DEAR SIR

Dust Emission via Absorption and Reproccessing, from Starlight to IR

Star Formation and Chemical Evolution Group

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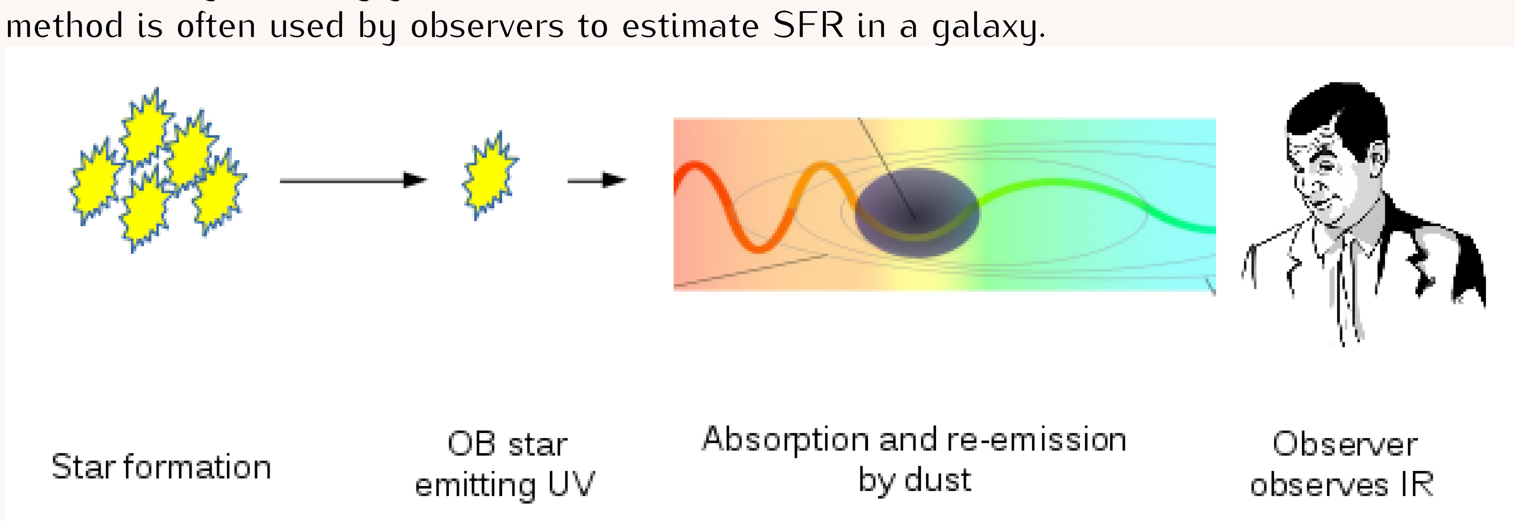
Introduction

Star formation (SF) is the primary process that made the dark Universe visible to our eyes and made possible to study the dynamics and evolution of the Universe itself. To understand the evolution, one often needs a statistical information of the star formation rate (SFR) in a sample of galaxies. Despite the fact that the star formation process itself produces huge amount of ultraviolet (UV) light which is strongly correlated with SFR, the SFR often can not directly be measured due to the presence of neutral gas in the interstellar medium (ISM) of the galaxy. However, the SFR can be estimated from the recombination lines (like Hα) intensities. Another very convenient way to estimate the SFR is to directly measure the infrared (IR) luminosity as the dust present in the ISM reprocesses the UV light and emits blackbody radiation. Since the IR luminosity is strongly correlated with the SFR and can be visible from distant universe, this method is often used by observers to estimate SFR in a galaxy.



With a simple assumption that if all of the bolometric luminosity coming from the star forming region is getting converted to IR - band ($8 - 1000\,\mu m$), the star formation rate can be written as (Kennicutt 1998)

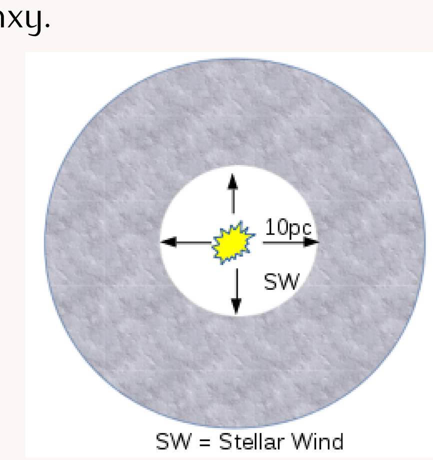
$$SFR(M_{\odot} yr^{-1}) = 4.5 \times 10^{44} L_{IR}(erg\ s^{-1}) \qquad (1)$$

Motivation

Though Kennicutt's relation has been widely used in the literature to study the SF process in distant galaxies, the main assumption in this relation regarding the conversion of the bolometric to IR luminosity remained unexplored. It is clear that the proportionality constant in eqn (1) depends on the local dust properties like, size distribution and column density of the dust grains. Therefore, we aim to study the dependency of the Kennicutt's relation on the local dust properties.

A toy model of star forming region

In reality, the stars form inside dusty environment which allows the dust to reprocess available UV light from OB stars. Since the OB stars are short lived (~ few Myrs), they are excellent measure of the SFR inside a galaxy.



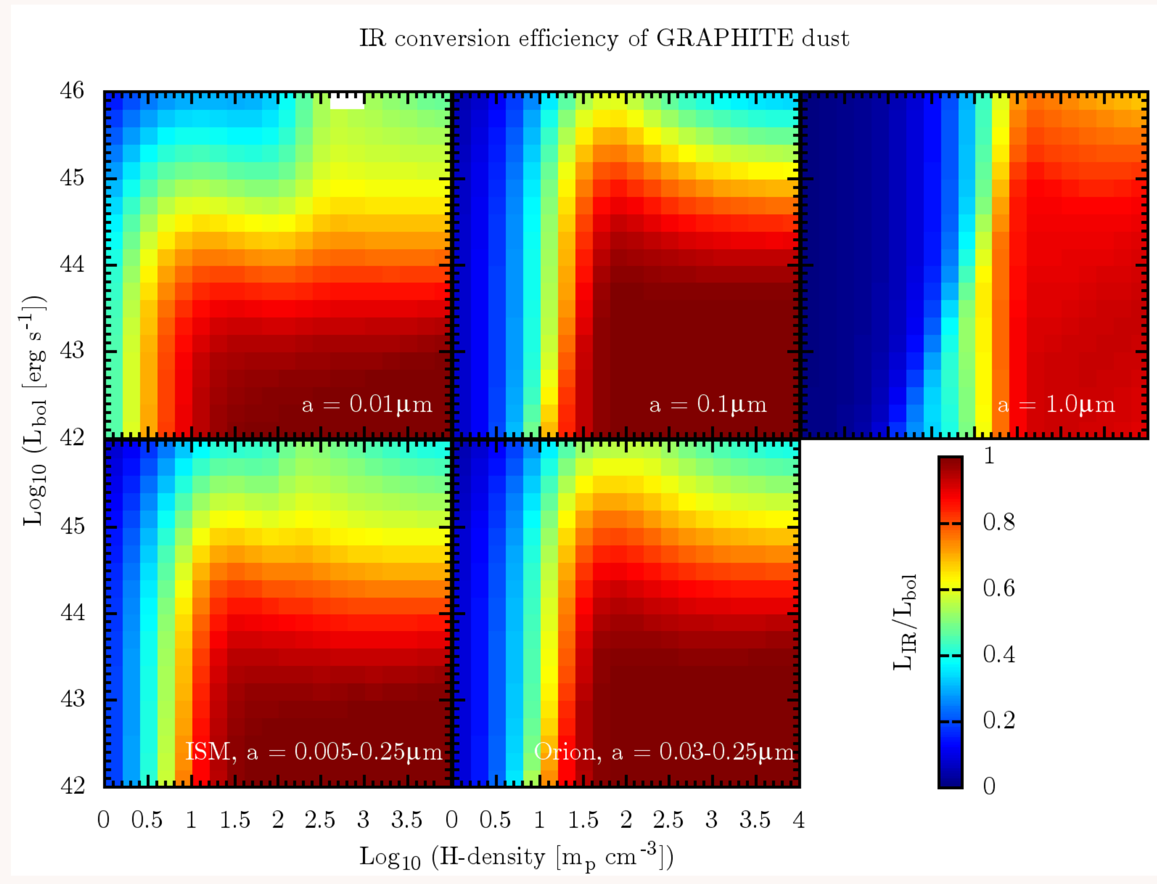
The real situation has been approximated by a central bright stellar source (few OB stars) and a ball of dust and gas surrounding the source.

Simulation Tool, parameters and details

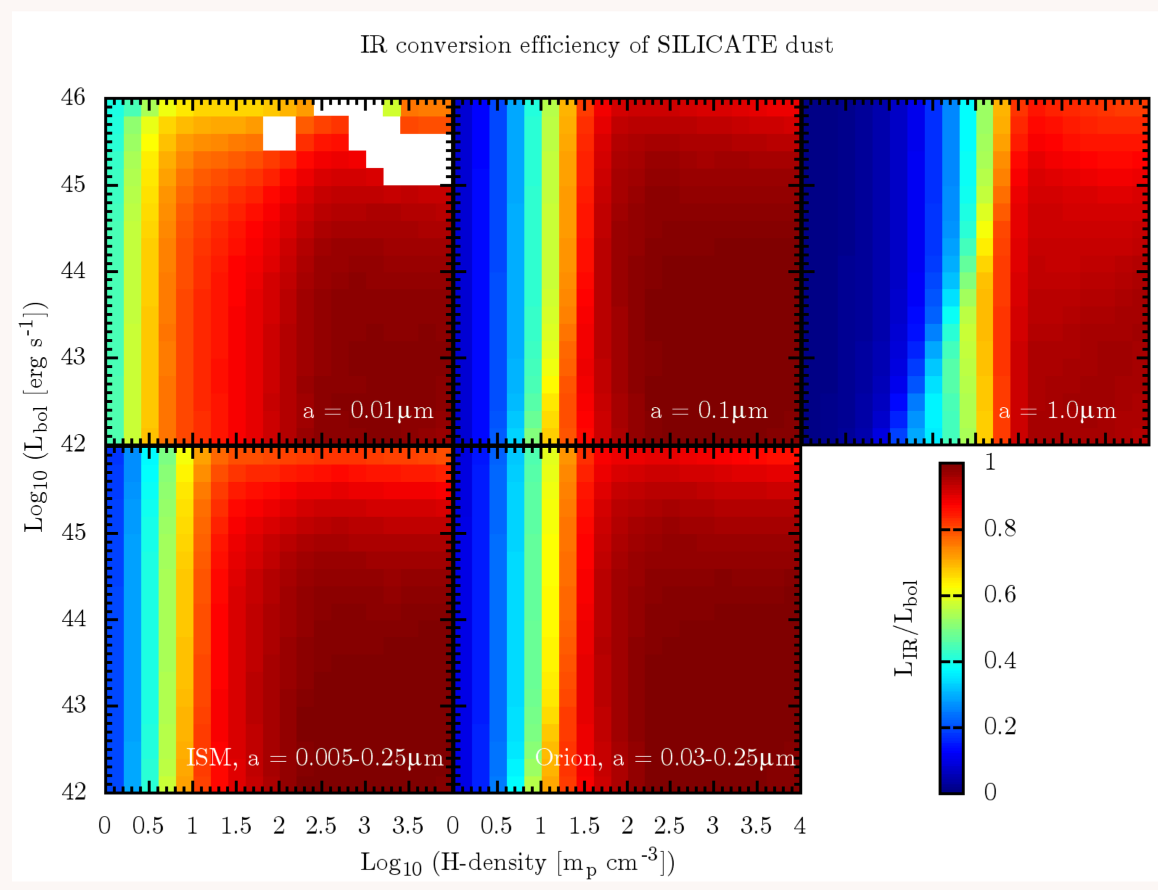
The photoionization code CLOUDY (experimental version of C16, Ferland et al., 2013) has been used to simulate the toy model under a broad range of conditions.

- We consider a solar metallicity for the ball of gas around the SF region.
- The dust grain sizes were varied from $0.01 - 1.0\,\mu m$ and along with mixed size distributions.
- The bolometric luminosity from the SF region is approximated as coming from OB associations of temperature $43600\,K$.
- Considered cosmic ray background to sustain the chemistry inside the low temperature cloud.
- CLOUDY was stopped when the following conditions were reached
  - → Visual band magnitude $A_V = 20$
  - → Toal gas column density $= 10^{23} cm^{-2}$
  - → The thickness of the cloud $= 100pc$ (since in reality, dust is confined to the galactic disc only)

Results



- Smaller and therefore hotter grains are most effective in increasing the efficiency even in lower densities. The bigger and colder grains require higher density to efficiently convert UV to IR. The standard Galactic ISM and Orion type size distribution works fine for a density $> 10\, m_p cm^{-3}$.
- For higher bolometric luminosities, because of the finite thickness of the cloud, the amount of dust becomes inadequate to convert all the light into IR and therefore the efficiency decreases to approximately 0.5.



- The conversion efficiency of Silicate dust is higher compared to graphite ones

* The empty grids in the plot are when CLOUDY stopped due to unexpected reasons and did not produce any data

Discussions and Conclusions

- The bolometric to IR conversion efficiency in starburst regions depends on the details of grains present in the medium. Smaller grains are most effective in converting starlight to IR.
- High SFRs may be underestimated due to finite thickness of dust in the galaxy.
- The dependence of the Kennicutt's relation on the dust column density, and a realistic spectra of the SF region is still under investigation.
- High SFR gives rise to high cosmic ray (CR) energy density in the ISM and can contribute to the IR emission via heating of the dust. However, this contribution has not been estimated from our simulations and under investigation.
- The escape of starlight from the dusty region can sufficiently decrease the radiation pressure on the ISM and can have important implications in CR driven galactic winds.

References & Acknowledgements

1. R. C. Jr. Kennicutt, 1998, ARA&A, 36, 189
2. G. J. Ferland et al., 2013, RMxAA, 49, 137

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