The DustOrigin group

Prof. Ilse De Looze

My research revolves around the study of interstellar dust on small scales (~pc) in supernova remnants up to galaxy-wide (~kpc) scales. I am interested in what sources contribute to the dust production and destruction, both in the very first galaxies to have formed in the Universe until the present day. I have received my PhD degree at Ghent University in 2012, which was followed by a post-doc position in Ghent. Between 2014 and 2018, I spent four years in England (Cambridge University, University College London) as a post-doctoral researcher before returning to Ghent as a post-doc in 2018. I am working as a Faculty member in Ghent since Sept 2020, where I am doing research on interstellar dust in my "DustOrigin" group.

Jérémy Chastenet

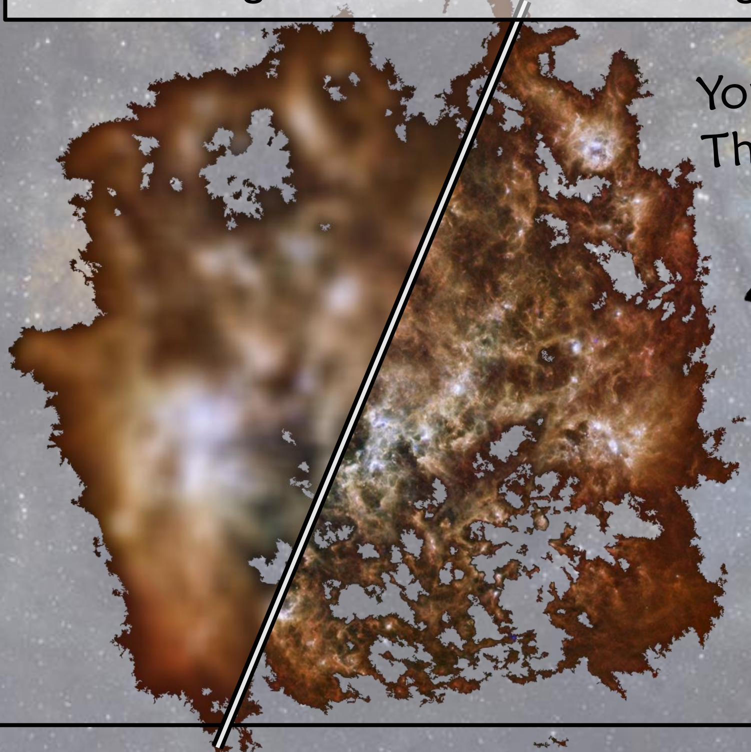
My research interests revolve around the interstellar medium of nearby galaxies, with a special focus on the dust component. I got my PhD from the University of Strasbourg (France) and the Space Telescope Science Institute in Baltimore (Maryland, USA), followed by a postdoc in San Diego (California, USA). I have extensively used different dust models that reproduce the dust observations (extinction, emission, abundance and polarisation) to derive their properties in the Magellanic Clouds (two very close irregular dwarfs) and then in ~ 1000 other galaxies thanks to a large catalog of Herschel observations I created. My work in Gent with Pr De Looze focuses on more specific cases: dust in supernova remnants. I use polarisation data as an additional constraint, and estimate how much dust is produced and destroyed, as well as its composition.

FACULTY OF SCIENCES

Creating high-resolution abundance maps of very small grains

The interstellar medium–between the stars of a galaxy–is filled with gas and dust grains. These dust grains play a key role in many physical processes pertaining to the evolution of their host galaxy: heating the gas, cooling the dense clouds, fueling star formation, etc. The smallest of these grains are particularly interesting: they are planar, hydrocarbons, and may represent the seeds of the growth of grains in the interstellar medium. Their emission is easily recognizable through broad and bright features in the mid-infrared. Quantifying their impact on their surroundings implies measuring their abundance. Unfortunately, this often requires to significantly degrade the infrared images we have in hand, leading to a loss of important information at very short scales.

Your target:
The Large Magellanic Cloud



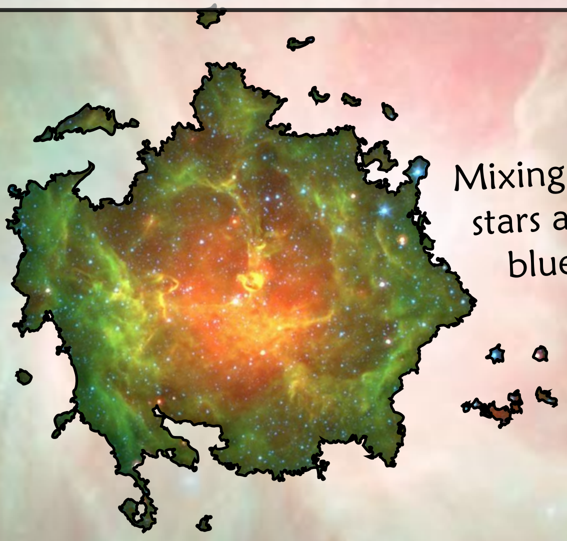
In this project you will reconstruct high-resolution maps of the abundance of very small grains in nearby galaxies. Combining the information from infrared dust emission modeling, and high-resolution images from space observatories like Spitzer, Herschel and WISE, you will find empirical relations to gain back in spatial resolution. These new images then can be matched to other tracers of galaxy physics and will allow you to accurately study the variations of very small grain abundance throughout a galaxy.

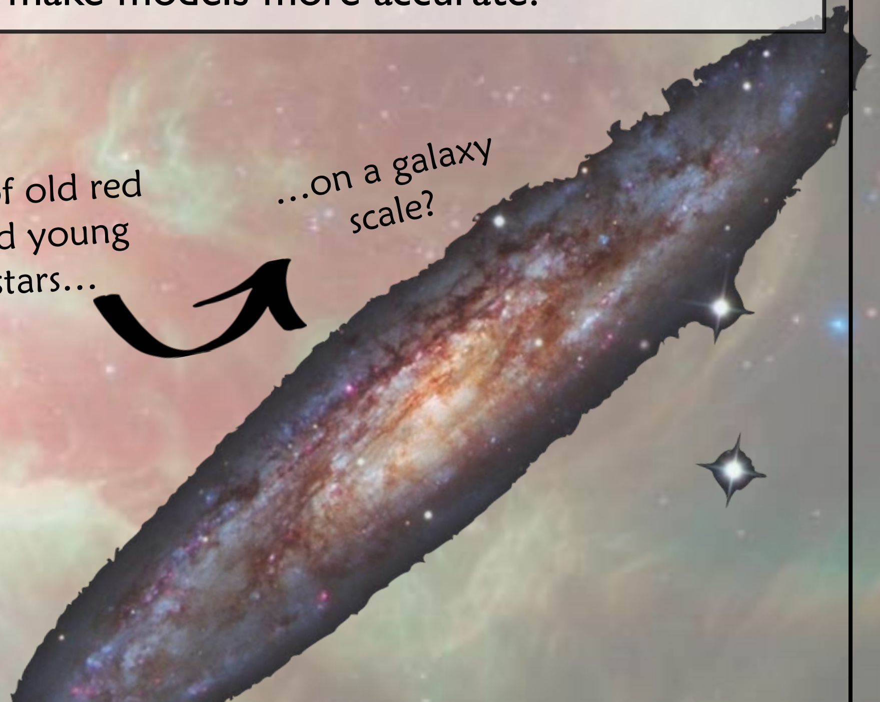
Supervisor: [Jérémy Chastenet]

Hardness vs intensity: modeling the dust heating in galaxies

Dust grains in the interstellar medium of galaxies emit infrared emission after absorbing UV and optical photons. Using solid physics and optics, dust models attempt to synthetically recreate the absorption and emission of these grains from an analytical standpoint. Along the way, a number of assumptions have to be made, based on our limited knowledge and observations. Among these assumptions: the spectrum of the radiation coming from diverse populations of stars, and that heats the dust grains. There are two key aspects to this spectrum: its hardness, that is related to the energy of the photons, and its intensity, the number of photons. Commonly, dust models use seminal works from the 1980s. Consequently, we apply to external galaxies a description that fits the Milky Way, regardless of its limitations. But the increasing quality and quantity of astrophysical measurements led to a wealth of data that can help revisiting these assumptions and make models more accurate.

Your objective in this project is to investigate the influence of the incident radiation heating the dust grains on the physical model outputs. In particular, you will quantify the degeneracies between 'hardness' and 'intensity' of the spectrum. This will lead to re-evaluating the common approach, and building new prescriptions for more rigorous applications of dust models to the nearby Universe.



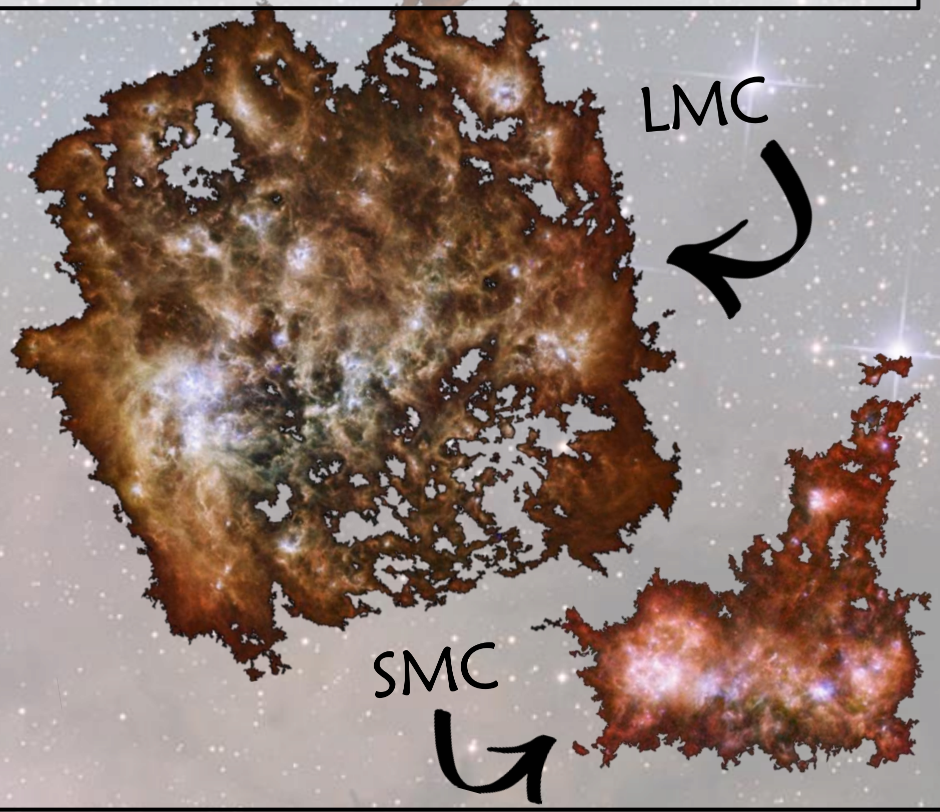


Supervisor: [Jérémy Chastenet]

Local geometries in the Magellanic Clouds

The interstellar medium of galaxies is an evolving mixture of gas and small dust grains. These two components are intertwined differently depending on environmental properties like gas temperature or density. The relative position of stars and dust (or gas) affects how we perceive the infrared emission of the galaxy because of the line-of-sight projection. The DIRTYGrid is a radiative transfer tool that provides a collection of spectral energy distributions from the UV to the infrared, with a number of varying parameters including 3D geometries. Namely, it allows us to investigate how the local geometry in a galaxy changes the observed dust emission. Observationally, this is only interesting when we can probe detailed structure. Fortunately, the Magellanic Clouds, two nearby irregular dwarf galaxies, are close enough that we can resolve down to very small physical scales.

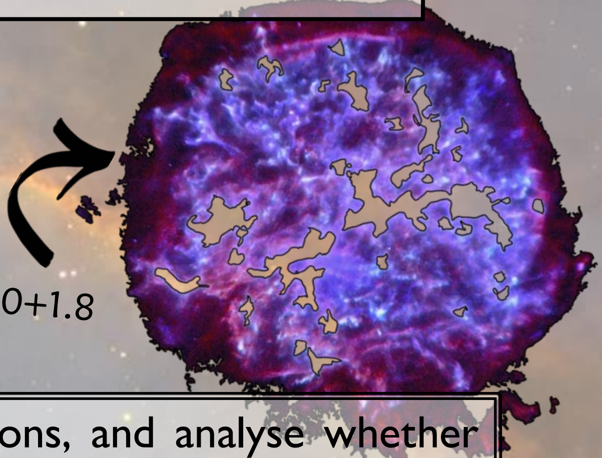
In this project, you will use the DIRTYGrid photometry to find out which galactic parameters reproduce the Magellanic Clouds emission the best and build a map of the local geometries. With high resolution images of stellar surface density and ionized gas, you will compare the distribution of dust and stars derived from the DIRTYGrid and other observational tracers. Disentangling the various galactic parameters that affect our observations, and modelisation, of interstellar dust is crucial to understand its life-cycle in nearby galaxies, its formation and destruction.

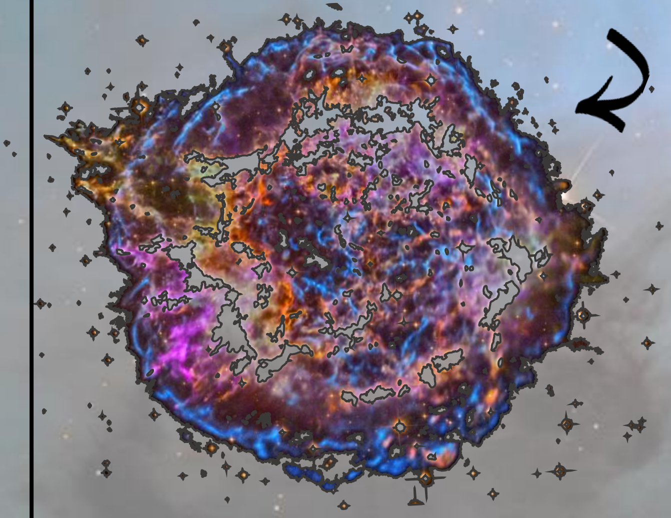


Supervisor: Jérémy Chastenet

Are core-collapse supernovae efficient dust factories?

Core-collapse supernovae are thought to be important contributors to the dust production in galaxies across cosmic time. But the efficiency of supernova dust formation remains poorly understood. The number of dust detections in recent supernovae has increased from a handful to several tens of supernovae over the last decade due to observations with the Spitzer and Herschel telescopes. But these detections correspond to roughly 10% of the entire observed supernova population and leaves us with the question whether dust condensation is simply inefficient in the remaining 90% of the supernova population.





This master thesis project will focus on these non-detections, and analyse whether observational uncertainties, too low supernovae dust temperatures and/or contamination by other emission components (e.g., synchrotron emission, interstellar dust) have led to these non-detections. You will perform a stacking procedure on “clean" (uncontaminated by other emission sources) samples of supernovae through co-adding images of these supernovae to boost the signal-to-noise. This will shed light on the efficiency of supernova dust condensation across the entire population of observed supernovae. The results of this study will be highly relevant to quantify the contribution of supernovae to interstellar dust budgets, and to inform supernova dust condensation models of the conditions under which dust grains can form.

Supervisor: Ilse De Looze

Revisiting galaxy scaling laws to probe the origin of dust

The interstellar medium roughly consists (by mass) of 99% gas and 1% dust in our own Milky Way. This canonical dust-to-gas mass ratio (DGR) of 0.01 is known to decrease by several orders of magnitude when the metallicity (which is linked to the mass of metals in the gas phase) drops significantly below the Milky Way value. There are currently two opposing views on how the DGR evolves with metallicity. For distant Damped Lyman Alpha (DLAs) systems, the DGR scales linearly with metallicity. On the other hand, observations of local low-metallicity galaxies suggest that the DGR decreases much faster than the metal masses in the gas. The observations of these extremely low dust-to-gas ratios, however, suffer from observational biases.

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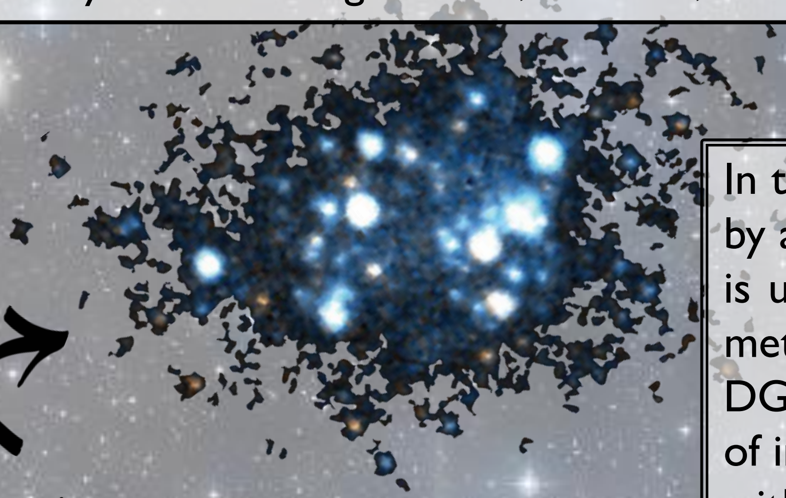


Leoncino galaxy
the lowest metallicity galaxy

In this master thesis project, you will investigate some of these observational biases by accounting for the extent of the HI gas mass reservoir and removing the gas that is unassociated with dust. You will also explore how the assumed homogeneity of metallicity measurements influences the inferred relation between metallicity and DGR. The results of this study will provide us with important insights on the origin of interstellar dust. In case of a linear trend, the dust mass is thought to simply scale with the amount of metals produced by stars, and most dust is thought to have condensed in these stellar environments. The confirmation of these steep trends would suggest that dust is mostly grown in interstellar clouds (not in stars) once a given metallicity threshold has been reached.

Supervisor: Ilse De Looze

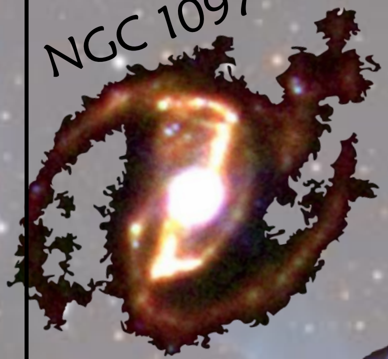
How does the [C II] cooling line perform as a tracer of the star formation activity?

Educational Master!

The far-infrared [CII] 158 µm line is an important coolant of the neutral gas in the interstellar medium, and it is also one of the brightest infrared lines accounting for 0.1-1% of the total infrared (TIR) luminosity in a galaxy. The [CII] line is a popular tracer of star formation activity across cosmic time. But variations in the [CII]/TIR ratio—with TIR probing the stellar light processed by dust and providing an alternative star formation rate (SFR) tracer—suggest that the [CII] line is not performing well as a SFR diagnostic under specific conditions. Part of these [CII]/TIR variations may be driven by old stars contributing to the dust heating and hereby contaminating the TIR emission.

NGC 0925

NGC 1097



NGC 4725

You will analyse the [CII]/TIR ratios in a sample of well-resolved nearby galaxies from the Herschel KINGFISH survey. Through modelling the panchromatic spectral energy distribution in these galaxies with a dust energy balance code (e.g., MagPhys, CIGALE), you will be able to dissect the TIR emission from dust heated by young stars (TIR_{young}) and by old stellar populations (TIR_{old}). This method will enable you to analyse the [CII]/TIR_{young} ratio—where both quantities are directly related to young stars—and to infer whether any additional variations occur that could point to [CII] being an unreliable SFR indicator.

Since this project will exploit multi-wavelength datasets, this project could be an ideal educational master thesis topic in which the student can develop a series of lectures at high-school level on the individual components of a galaxy and its interstellar medium (stars, gas, dust) and how they reveal themselves at various wavelengths.

NGC 6946

Supervisor: Ilse De Looze