CASIMIR

Caltech Airborne Submillimeter Interstellar Medium Investigations Receiver

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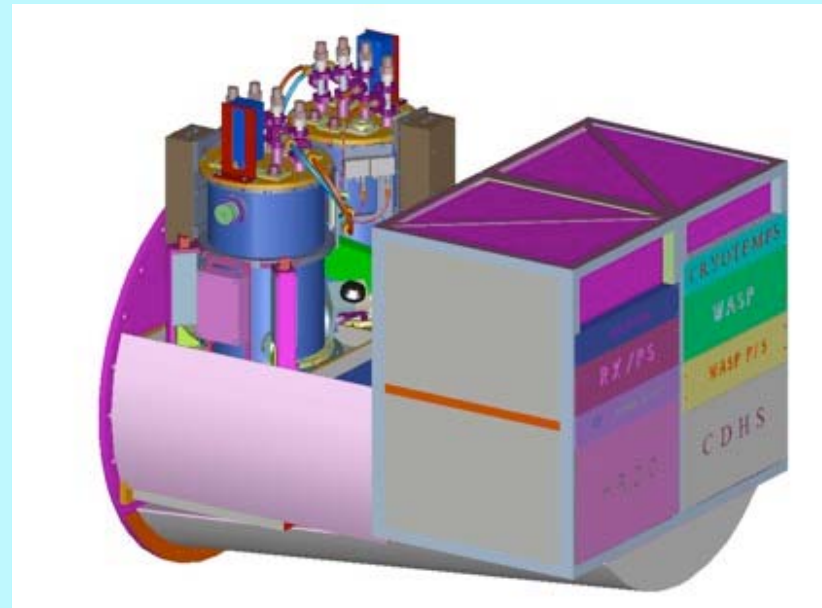
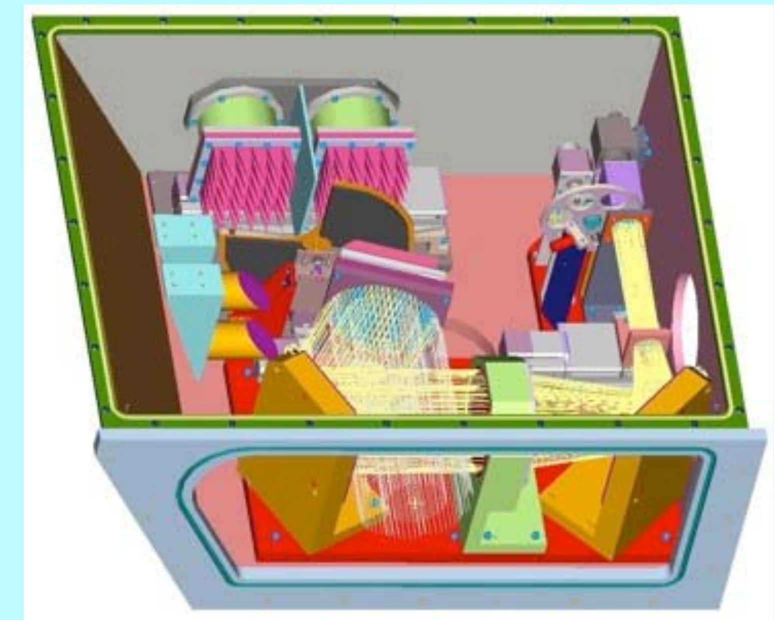
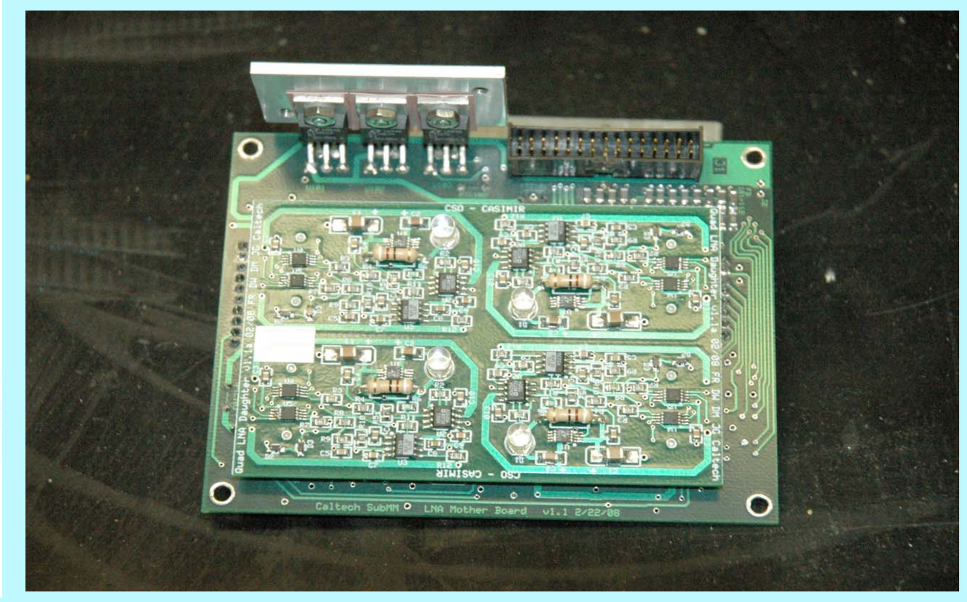
CASIMIR, the Caltech Airborne Submillimeter Interstellar Medium Investigations Receiver is a multiband, far infrared and submillimeter, high resolution, heterodyne spectrometer under development for SOFIA. It is a first generation, PI class instrument, designed for detailed, high sensitivity observations of warm (100 K) interstellar gas, both in galactic sources, including molecular clouds, circumstellar envelopes, and protostellar cores, and in external galaxies.

Combining the 2.5 m SOFIA mirror with state of the art superconducting mixers will give CASIMIR unprecedented sensitivity. Initially, CASIMIR will have four bands: 550 GHz, 750 GHz, 1000 GHz, and 1250 GHz; with a fifth band under development at 1400 GHz. Any four bands will be available on each flight, contributing to efficient use of observing time. For example, searches for weak lines from rare species in bright sources can be carried out on the same flight with observations of abundant species in faint or distant objects.

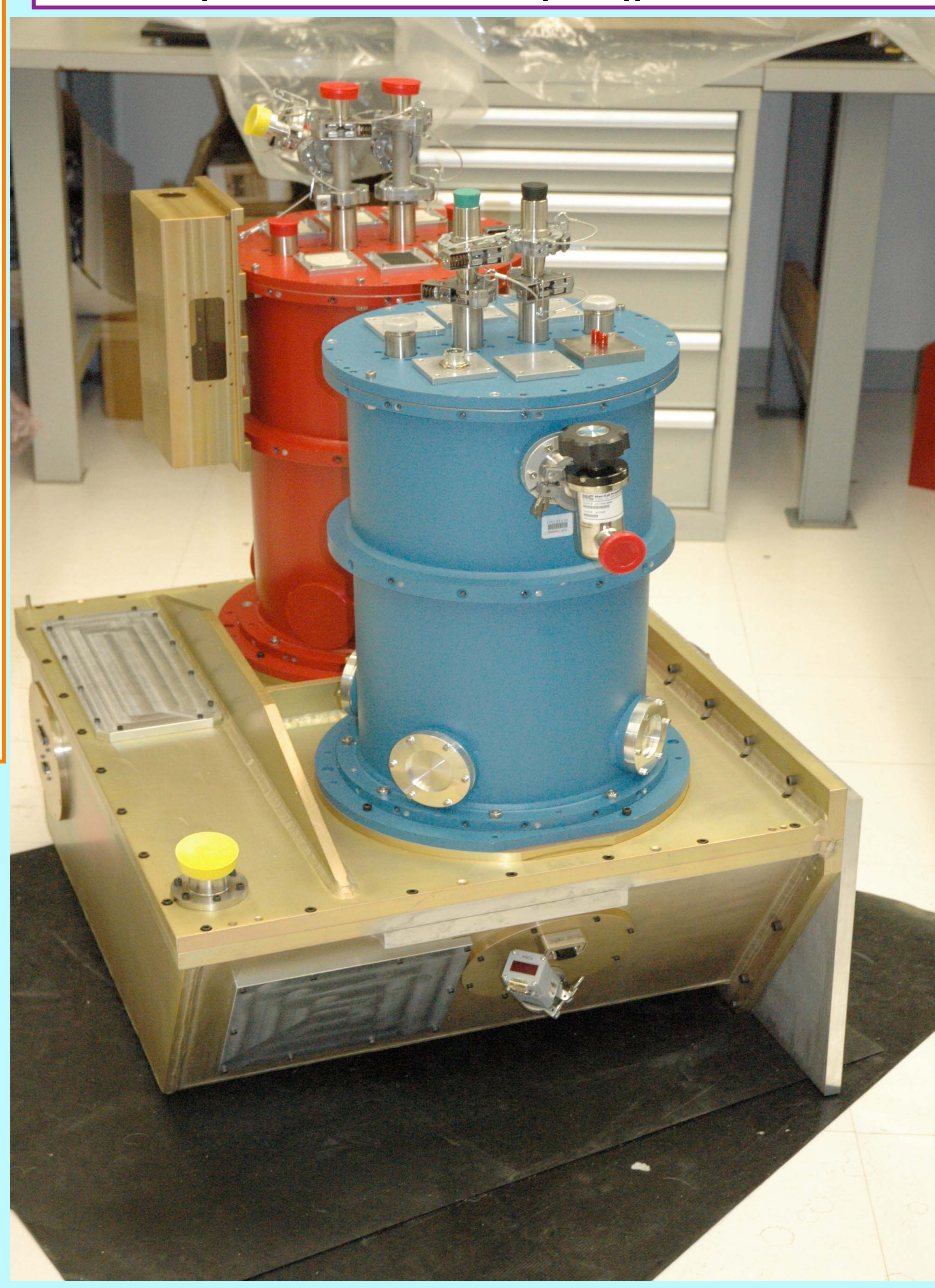






Instrument Configuration

CASIMIR (below) embodies a versatile and modular design, able to incorporate future major advances in detector, LO and spectrometer technology. It mounts on the SOFIA SI flange (above left). The entire instrument is about 1.5 m long and 1 m diameter, weighs about 550 kg. Two cryostats each hold two mixers – thus four mixers are available on each flight. The optics box supporting the cryostats is open to the telescope cavity and contains the relay optics and calibration systems (above center). Besides the cryostat windows, all the optics are reflective and can accommodate the entire 8' telescope field of view. Bias electronics (above right) and warm IF amplifiers are mounted on the cryostats, while electronics racks contain backend spectrometers, control electronics, and power supplies.



Scientific Objectives

CASIMIR will enable the study of fundamental rotational transitions of many astronomically significant hydrides and other molecules (table below). Even at excellent sites, such as Mauna Kea or the high Chilean Andes, the atmosphere is opaque to most of these lines from the ground. Many of these lines have been observed by the ISO/LWS instrument. Observations of these species can provide critical tests of our understanding of interstellar chemical networks and reactions.

Oxygen is the third most abundant element, yet its chemistry in interstellar clouds is poorly understood. The atmosphere is opaque to many of its key species, such as O, O_2 , H_2O, H_3O^+ and OH, limiting detailed ground observations.

The H_2D^+ ion is of particular interest, as it is the deuterated version of H_3^+, which is believed to be responsible for driving much of the chemistry of molecular clouds. The 372 GHz line of H_2D^+ now has been observed in several molecular clouds with the APEX telescope on the Chajnantor plateau in Chile. However, this is an excited transition that traces hot, dense gas, which has more complicated chemistry. In addition, the abundance of the species is low. The ground state line at 1371 GHz will be a better choice for studying the overall distribution of this important molecule. To date, there has been only one tentative detection of the 1371 GHz line in Orion with the KAO.

Another transition of major importance is the 1461 GHz transition of the nitrogen ion, N^+, which traces the warm, ionized interstellar medium. COBE has shown that, apart from the 1900 GHz C^+ line, the two fine-structure N^+ lines are the brightest emitted by our Galaxy.

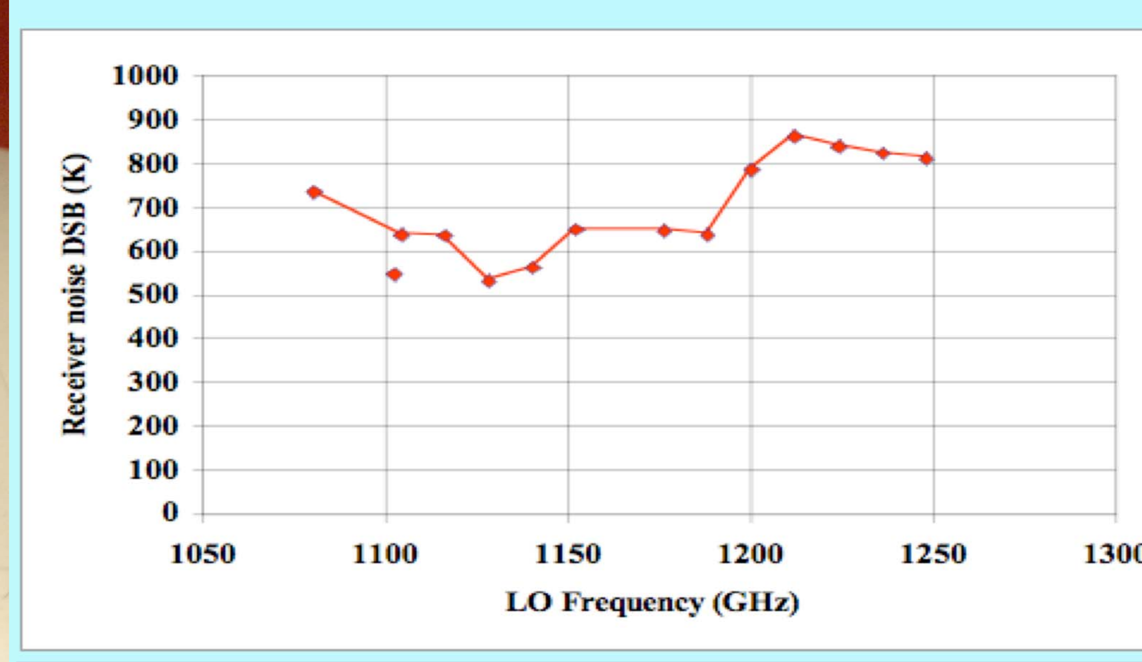
The high *J* lines of CO will also be observed with CASIMIR. These lines typically trace shocked gas and have been studied extensively with the KAO with high-resolution, heterodyne spectroscopy.

Molecular Lines

Band [GHz]	Species	Line [GHz]	Atm. Trans. [%]
550	CH	532, 537	98, 97
	$H_2^{18}O$	547	81
	NH_3	572	94
	CO	576	80
750	$H_2^{18}O$	745	82
1000	H_3O^+	985	65
	CH_2	946	99
	NH	975	96
	$H_2^{18}O$	995	73
	CO	1037	94
1200	$H_2^{18}O$	1137, 1181	70, 75
		1189, 1199	87, 81
	HF	1232	30
1400	H_2D^+	1371	94
	N^+	1461	92

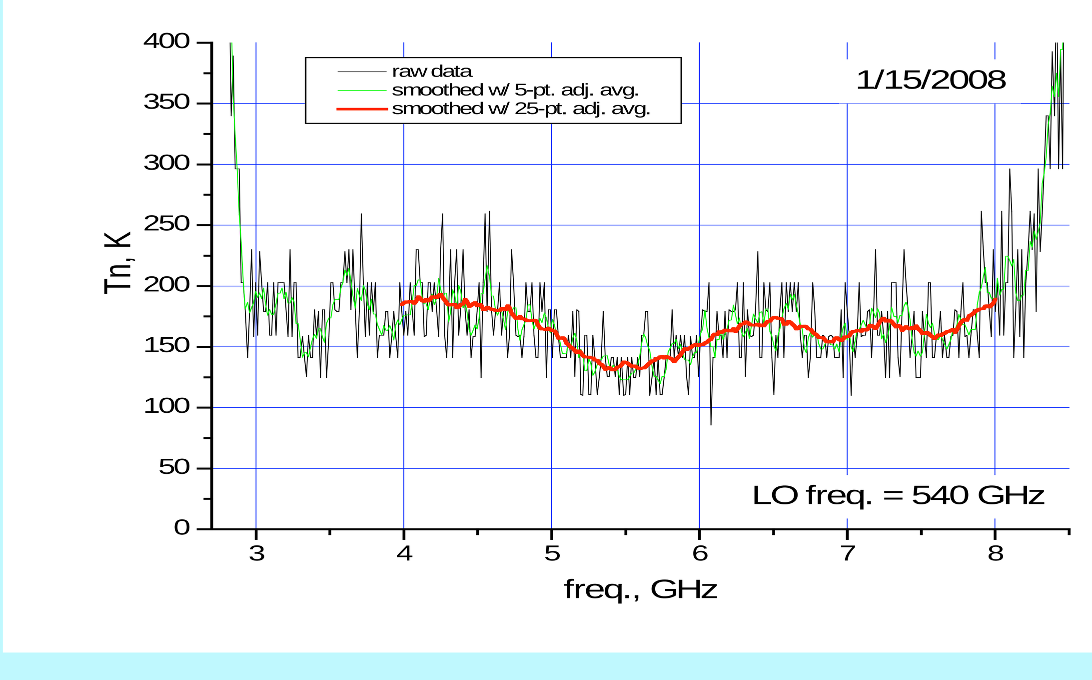
Local Oscillators

Each band uses a tunerless solid state local oscillator driven by a single, common commercial 26-40 GHz microwave frequency synthesizer. Chains of power amplifiers and frequency multipliers then generate the high frequency signals for each band. The 550 GHz and 1400 GHz LOs were made by Virginia Diodes; the 1200 GHz LO was developed at JPL, based on a Herschel/HIFI design; the 750 GHz and 1000 GHz LOs are under development. The LOs are mounted on the outside of the receivers, with the signal optically coupled to the mixers via reflecting optics, vacuum cryostat windows, and cryogenically-cooled mylar beamsplitters.



Mixers

All the CASIMIR bands use advanced Superconductor-Insulator-Superconductor (SIS) mixers fabricated with Nb/AlN/NbTiN junctions in the JPL Micro Devices Lab. These planar mixers are quasi-optically coupled with twin slot antennas, and silicon hyperhemisphere lenses with Parylene antireflection coatings. Simulations show this mixer technology is usable up to 1.6 THz. With ongoing development, expectations are for DSB noise temperatures to improve to 3 *hν/k* at frequencies below 1 THz (graph below), and 6 *hν/k* above 1 THz (graph above).

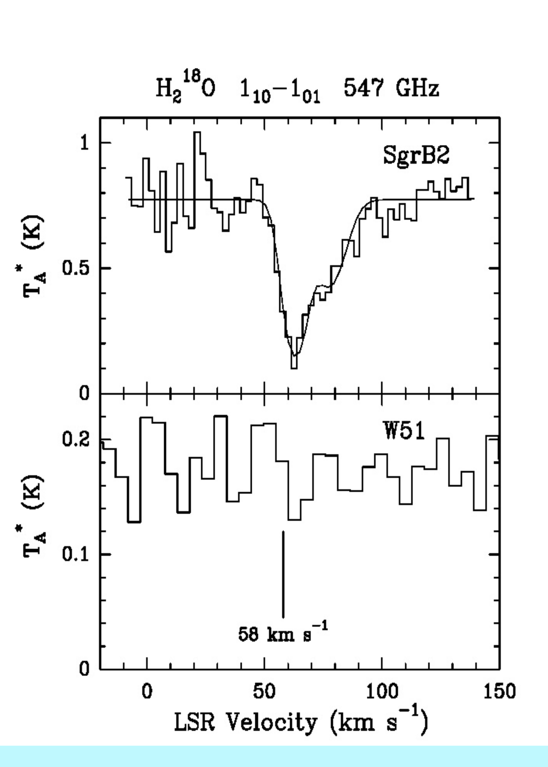


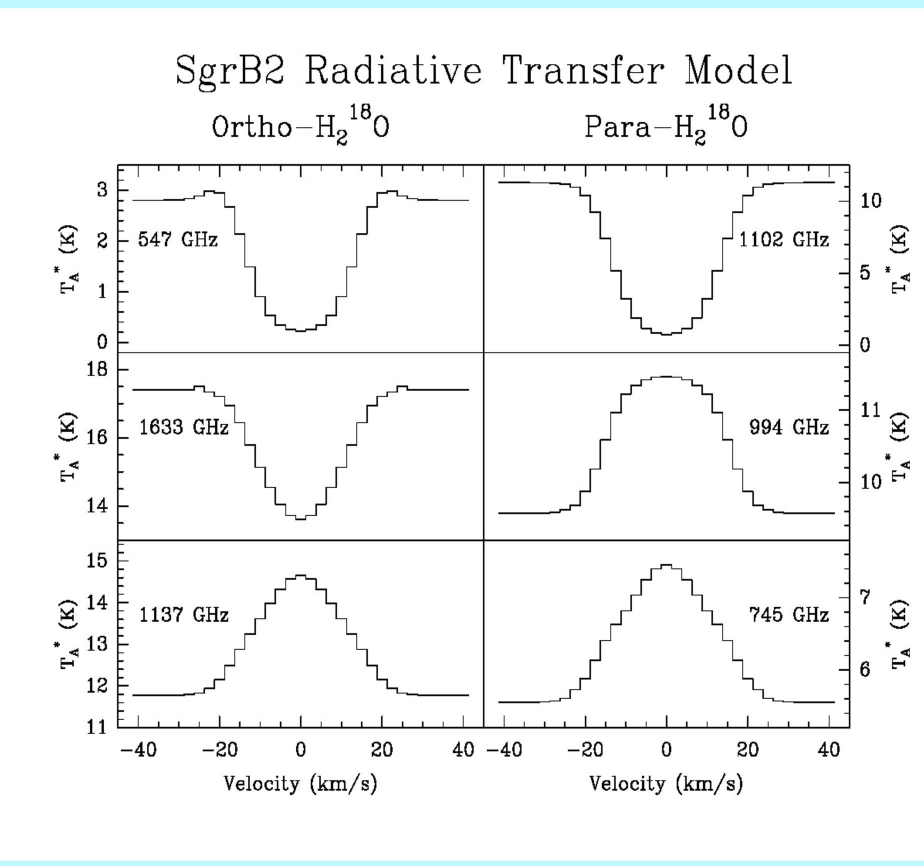
Water

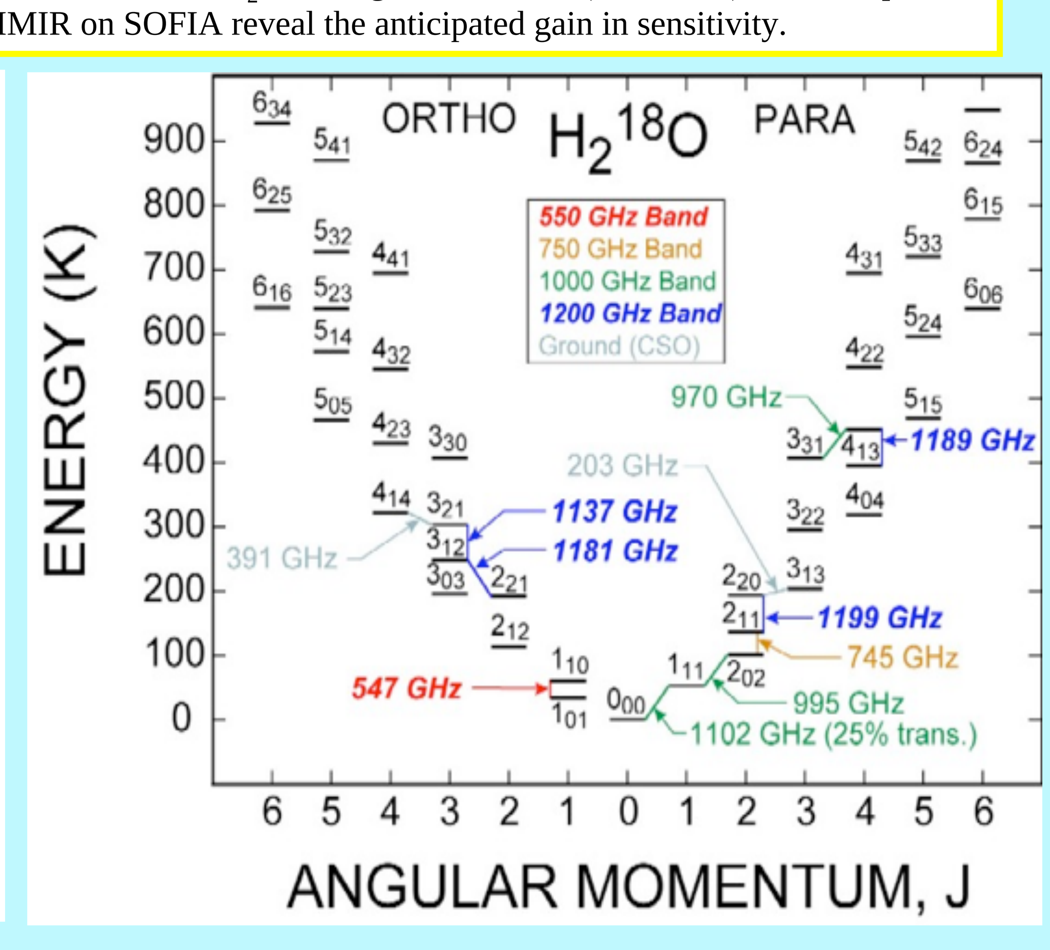
Water vapor plays an important role in the energy balance of molecular clouds by mediating radiative heating and cooling through its rotational transitions in the far infrared and submillimeter. CASIMIR will allow the study of the abundance and distribution of interstellar water with exceptional sensitivity and spatial and spectral resolution.

Even at the SOFIA operating altitude (above 12 km), there is too much terrestrial water to observe the common $H_2^{16}O$ isotopomer in astronomical sources. In its initial four bands, CASIMIR can detect nine rotational transitions of the rare $H_2^{18}O$ isotopomer, including several lines near the ground state (below right). Only two relatively high energy transitions can be observed from the ground (i. e., CSO).

Comparison of KAO observations at 547 GHz of $H_2^{18}O$ in SgrB2 and W51 (below left) with line profiles and intensities predicted for CASIMIR on SOFIA reveal the anticipated gain in sensitivity.







Spectrometers

CASIMIR will have a high resolution digital FFT spectrometer developed by Omnisys. This instrument consists of two processing modules, each with two high speed samplers and an FPGA engine. The spectrometer covers the entire 4 GHz IF bandwidth, providing 8192 channels and a maximum resolution 250 kHz per channel, which corresponds to a velocity resolution 750 m s-1 at 1000 GHz observing frequency. Lower resolution is possible by averaging channels.

CASIMIR http://www.submm.caltech/casimir

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