# Variations of UIBs in NGC 7023

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**Abstract**

We have obtained ISOCAM observations with the Circular Variable Filter in the photo-dissociation region NGC7023 to study the spatial behavior of Unidentified Infrared Bands at 6.2, 7.7, 8.6 and 11.3$\mu$m. In a first part we show the spatial correlation between the HI gas and the UIBs. As a second result we discuss the relative variations of these bands with an emphasis on the properties of the carrier of UIBs. It allows us to provide strong constraints on the nature of the carrier and its heating mechanism.

## 1 Introduction

The astronomical Unidentified Infrared Bands (UIBs) at 6.2, 7.7, 8.6 and 11.3 $\mu$m have been extensively attributed to carbonaceous material. Many authors have claimed that the carrier must be 2-dimensional molecules, Polycyclic Aromatic Hydrogenous molecules (PAHs)[7][3] , which undergo stochastic heating in a UV radiation field. But the nature of the carrier and its heating mechanism are still a matter of debate. Studying the observational properties of the UIBs and their variations with the InterStellar Medium (ISM) conditions (ie, radiation field, gas properties ...) can provide useful constraints on models for the UIBs. This study is important as the UIBs are present in a wide range of astrophysical conditions.

NGC 7023 is one of the simplest Photo-Dissociation Region (PDR) accessible in the Mid InfraRed (MIR). It is an edge-on PDR, embedded in a molecular cloud and being heated by a single star (HD 200775 Spectral type B3Ve). Two HI clouds sit adjacently to the front of the molecular cloud, which is probably viewed edge-on. As this region has a simple geometry and a well known gas distribution [6], it is well suited for a study on spatial variations of UIBs.

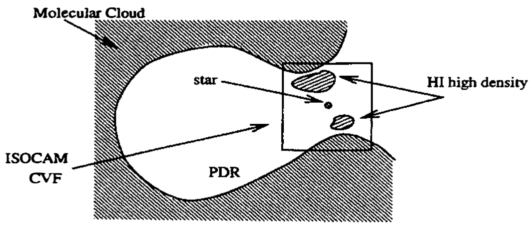


Figure 1: A schematic view of the geometry of NGC 7023, projected on the plane of the sky. The square indicates the region observed by ISOCAM.

# 2 Observations and data reduction

## 2.1 Observations

NGC7023 has been observed with ISOCAM using its Circular Variable Filter (CVF) capability. The pixel field of view (PFOV) of these observations is 6" so that the field covered is 3'12". This field is centered around the star HD200775, and includes the two HI concentrations as well as a part of the front between the HI clouds and the molecular cloud (see Figure 1.). The wavelength range of the CVF is 5.$\mu$m to 16.5$\mu$m, with a spectral resolution of 0.1 $\mu$m. Two full scans, in opposite directions, have been obtained in order to correct for memory effects of the camera.

## 2.2 Data reduction

The data have been reduced using CIA software [9], and a careful correction of the transient behavior of the array has been made using the IAS method [1] as it results in a lower discrepancy between the two CVF scans. Thus we can be confident in the shape of the spectrum derived from the observations. Finally, to get a higher S/N ratio, we have added the two corrected scans.

## 2.3 Extraction of the UIBs

Extraction of the bands is quite straight-forward if the underlying continuum is well defined around the band (Fig 2). Unfortunately, this is only the case for the 6.2 $\mu$m band. The 11.3 $\mu$m band also exhibits a simple continuum at long wavelength, but emission rises at shorter wavelengths (11.0$\mu$m ) so that it is quite difficult to differentiate between the continuum and the band itself. The most difficult bands to extract are the 7.7 and 8.6$\mu$m bands. First, the underlying continuum seems to be a large bump starting at 6$\mu$m and decreasing up to 9$\mu$m. And second, the flux level at 8$\mu$m between the two bands is probably affected by emission from both bands.

We used the following method to derive the continuum: from the few points surrounding a band we fitted a linear continuum and subtracted it from the spectrum to obtain the band flux by summing between the limits. In figure 2, we show how the bands extraction has been done for two different shapes of the spectrum. Note that the continuum interpolated for the 7.7$\mu$m band is approximately the continuation of the 6$\mu$m continuum. All the underlying continua

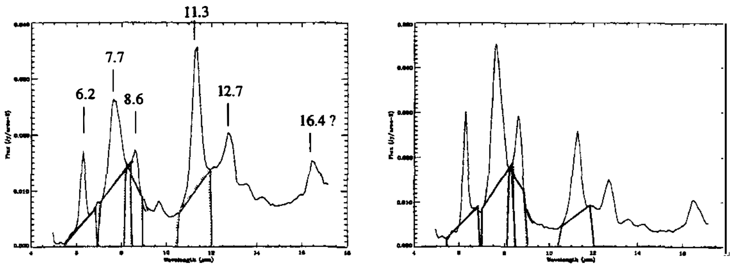


Figure 2: Spectral decomposition, lines indicate the continuum subtracted in order to get the flux in the bands at 6.2, 7.7, 8.6 and 11.3$\mu$m. The bands indicated at 12.7 and 16.4 $\mu$m are likely connected with the UIB carrier.

have the same shape from one spectrum to the other; only the contrast between the bands and their continuum changes. As our discussion will focus on band relative variations, our results should be little affected by systematic errors on the continuum evaluation.

# 3 Results and discussion

## 3.1 The HI and UIBs correlation

In figure 3 we show the distribution of the 6.2 and 11.3$\mu$m bands surface brightness along with contours of the HI column density [6]. The first striking result we see is the strong spatial correlation of the UIBs and HI column density. Furthermore, emission in the UIBs decreases dramatically as soon as we enter the molecular cloud which surrounds the HI (see Fig. 1). From this behavior, we can draw three hypotheses:

- The carrier of the UIBs is not present in the molecular cloud (As is it expected in some PAH models [2]). [1]
- The heating process is due to UV photons, which also dissociate the $H_2$ and whose number density falls dramatically as one passes the dissociation front.
- The excitation mechanism for the UIBs is somehow connected to the HI gas.

In fact the second hypothesis implies the first one: There are several indications from other observations [4][8] that not only UV but visible photons also can heat the dust. As the $H_2$ molecule is only photodissociated by UV photons and as visible photons penetrate deeper in molecular cloud than UV photons, then the UIB carrier should emit a bit further in the molecular cloud than the HI gas does. Therefore there should exist a shift between the emission of the UIBs and the HI. As it is not seen, one has then to assume the disappearance of the dust in the molecular cloud in order to explain the strong spatial correlation between UIBs carrier and HI gas.

Studying the relative variations of the bands will help us to see the effect of the dust processing and therefore its adsorption if any.

[1]This absence could be due to adsorption of the carrier on larger grain for example.

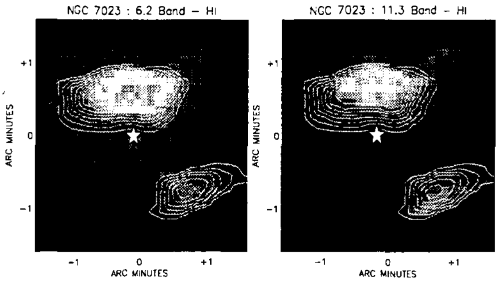


Figure 3: Brightness maps of the 6.2$\mu$m and 11.3 $\mu$m bands, HI column density map is superposed.

## 3.2 Relative variations

The intensity observed in a band reflects two physicals properties of the emitting carrier: (1) The heating mechanism that induces the absorbed energy to be reprocessed in a given band, and (2) the nature and the evolution of the dust itself that determines the spectral characteristic of the grain and thus also the emission spectrum. Even if these two physical properties are closely linked, they can however have different physical origins. For example, the heating mechanism is widely believed to be the absorption of the UV radiation while the nature of the dust could be modified either by the UV flux and/or physical interaction between the carrier of the bands and the gas. From the PAH hypothesis point of view, the two mechanisms have mainly the same origin: the UV radiation heats the PAH molecules and also affects their size distribution by destroying the smallest ones or ionizes them. Interaction with the gas could also be a way of modifying the PAH (hydrogenation, sputtering ...[3][2]).

In studying the spatial variations of the ratio of two bands, one can see the effects of the two mechanisms in the redistribution of the flux in the bands. Moreover if radiation is the dominant factor in the two mechanisms (heating and modification of the dust) the relative variations of the bands should trace out spatial regions of identical radiation conditions. As NGC7023 is heated by a single star, those regions must have a simple geometry and be more or less concentric to the star.

We have classified the band by their variability with respect to the others. The 6.2/11.3, 7.7/11.3 and 8.6/11.3 maps have very similar distributions. This can be explained by the fact that the strong variations of the 11.3 $\mu$m band across the map dominates the ratios. In the same manner, the 8.6$\mu$m band variations dominate the 7.7$\mu$m and 6.2$\mu$m bands variations. The region of low 6.2/11.3, 7.7/11.3 and 8.6/11.3 ratio follows the photodissociation front (Fig 4.). This region is clearly not concentric to the star. In the same manner the 6.2/8.6 and 7.7/8.6 maps delineate a region parallel to the photodissociation front. However this region is not the same as that delineated by the 6.2/11.3 ratio: the two are parallel and the region of low 6.2/8.6 is closer to the star. The 6.2/7.7 ratio map ratio traces out a very different region correlated with the HI column density: the higher the HI column density, the lower the 6.2/7.7 ratio. It is to be pointed out that all these ratio maps delineate iso-ratio regions that are in very different flux radiation conditions. The fact that the 11.3$\mu$m and the 8.6 $\mu$m bands appear to be very

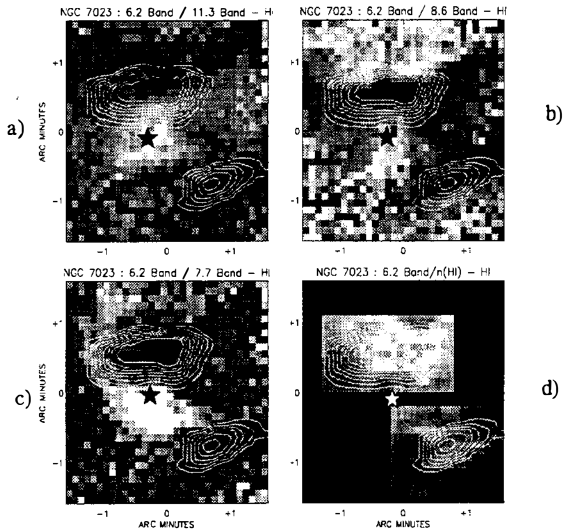


Figure 4: MIR ratio maps: (a) 6.2/11.3, (b) 6.2/8.6, (c) 6.2/7.7 and (d) 6.2/N(HI) map. White indicates high ratio, black indicates low ratio.

sensitive to the photodissociation front could be a consequence of the nature of these bands: the two are related to a C-H vibration.

But the main result is that all the relative variations are not connected with the radiation field intensity but rather with the gas distribution. It tell us that the spectral distribution of the energy emitted in the UIBs is much more sensitive to the gas distribution than it is to the radiation field.

The second most important result is the ratio level of all the maps: while the ratio decreases in the front between the HI cloud and the molecular cloud for the 6.2/11.3 maps, this ratio is the same in the molecular cloud and near the star, where the HI column density is low. In the case of the maps 6.2/7.7, iso-ratio are correlated with HI density. But if the carrier of the UIBs is heated by UV photons and absent in the molecular cloud, one would expect a monotonic trend in the relative variation with the distance from the star. This is not seen. Thus it implies that there are other mechanisms that counteracts this trend.

## 3.3 UIB brightness and HI column density ratio

We see that UIB emission is closely correlated with the HI gas much more than with the molecular cloud. And in the previous section we saw that the combination of the heating mechanism and the nature of the carrier of UIBs is correlated with the atomic gas. Here we present a further evidence of this.

The absolute brightness of a band is the product of the column density of the emitting dust and the available energy for band emission. One could be thus tempted to evaluate the emission of the UIBs for a given amount of dust. If the number density ratio between HI and the carrier of the UIBs is constant, the ratio UIBs/N(HI) represents the brightness of a fixed amount of dust. And once again (see Fig 5 for the 6.2 $\mu$m case, the other bands do exhibit the same behavior) the regions delineated are not strongly connected with the radiation field. Moreover, the emission is not a linear function of the HI density ; thus either the UIB carrier density increases in the inner region of the cloud, *i. e.* the density ratio is not constant, or the HI density can influence emission in the UIB.

# 4 Conclusions

We have shown that, in NGC 7023, the UIBs properties are strongly correlated with the gas conditions:

- The UIB brightness is spatially correlated with the HI column density.

- The relative variations of the UIBs delineate regions correlated with the front between the HI and the molecular cloud or with the HI column density. Therefore the radiation field is not the dominant factor when the combined effects of heating mechanisms and changing nature of UIB carrier are concerned.

- If the dust to gas density ratio is constant then the emission mechanism is correlated with the HI density.

These three observations lead to the following conclusions: (1) The spectral distribution of the energy reemitted in the UIBs is correlated with the HI gas. (2) If the carrier is heated by UV photons, then this carrier must vanish in the molecular cloud. And if so, there must be another effect at work to explain the non-monotonic trend of the band ratio on both side of the photodissociation front. It is simpler then to assume that the heating mechanism is connected to the HI gas.

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