field of stellar feedback galaxy evolution.

<u>1) Observations of stellar feedback: the resolved nearby Universe</u>
Observationally quantifying the various feedback mechanisms across different environments in the Universe is the missing key to properly implementing feedback in models. This section of the meeting will be focused on discussing results, techniques, and methods of feedback observations in the nearby Universe, where we are able to resolve single star-forming regions and even single stars. This first part will culminate in a discussion session centered on 2 questions: what do we learn from resolved feedback observations? How can this be translated to high-redshift observation?

<u>2) Observations of stellar feedback: integrated properties and scaling relations at high redshifts</u>
High redshift galaxies are characterized by environments that differ from those of nearby galaxies, e.g. in terms of metallicity, gas fractions, and star formation rates. Moreover, given the large distances to these objects, we are not able to resolve single stars (or even most star clusters), and are required to rely on integrated (galaxy-scale) properties. Several empirical important relations that hold at these integrated galaxy scales (e.g., the Kennicutt-Schmidt relation) appear to break down on smaller, molecular cloud scales. To make progress in the field it is imperative to connect the local and high-redshift communities to (i) characterize stellar feedback across cosmic time, and (ii) disentangle feedback as a function of galactic environment and spatial scales.

<u>3) Numerical models: state-of-the-art and missing physics</u>
Participants working on the theoretical side of feedback and galaxy evolution will be invited to discuss the various numerical methods and models, the state-of-the-art feedback recipes, the observational input that is required to make progress on the numerical front, and how simulations can help better interpret the observations.

<u>4) “Observing the simulations”: towards realistic comparison methods between observations and models</u>
This final, key part of the meeting will begin with a discussion session in which we will identify strategies and methods for a meaningful observation/simulation comparison. This will be followed by a breakout session in which the newly-formed collaborative groups will have the chance to set realistic goals and discuss long-term plans.