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Project Facts

- Acronym: OCEANS
- Full title: Overcoming Challenges in the Evolution and Nature of Massive Stars
- Number of institutes: 16
- Number of countries: 9
- Programme: Marie Skłodowska-Curie Staff Exchanges
- Duration: 4 years
- Project Number: 101183150
- Coordinator: Astronomical Institute, Czech Academy of Sciences, Ondřejov, Czech Republic, Dr. Michaela Kraus

For more information, visit the project webpage:

`https://stel.asu.cas.cz/OCEANS/`

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Overcoming Challenges in the Evolution and Nature of Massive Stars (OCEANS)

1 Jan 2025 – 31 Dec 2028

OCEANS

Overview

OCEANS (**O**vercoming **C**hallenges in the **E**volution **A**nd **N**ature of Massive **S**tars) is a project that was top-ranked for receiving funding from the European Union. This project investigates a variety of physical aspects that contribute to understanding of the life and death of massive stars that were born either as single objects or with one or more siblings.

For this, scientists from the Stellar Department of the Astronomical Institute in Ondřejov established an international network by bringing together researchers in various states of their scientific career from Europe and North and South America and with expertise in various disciplines. The tight collaboration leads to efficient knowledge transfer and creates synergies between theorists and observers.

Motivation

Massive stars are born with masses greater than eight times the mass of the Sun. These short-living objects are the cornerstone of the dynamic and chemical evolution of the cosmos, enriching it as they evolve with chemically processed material that is blown away from their surface by energetic winds and eruption processes. Despite the importance of massive stars, their evolution from cradle to death as spectacular supernova explosions still poses many mysteries due to crucial knowledge gaps in the physical processes taking place in their interior and atmosphere and the mutual influence by close-by siblings. With the project OCEANS, we aim to elucidate the physical properties and evolution of massive stars impacted by companions and their contribution to the generation of gravitational waves.

Massive Stars and their Siblings

The majority of massive stars are born in multiple systems and their evolution can be significantly influenced by the interaction with close companions. Studying massive binary systems helps us to understand how stars interact, exchange matter, and in the end of their life explode as supernovae. These systems can also merge, creating gravitational waves that allow us to "listen" to the dying of stars. Massive binaries also offer us the unique opportunity to extract fundamental parameters of the stars, providing important constraints on stellar evolution models.

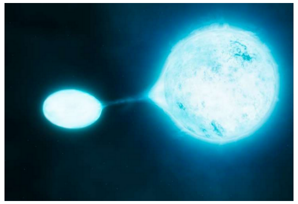

Figure 1: Illustration of mass transfer in an interacting massive binary system. Credit: ESO/M. Kornmesser/S.E. de Mink.

To discover new companions, we collect optical long-baseline and speckle interferometric observations of massive stars. These modern techniques allow us to directly resolve siblings. The companions are classified using spectroscopic observations (for example from the Perek 2-m telescope). Moreover, radial velocity measurements reveal orbital elements and mass ratios of the systems, which can be verified using models of stellar dynamics and evolution.

Mass-loss Processes and the Formation of Circumstellar Discs, Jets, and Outflows.

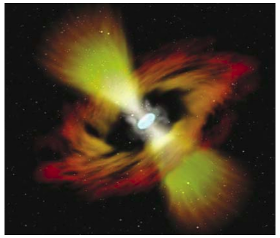

Figure 2: Artist's view of a rotating Be star with a circumstellar disc and polar wind. Credit: A. Meilland.

Massive stars are known for their powerful winds and outflows, which cause enormous mass loss and lead to the formation of nebulae, shells, discs and rings. However, the physics of mass loss still remains enigmatic as existing quantitative descriptions often yield predictions that are in conflict with observational constraints. One example is the discs around Be stars, whose formation and disappearance are highly debated.

We employ observational diagnostics of the winds and eruptions and explore the power of instabilities inside the star to trigger mass ejections that can lead to the formation of characteristic circumstellar structures. We also study colliding winds in massive binaries and the interaction of winds and outflows with the interstellar medium.

Stellar Variability

Stellar pulsations, winds and companions can cause brightness variations of stars. The light curves of massive binaries consisting of pulsating, interacting stars with winds and outbursts, hence pose challenges on their interpretation. To separate the individual contributions, we develop progressive methods for signal processing. We also construct detailed models for stellar atmospheres and internal structures of massive stars along their evolutionary paths to precisely describe their wind and pulsation properties and their imprint on the temporal evolution of the stellar brightness. These model results are then confronted with observational data obtained continuously by the monitoring sky surveys.

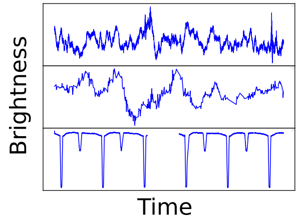

Figure 3: Light curves of massive stars affected by pulsations (top), outbursts (middle) and siblings (bottom).

Big Data & Astrostatistics

We are living in an era where all-sky surveys deliver vast amounts of observations and we need to provide the framework and tools to manage, analyse and derive valuable insights from this data. For this task, machine learning is fundamental and indispensable.

We exploit the avalanche of public data archives and develop advanced algorithms for the detection and classification of massive stars and binaries, for building statistical ensembles of objects in various evolutionary phases, and to cope with challenging tasks in the processing of astronomical data such as the period detection in complex light curves. Our algorithms will be particularly suitable for handling the large inflow of data from the next generation of breakthrough surveys, such as the Large Synoptic Survey Telescope.

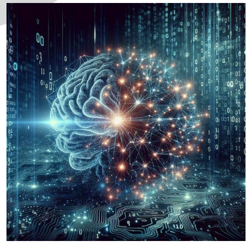

Figure 4: Neural networks illustration, created by AI.

Training and Communication of Results

The OCEANS philosophy is centred on training and exchange of expertise, which provides early-career scientists and students the opportunity to develop skills for their future careers in academia and industry. To achieve this,

- we organize schools on diverse topics with the aim of teaching and training students in relevant research tools and high-performance computing under the guidance of experts from the OCEANS consortium, and
- offer mentoring during exchange visits to the different participating institutes.

For communication and dissemination of our ongoing research and the achieved results, we

- organize scientific workshops and conferences,
- publish our results in open access journals and promote them through press releases, and
- develop planetarium shows on various scientific topics.

In addition, we reach out to the general public through events such as Days of Open Doors and Researchers Nights organized at the participating institutes.