Astrochemistry: Recent Successes and Current Challenges
Poster Book IAU Symposium No. 231, 2005
A. J. Markwick-Kemper, ed.

DOI: 00.0000/X000000000000000X

Astrochemistry with the Mid-InfraRed Instrument on JWST

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Abstract. JWST-MIRI will have imaging and medium resolution ($\lambda/\Delta\lambda \approx 2000-3000$) integral field spectroscopy with orders of magnitude improvements in sensitivity and/or spatial resolution compared with existing facilities. It will be a prime facility for astrochemical studies of gases and solids in a wide variety of objects in the next decade.

1. Introduction

Mid-infrared spectroscopy is becoming a powerful tool in astrochemistry, with studies of molecules and sources that are highly complementary to those at millimeter wavelengths. Molecules without permanent dipole moments such CH_4, C_2H_2 and CO_2 can only be observed through their vibration-rotation transitions. Space-based missions open up the possibility to study molecules which are abundant in ouw own atmosphere, in particular H_2O. Polycyclic Aromatic Hydrocarbons have their most prominent features at mid-infrared wavelengths, and the pure rotational transitions of the dominant molecule in the universe, H_2, also occur in this band. Solid-state material is uniquely probed in the mid-infrared, including characteric bands of ices, silicates, oxides, carbides, carbonates and sulfides.

The wealth of mid-infrared spectroscopy has been demonstrated by results from the ISO satellite (see van Dishoeck & Tielens 2001, van Dishoeck 2004 for reviews), by pioneering ground-based studies (Lacy et al. 1989, Evans et al. 1990) and most recently by the Spitzer Space Telescope. Targets include molecular clouds, PDRs, shocks, deeply embedded young stellar objects, UC HII regions, protoplanetary disks, planetary atmospheres, comets, evolved stars and even entire galaxies. In addition to an inventory of gaseous and solid-state material, the lines and line ratios provide powerful diagnostics of temperatures, densities, UV field, elemental abundances, etc. Systematic variations in features from region to region allow the physical and chemical processes to be traced.

The MidInfraRed Instrument (MIRI) on board the 6m James Webb Space Telescope (JWST) provides the first opportunity after Spitzer for mid-infrared spectroscopy from space. The instrument will have orders of magnitude improvements in sensitivity, spatial and/or spectral resolution compared with other facilities and will be a unique facility for astrochemistry in the next decade. The combination of medium resolution spectroscopy and subarcsec spatial resolution is particularly well suited for studying gases and solids in disks around young stars and in the nuclei of (starburst) galaxies.

2. The MIRI instrument

The MIRI instrument consists of an imager and a spectrometer operating in the 5–28 μm wavelength range and cooled to 7 K (Wright et al. 2003, Rieke et al. 2005). The imager has a 1024×1024 pixel Si:As array with a $1.8' \times 1.3'$ FOV with diffraction-limited image widths of $0.2''$ at 5.6 μm up to $0.9''$ at 25.5 μm. It includes low resolution ($R \approx 100$) slit spectroscopy and coronography in four filter bands using fixed masks. The spectrometer has two 1024×1024 Si:As arrays and can obtain simultaneous spectral and spatial data on a few arcsec region by using four integral field units (IFUs) constructed of image slicers (see Table 1). A full 5–28.5 μm spectrum requires 3 exposures, with the dichroic/grating wheels moved between each exposure.

MIRI will be at least three orders of magnitude more sensitive than any 8-m class ground-based telescope in the 5-30 μm range, a large part of which (>50 %) will be completely blocked by atmospheric features from the ground. Compared with Spitzer, MIRI will have more than an order of magnitude increase in sensitivity and spatial resolution, and a significant increase in spectral resolution.

MIRI is being constructed as a joint effort between US and European institutions. It has passed its preliminary design review in March 2005. The structural and mechanical models have undergone vibration testing, and the verification models are being built. The first engineering arrays from Raytheon have been delivered. MIRI will have its critical design review in 2006 and be launched on JWST around 2013.

Channel	Wavelength range (μm)	FOV $''$	slice width $''$	$\lambda/\Delta\lambda$
1	4.9– 7.7	3.7×3.7	0.18	2500–3700
2	7.4–11.8	4.5×4.5	0.28	2500–3700
3	11.4–18.2	6.1×6.1	0.39	2500–3700
4	17.5–28.8	7.7×7.7	0.65	2000–2500

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