

Far-IR spectroscopy towards Sagittarius B2

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The far-IR is a unique wavelength range for Astrophysical studies, however, it can only be fully sampled from space platforms. The fundamental rotational transitions of light molecules, the high- J transitions of polyatomic species, the bending modes of non-polar molecules, several atomic fine structure lines and many frequencies blocked by the earth atmosphere can only be observed between 50 and 200 μm (6.0 and 1.5 THz). In this contribution we present the far-IR spectrum of Sgr B2 at a resolution of $\sim 35 \text{ km s}^{-1}$, the “*Rosetta stone*” of ISO’s spectra. We also discuss the perspectives of the far-IR Astronomy in the context of the future telescopes under development.

1 Introduction

Due to the atmospheric opacity, the far-IR domain has been the last window used in Astronomy. For the first time, the *Infrared Space Observatory* (ISO) has opened this spectral frequency range through *molecular spectroscopy*. The sensitivity of the instrumentation on board this platform has no comparison with the few previous space missions or airborne observations carried before the launch of ISO. Almost all the operative range of ISO in the far-IR was not explored before. The far-IR spectrum of the most significant galactic sources was unknown. In particular, the main radiation emitters, the molecules, were unidentified. Far-IR observations are specially suitable to the study of the *warm gas* in molecular clouds. Among these sources, Sgr B2 in the Galactic Center, is a paradigmatic object for our knowledge of the *chemical complexity* of the Galaxy.

The molecular species and the atomic fine structure lines that can be detected in the far-IR domain are essential for the study of the physical and chemical conditions of the interstellar medium. The bulk of these species can only be observed from space platforms. As a example, the water vapor abundance can determine if stars will be formed during the gravitational collapse of a molecular cloud. Another example are the non-polar carbon chains. These species can be the “*skeletons*” from which the large carbon molecules responsible of a great part of the IR emission in the Galaxy can be formed. Due to the lack of permanent electric dipole, these species do not have rotational spectrum to be observed from radio telescopes.

In this contribution we present the main results of our detailed study of the *Long-wavelength spectrometer* (LWS) spectrum of Sgr B2(M) between $43\ \mu\text{m}$ (7.0 THz) and $197\ \mu\text{m}$ (1.5 THz). Both with the grating ($\lambda/\Delta\lambda\sim 200$) and with the Fabry-Perot (FP; $\lambda/\Delta\lambda\sim 10000$).

2 The far-IR spectrum of Sgr B2(M)

Figure 1 shows the grating and FP observations of Sgr B2(M). The far-IR spectrum of Sgr B2 is dominated by the high thermal emission of the dust ($\sim 28000\ \text{Jy}$ at $\sim 80\ \mu\text{m}$ [$\sim 3.75\ \text{THz}$]) and by the molecular/atomic lines.

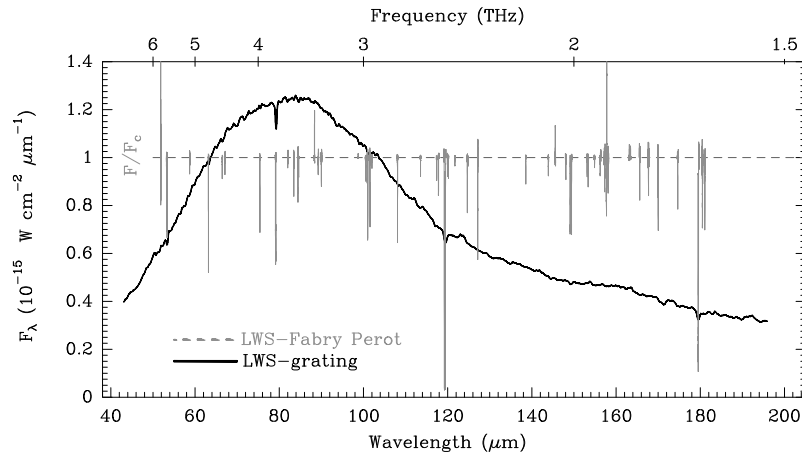


Fig. 1. LWS/grating spectrum of Sgr B2(M) ($\alpha=17^{\text{h}}44^{\text{m}}10.61^{\text{s}}$, $\delta=-28^{\circ}22'30.0''$ [J1950]) between 43 and $197\ \mu\text{m}$ and main detections with the LWS/FP. Ordinate is valid for the grating (in $\text{W cm}^{-2}\ \mu\text{m}^{-1}$) and for the FP observations (in F/F_c).

Figure 2 shows the most abundant species that can be detected with ISO in the far-IR (see Goicoechea et al. 2004) and gives insights of which could be detected in other molecular clouds of the interstellar medium (ISM).

The molecular richness in the outer layers of Sgr B2 is probed by the FP detections towards Sgr B2(M), where more than 70 lines from 15 molecular and atomic species are observed at high signal to noise ratio.

The spectral lines that appear in the far-IR and that have been observed in Sgr B2 can be classified in:

- **Rotational lines** of light *O-bearing* molecules such as H_2O , H_2^{18}O , OH , ^{18}OH , and H_3O^+ , *N-bearing* molecules such as NH , NH_2 and NH_3 and other diatomic species such as CH , HD or HF .
- **Bending modes** of non-polar species such as the C_n carbon chains.
- **Atomic fine structure lines** of $[\text{O I}]$, $[\text{O III}]$, $[\text{C II}]$, $[\text{N II}]$ and $[\text{N III}]$.

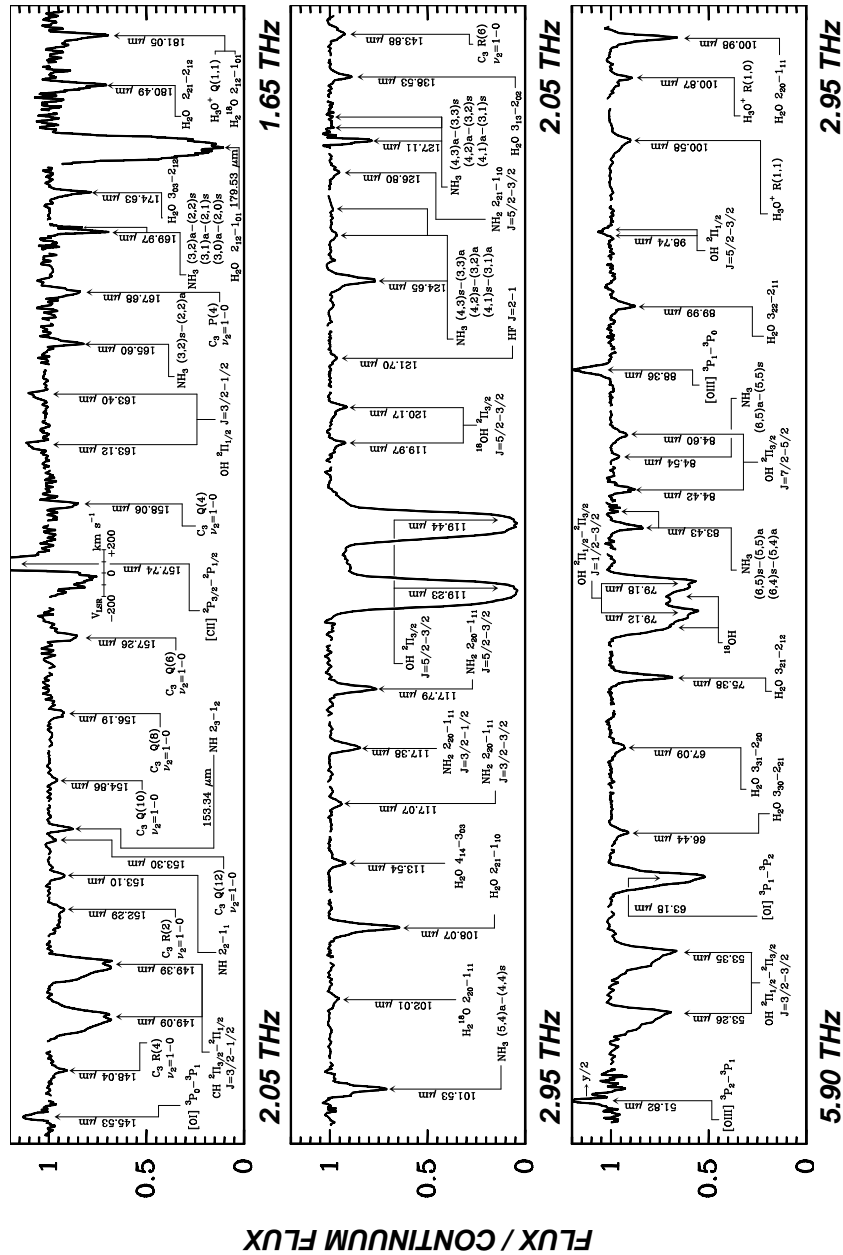


Fig. 2. Far-IR features in the spectrum of Sgr B2(M) taken with the ISO/LWS Fabry-Perot. Note the wavelength discontinuity of the spectrum after each line.

The far-IR observations have offered the opportunity of studying the chemistry of O^- and N -bearing species through the $H_3O^+/H_2O/OH/O$ (Goicoechea & Cernicharo 2001, 2002) and $NH_3/NH_2/NH$ observations. In addition, the abundance of non-polar molecules such as C_3 have been determined for the first time (Cernicharo et al. 2000). Finally, the influence of the UV radiation field in the external layers of Sgr B2 (the environment of the cloud) has been shown through the analysis of the atomic fine structure lines (Goicoechea et al 2004). All these new scientific goals can be obtained only through space observations in the far-IR spectral range.

3 Future Perspectives

The spatial scales of the physical and kinetical phenomena within molecular clouds and the amount of molecular species that could be present, claim for a much better sensitivity and spectral/spatial resolution in the far-IR. In the next years, most of these handicaps will be overcome by *ALMA* (~ 2010) for interferometric observations with $\lambda > 350 \mu m$. On the other hand, the *Herschel Space Telescope* (~ 2007) will offer much better spectral resolution than ISO for $\lambda > 157 \mu m$. However, the spatial resolution will be similar to that of current millimeter single-dish telescopes.

In any case, the full spectral window between 50 and 200 μm (6.0 and 1.5 THz) is not going to be sampled by any planned space mission in the next decade. Taking into account all the background learned from the ISO/LWS observations (which is only the top of the iceberg), the request of high spectral and spatial resolution is mandatory in order to understand and get deeper into the unique phenomena occurring in the far-IR domain. The high spectral resolution ($< 1 \text{ km s}^{-1}$) can be achieved by a single-dish heterodyne instrument, while the high spatial resolution can only be achieved with a large single dish telescope with direct/heterodyne detection techniques or with a heterodyne space interferometer.

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References

- Cernicharo, J., Goicoechea, J.R., & Caux. E. 2000, *ApJ*, 534, L199
- Goicoechea, J.R., & Cernicharo, J. 2001, *ApJ*, 554, L213
- Goicoechea, J.R., & Cernicharo, J. 2002, *ApJ*, 576, L77
- Goicoechea, J.R., Rodríguez-Fernández, N.J., & Cernicharo, J. 2004, *ApJ*, 600, 214