STEP'UP Phd Congress 2024

Modeling the neutral gas heating in low metallicity galaxies

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What is interstellar medium (ISM) ?

- Compose $\simeq 5\%$ of the mass of the Galaxy
- Composed of gas and dust ($< 1\%$ in mass)
- Three phases: ionized, **atomic neutral** and molecular neutral

Metallicity: fraction of metal (e.g not H or He) in the ISM. Key parameter in ISM comprehension

Figure: IC10 - courtesy D.Nobre

The baryon cycle

- Neutral atomic ISM: gas reservoir for long-term star formation
- Stellar feedback counters gravitationnal collapse
- Differents processes for stellar feedback: turbulence, SN, **thermal heating**

We need to understand heating to better understand star formation

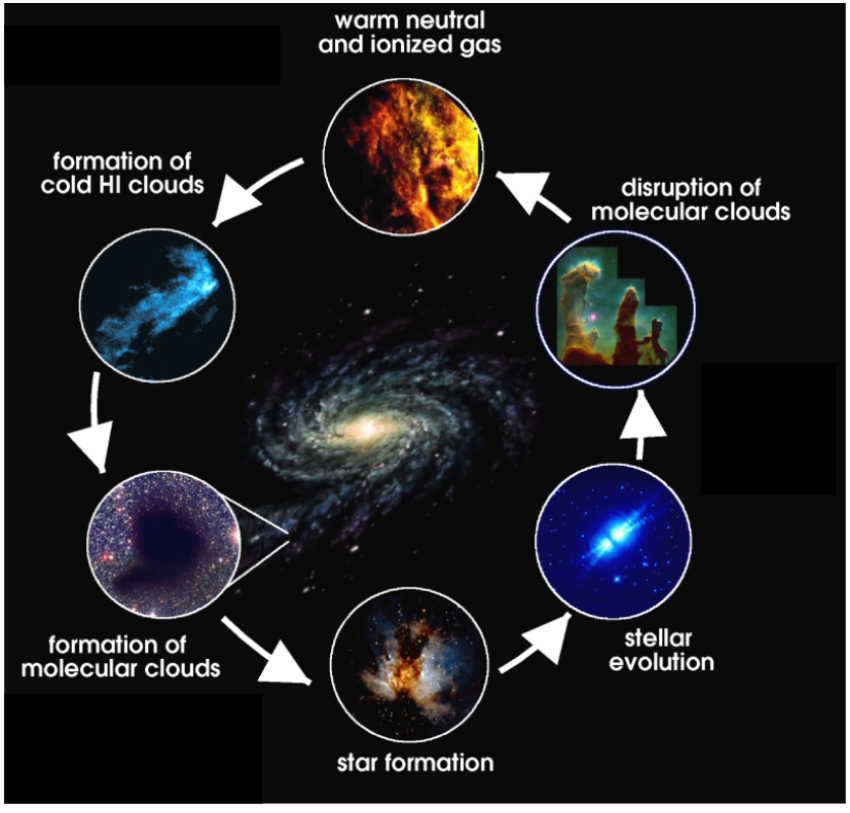
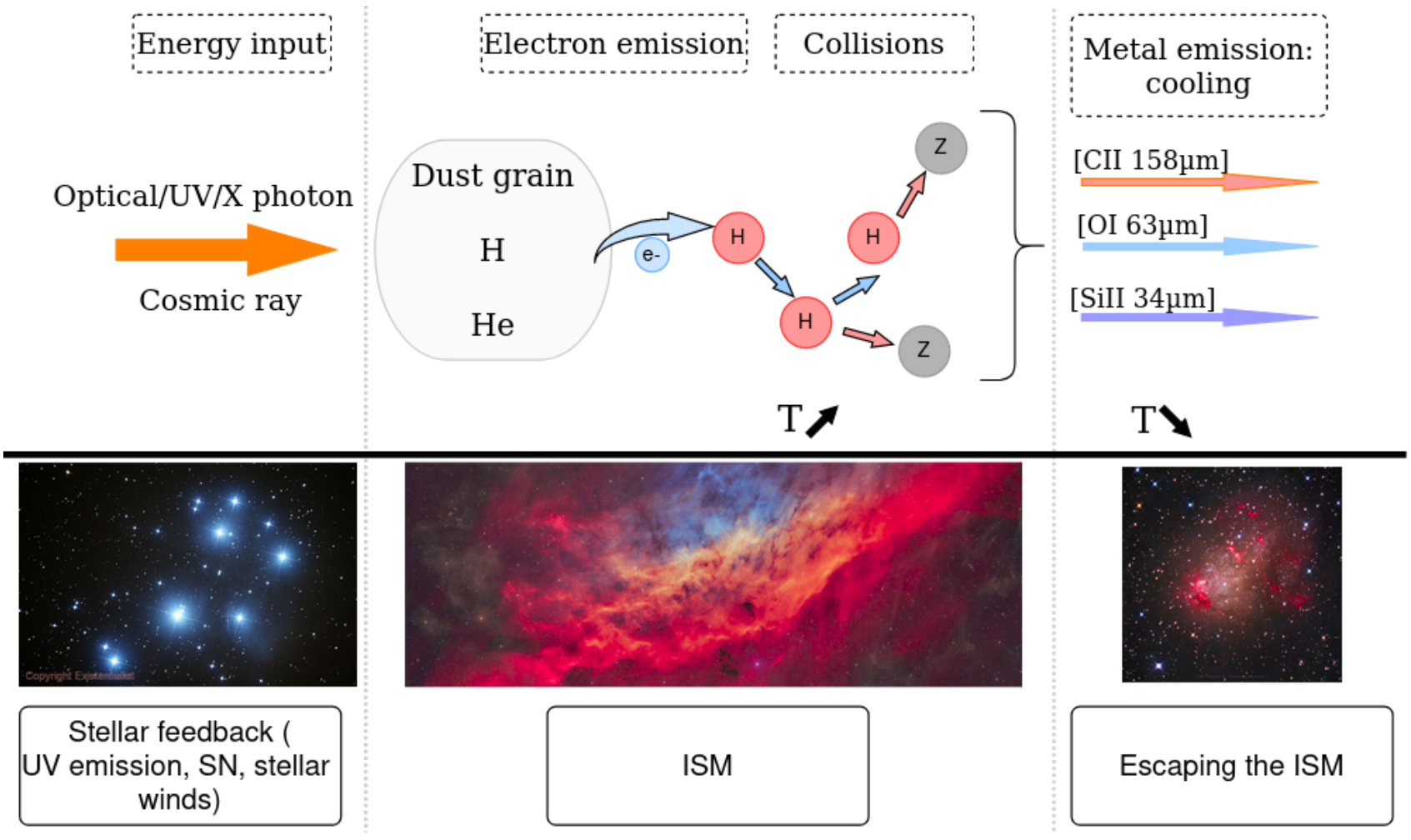


Figure: Baryon cycle - A.Kepley (NRAO)

Thermal heating: general mechanism



Thermal heating: state of the art

- At milky way metallicity: photoelectric effect (PE) dominates heating (Weingartner & Draine 2001, Berné et al. 2022)
- At lower metallicity: Dust/Gas mass ratio and PAH emission shrinks. We expect PE heating to be less important

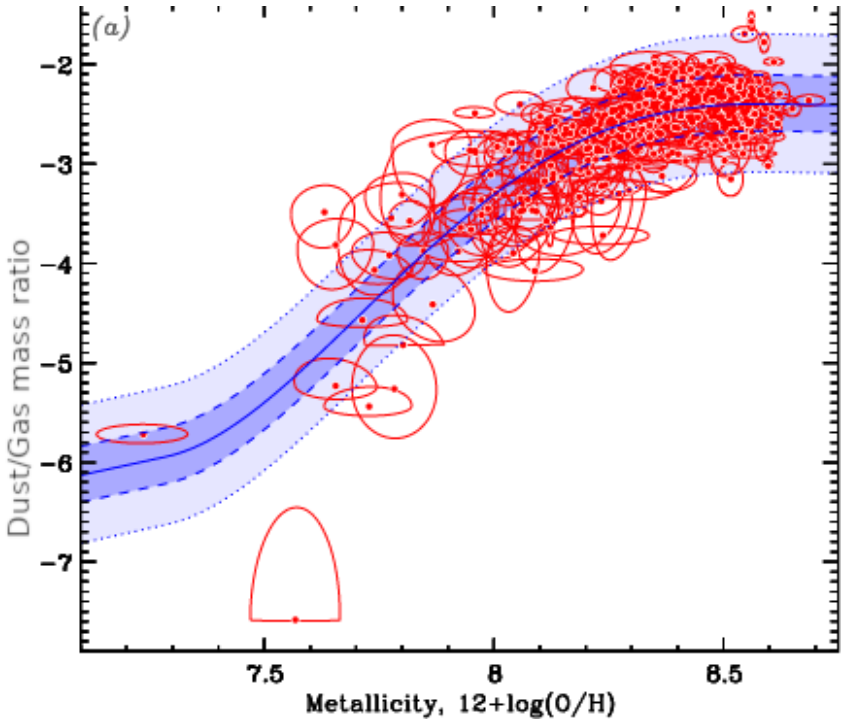
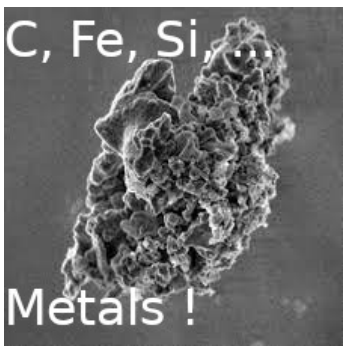
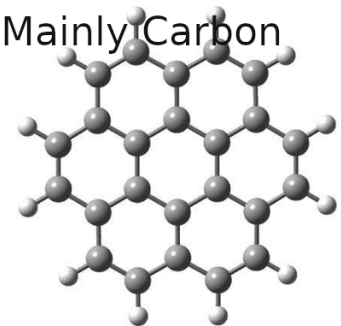


Figure: Dust/Gas mass ratio vs metallicity, Galliano et al. 2021





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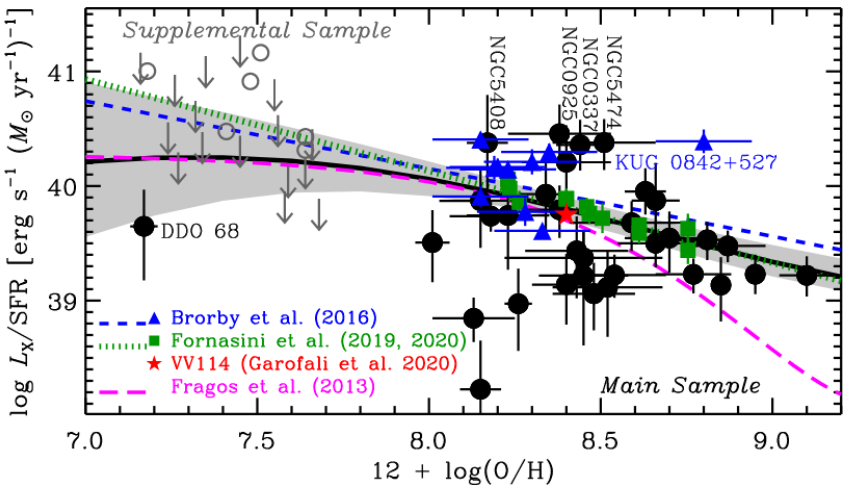

Figure: X-ray sources luminosity vs metallicity, Lehmer et al. 2021

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- At lower metallicity: Dust/Gas mass ratio and PAH emission shrinks. We expect PE heating to be less important
- Number and luminosity of X-ray sources (involving compact objects) increase
- Cosmic rays and photoionisation may dominate the heating at low metallicity

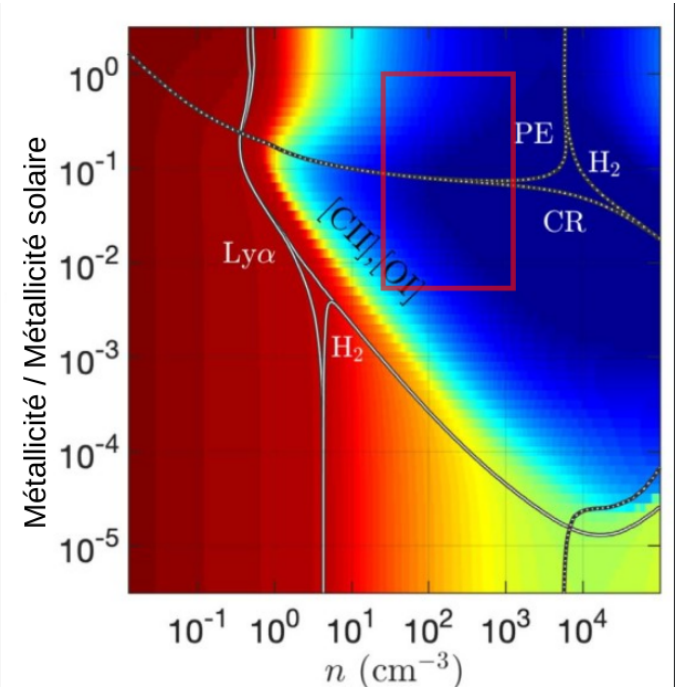


Figure: Dominating heating mechanisms depending on Z and n, theoretical study, Bialy & Sternberg 2019

Method

- 39 low metallicity galaxies observed **spectroscopically in IR** $(5 - 200)\ \mu\mathrm{m}$
- The detected emission lines are reproduced with multiphase radiative models
- **Thousands of models** are combined to account for the complexity of a galaxy: need for a robust statistical framework (MULTIGRIS, using MCMC; Lebouteiller & Ramambason 2022)
- We infer physical parameters (Z, n, X luminosity) and processes **(heating and cooling rates)**

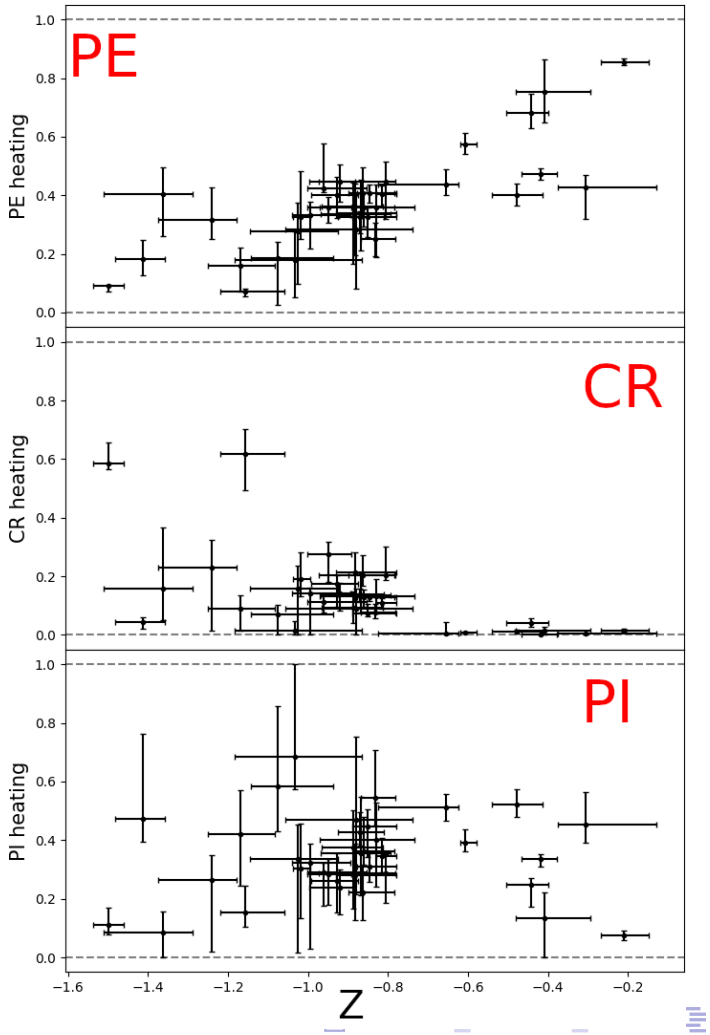
Result

Heating mechanisms

- High Z: Photoelectric effect dominates
- Low Z: ionisation (cosmic rays + photoionisation) dominates
- Photoionisation (UV/X): can dominates in some galaxies

Caveats

- Only 1 CR ionisation rate, probably over-estimated (Krumholtz et al. 2023, Rémy-Ruyer et al. 2014,2015)



Conclusion

- Using only IR spectroscopy as observations, we can recover the heating of the neutral ISM in galaxies
- Only integrated spectroscoy is required: no spatial resolution needed
- It offers an interesting prospective to study young (high-z), low metallicity galaxies, for instance observed with JWST