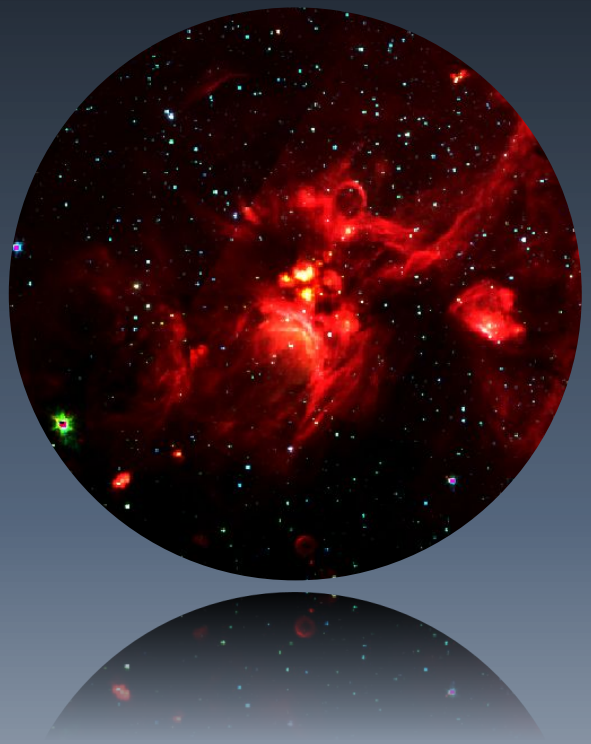
THE $^{13}CO/C^{18}O$ ABUNDANCE RATIO IN THE GALACTIC STAR FORMING REGION W33



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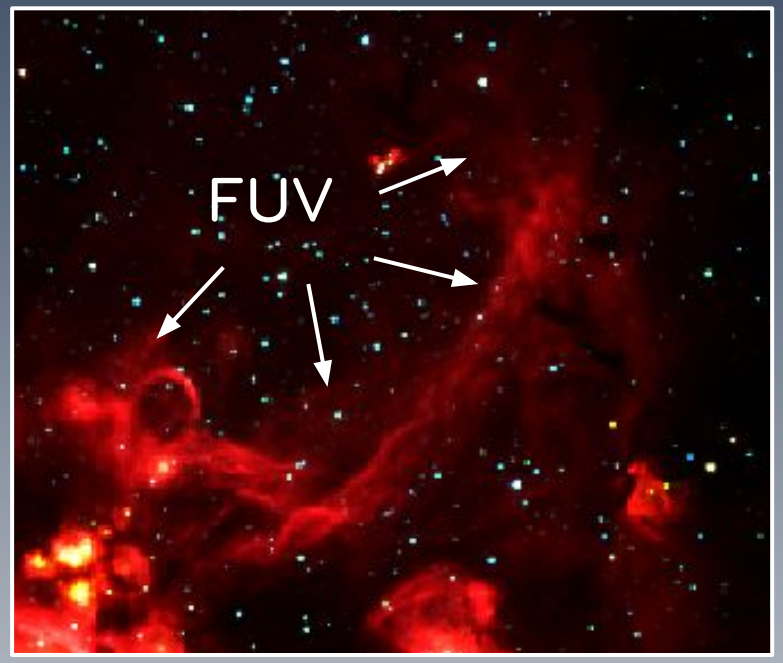
W33, located at a distance of 2.4 kpc, is a galactic high-mass star forming region, harboring many active clumps, OB stars, and HII regions. It is an appropriate region to study the interplay between the far ultraviolet (FUV) radiation and the dense molecular gas, which is useful to investigate the molecular cloud evolution and the star-forming processes that may occur within it.
Using ^{12}CO, ^{13}CO, and $C^{18}O$ J=1-0 data obtained from the FOREST unbiased Galactic plane imaging survey performed with the Nobeyama 45 m telescope, we study the $^{13}CO/C^{18}O$ abundance ratio throughout the molecular cloud associated with W33 in relation to the radio continuum emission distribution and another tracers of the FUV radiation field.

Introduction



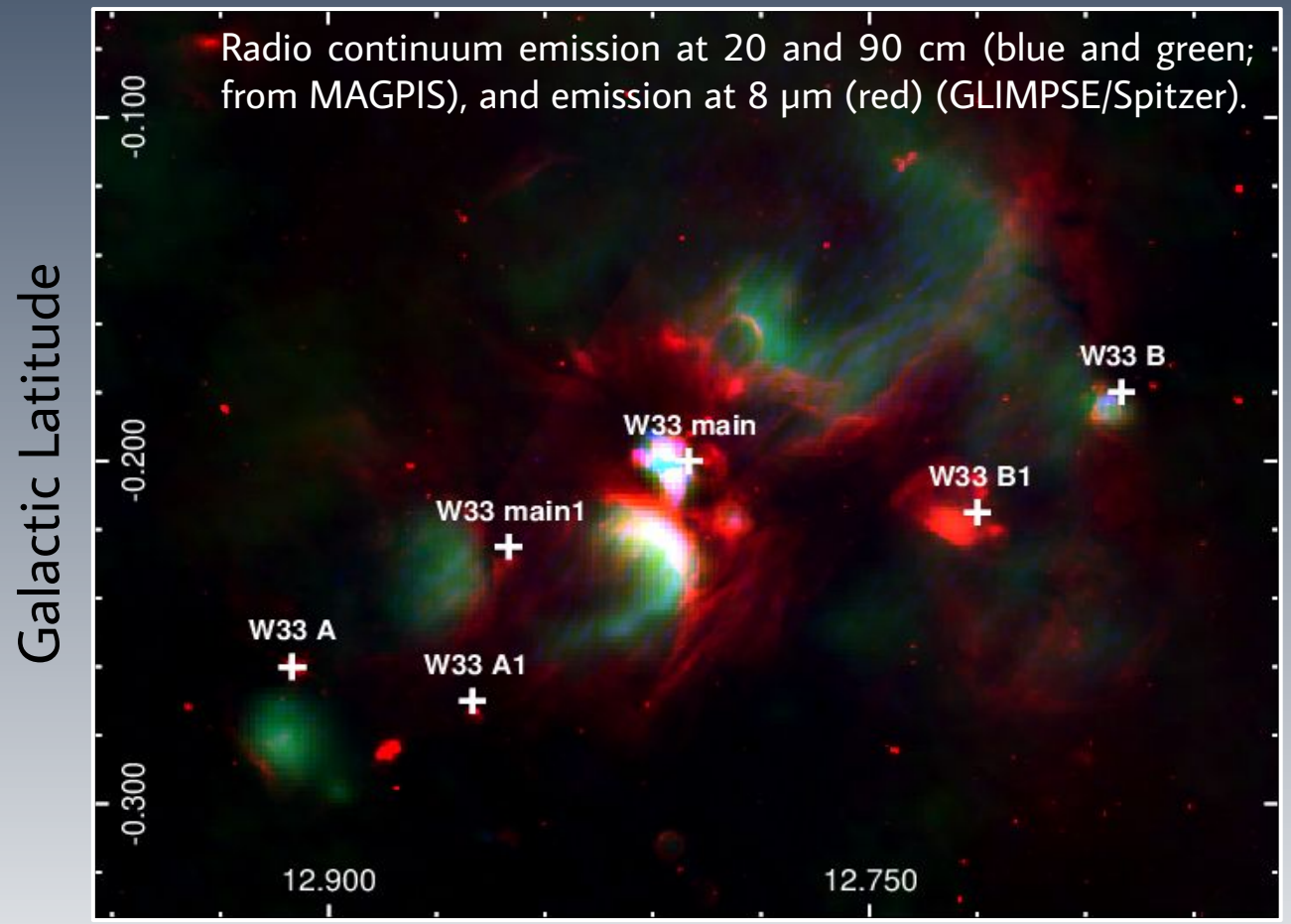
The study of molecular abundances towards molecular clouds located at different environments in the interstellar medium (ISM) is very useful for our knowledge of the chemical evolution of the Galaxy. It is known that the far ultraviolet (FUV) radiation selectively dissociates CO isotopes more effectively than CO (e.g. *Liszt 2007; Glassgold et al. 1985*) thus, the analysis of the ^{13}CO and $C^{18}O$ emission is useful for the study of the influence that the FUV photons have in the molecular gas.

Studying the $^{13}CO/C^{18}O$ abundance ratio ($X^{13/18}$) is important because they not only give us information about the relation between the molecular gas and the radiation, but also they point to establish new $X^{13/18}$ values obtained from the direct observation of the molecular lines, avoiding the use of indirect estimations from known elemental abundances such as the usually used of *Wilson & Rood (1994)*. Nowadays there are large molecular line surveys which allow us to perform this kind of studies across large regions of the ISM, and in the last years, several studies have been carried out (e.g. *Shimajiri et al. 2014, Areal et al. 2018, Paron et al. 2018, Areal et al. 2019, Yamagishi et al. 2019).*

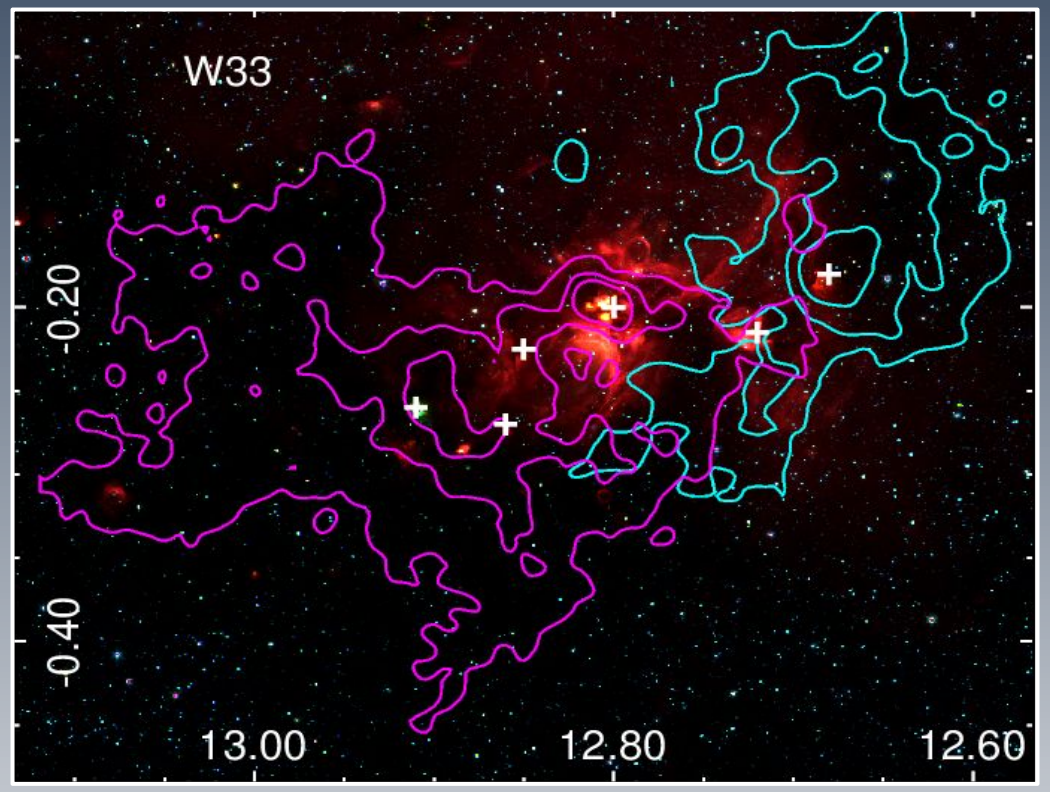
Star forming region W33

We study the molecular gas towards the high-mass star forming region W33, which harbors many active clumps, OB stars, and HII regions. *(Immer et al. 2013, Messineo et al. 2015)*

- Distance: about 2.4 kpc *(Xu et al. 2011)*
- Sub-regions:
  W33-A and -B (hot core)
  W33-main (HII region)
  W33-main1 (prestellar core)
  W33-A1 and -B1 (protostellar core).
- Molecular gas: two large clouds in the velocity ranges:
  30 - 40 km s^{-1} 50 - 60 km s^{-1}



Data



Infrared emission at 8 μm, 4.5 μm and 3.6 μm (red, green and blue, respectively) (from GLIMPSE/Spitzer). Contours are the $C^{18}O$ emission integrated between 30 to 40 km s^{-1} (magenta) and 50 to 60 km s^{-1} (cyan). Crosses indicate the sub-regions of W33.

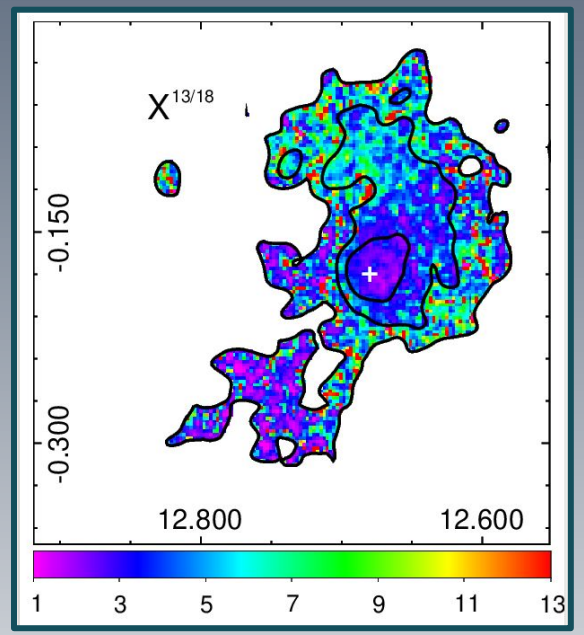
Using the emission from the ^{12}CO, ^{13}CO, and $C^{18}O$ J=1-0 line, obtained from the FOREST unbiased Galactic plane imaging survey performed with the Nobeyama 45 m telescope (FUGIN project; *Umemoto et al. 2017*)[1], we study the $^{13}CO/C^{18}O$ abundance ratio ($X^{13/18}$) throughout the molecular clouds associated with W33 in relation to the radio continuum emission distribution, which traces the ionized gas, and hence, the sources of far ultraviolet (FUV) radiation.

The angular resolutions are 20" for the ^{12}CO data, and 21" for the ^{13}CO and $C^{18}O$ data, and the spectral resolution is 1.3 km s^{-1} for all isotopes.

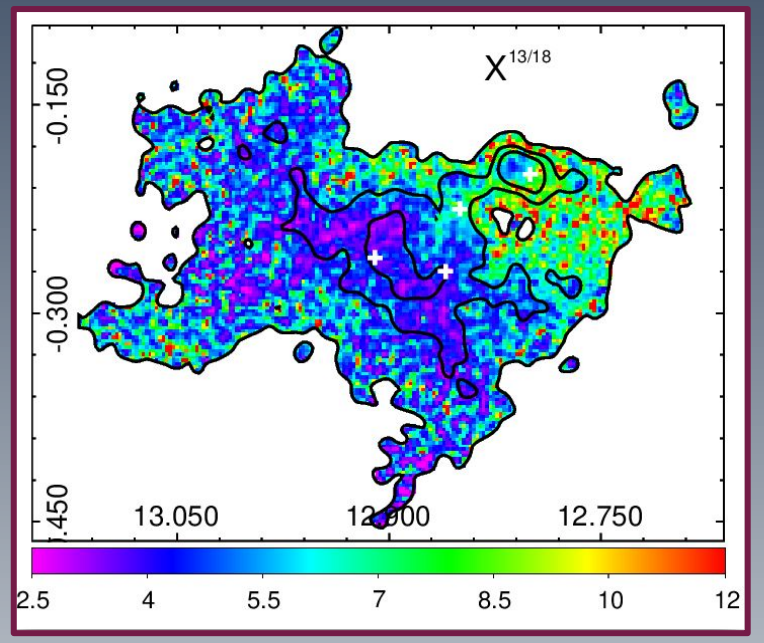
Graphical Astronomy and Image Analysis Tool (GAIA) and tools from the Starlink software package were used to analyze the data. Codes in python were used to obtain the maps of the analyzed parameters.

[1] Retrieved from the JVO portal (http://jvo.nao.ac.jp/portal/) operated by ADC/NAOJ.

Abundance ratio $X^{13/18}$



Map of the abundance ratio $X^{13/18}$ of the cloud that extends between 50 and 60 km s^{-1}. Contours of the integrated $C^{18}O$ are included. Crosses indicate the regions W33 B and B1.



Map of the abundance ratio $X^{13/18}$ of the cloud that extends between 30 and 40 km s^{-1}. Contours of the integrated $C^{18}O$ are included. Crosses indicate the regions W33 A, A1, main and main1.

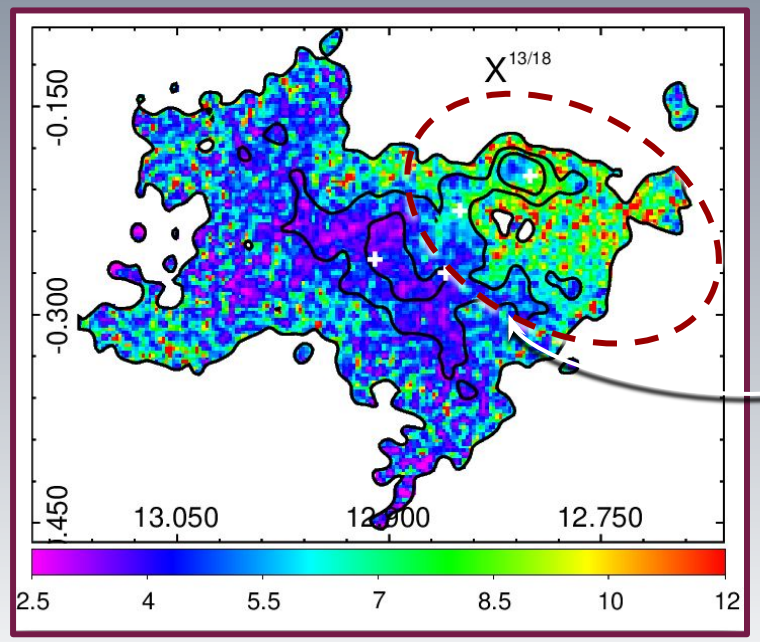
By assuming LTE and using ^{12}CO to obtain an excitation temperature pixel-by-pixel, we calculate the ^{13}CO and $C^{18}O$ column densities (N^{13} and N^{18}) pixel-by-pixel[1] within the molecular structures delimited by the $C^{18}O$ emission in two velocity ranges: 30-40 km s^{-1} and 50-60 km s^{-1}. Finally, maps of the abundance ratio ($X^{13/18} = N^{13}/N^{18}$) were obtained.

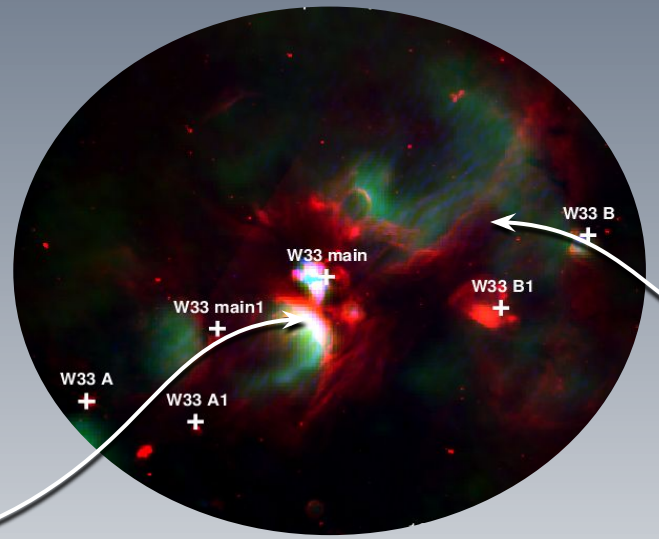
[1] For more details about the procedure see for example Areal et al. 2019.

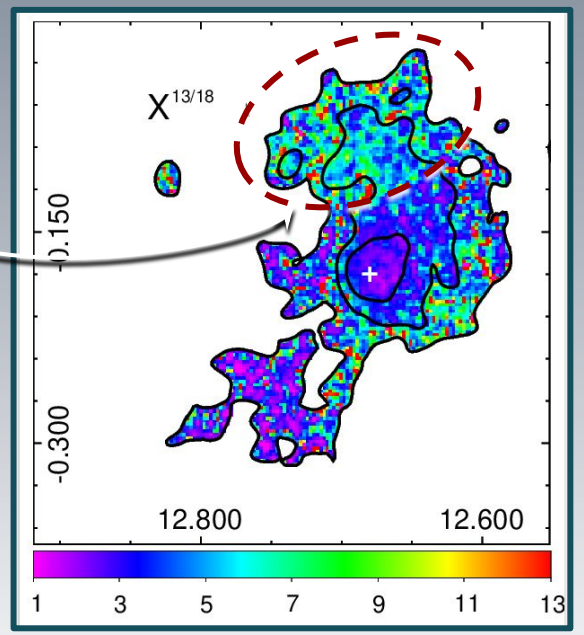
Abundance ratio $X^{13/18}$

In general, the $X^{13/18}$ ratio increases towards the edges of the molecular structure and mainly towards the northwest, in coincidence with W33-main.

We found two zones in which the selective photodissociation process is evident, each related to different sources of FUV. In particular, it is observed that W33-main affects the molecular gas belonging to the cloud in the velocity range between 30 and 40 km s^{-1}, but not the gas in the range of 50 to 60 km s^{-1}.





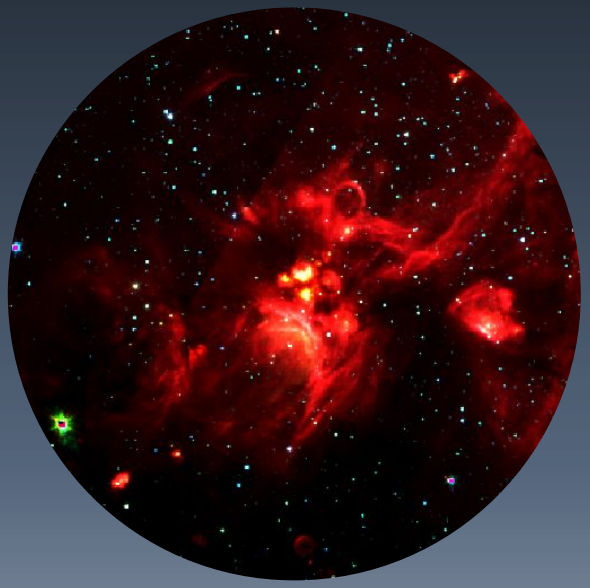


An increase in $X^{13/18}$ ratio is observed towards the northeast of the cloud related to the extended radio continuum emission.

Conclusions

We conclude that the $C^{18}O$ is indeed selectively photodissociated with respect to ^{13}CO in the regions most intensely irradiated by the FUV radiation from the stars that excite the HII regions and/or from the ISM radiation field. The behaviour of the $X^{13/18}$ gives us some hints about the molecular gas conditions and its distribution in W33, which it is something that it is not completely clear in previous works (we are working on that).

Similar abundance ratios studies towards different Galactic regions using different molecular transitions are in course.



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