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. A first generation PI class instrument, CASIMIR is 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, CASIMIR will have unprecedented sensitivity. Five bands are under development: at 550 GHz 750 GHz, 1000 GHz, 1200 GHz, and 1400 GHz. Any four bands will be available on each flight. The availability of multiple bands during each flight will allow for efficient use of flight 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.

Scientific Objectives

CASIMIR will study the fundamental rotational transitions of many astronomically significant hydride 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 observation from the ground.

The H_2D^+ ion is of particular interest because 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. This is, however, an excited transition that traces hot, dense gas, with 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.

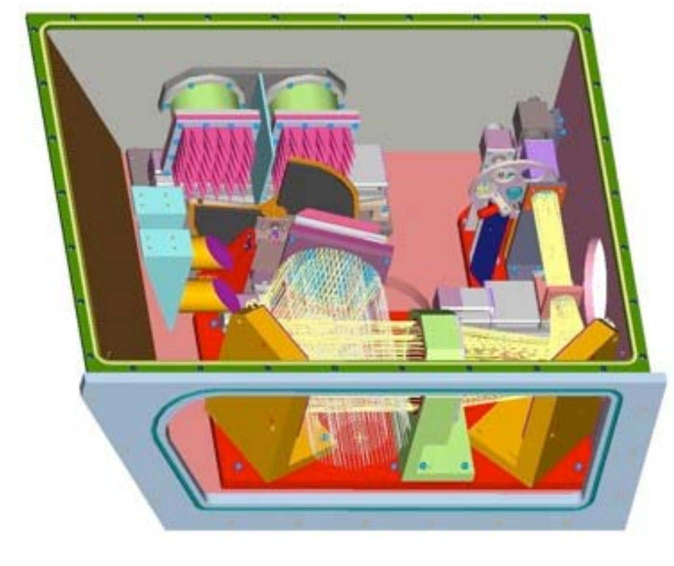
The high *J* lines of CO will also be observed with CASIMIR. These lines typically trace shocked gas and have been studied extensively with the KAO, including with high-resolution, heterodyne spectroscopy.

THz Molecular Lines

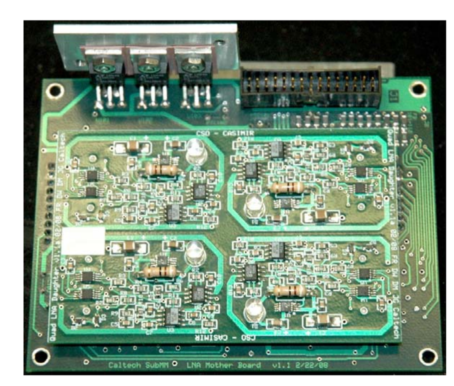
Band [GHz]	Species	Line [GHz]	Atm. Trans. [%]
550	CH	532, 537	98, 97
	$H_2{}^{18}O$	547	81
	NH_3	572	94
	CO	576	80
750	$H_2{}^{18}O$	745	82
1000	H_3O^+	985	65
	CH_2	946	99
	NH	975	96
	$H_2{}^{18}O$	995	73
	CO	1037	94
1200	$H_2{}^{18}O$	1137, 1181	70, 75
		1189, 1199	87, 81
	HF	1232	30
1400	H_2D^+	1371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

Selected interstellar molecules and lines in the CASIMIR observing bands. The atmospheric transmissions are for the SOFIA operating altitude, above 12 km. All of these transitions are impossible or exceedingly difficult to observe from the ground, even from excellent sites such as Mauna Kea or the high Andes in Chile.

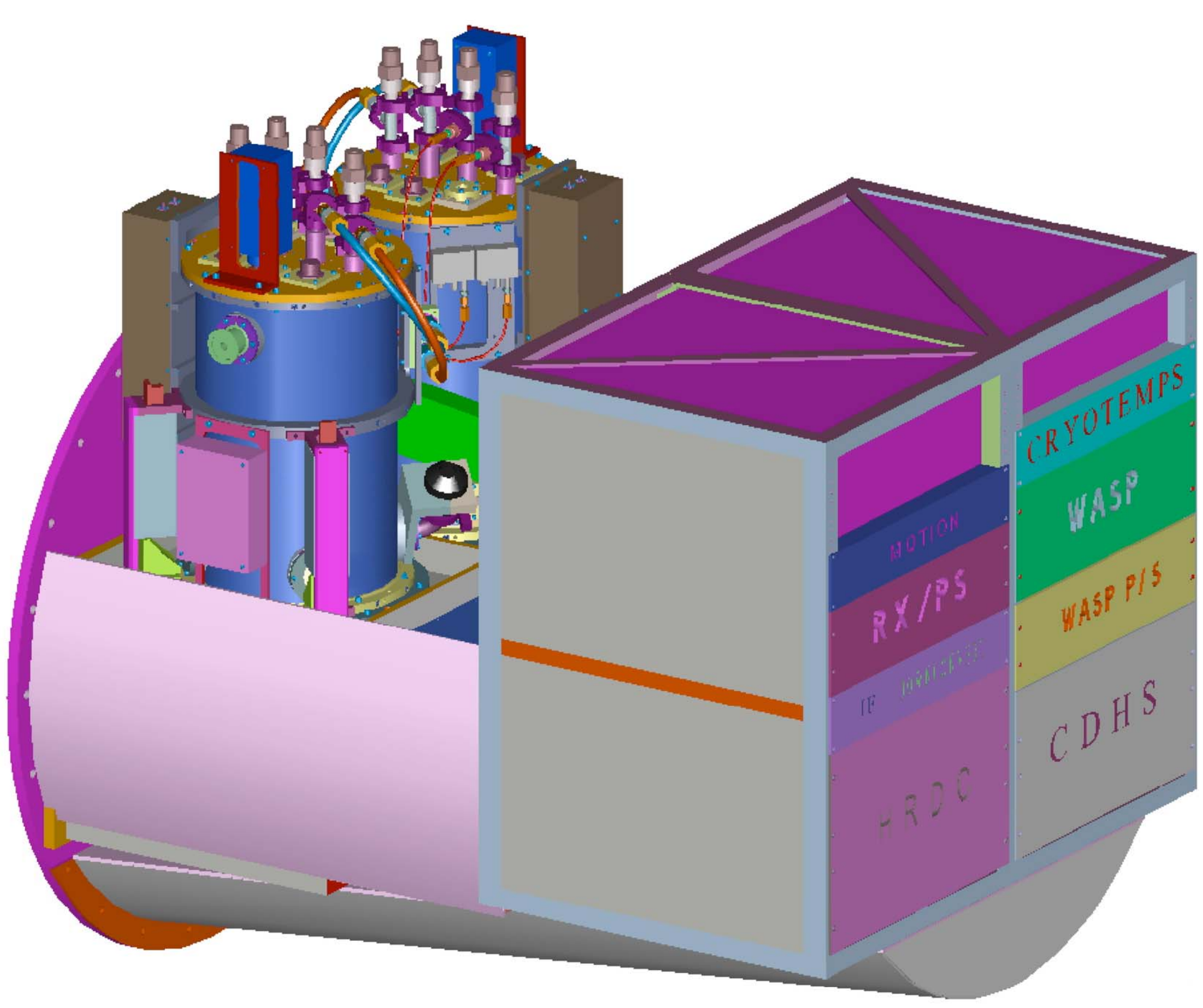
Above: CASIMIR flight cryostats mounted on the optics box. At frequencies below 1 THz, the mixers will operate at 4 K. For the higher frequency bands, the LHe bath will be pumped to operate the mixers at 2.5 K.



Optics box layout. This box supports the two cryostats and contains the relay optics, beam selection mirror, hot and ambient load calibration system, and optical boresight camera. The box interior is open to the telescope cavity and the exterior pressure.



Right: Receiver bias electronics module developed in collaboration with CSO.

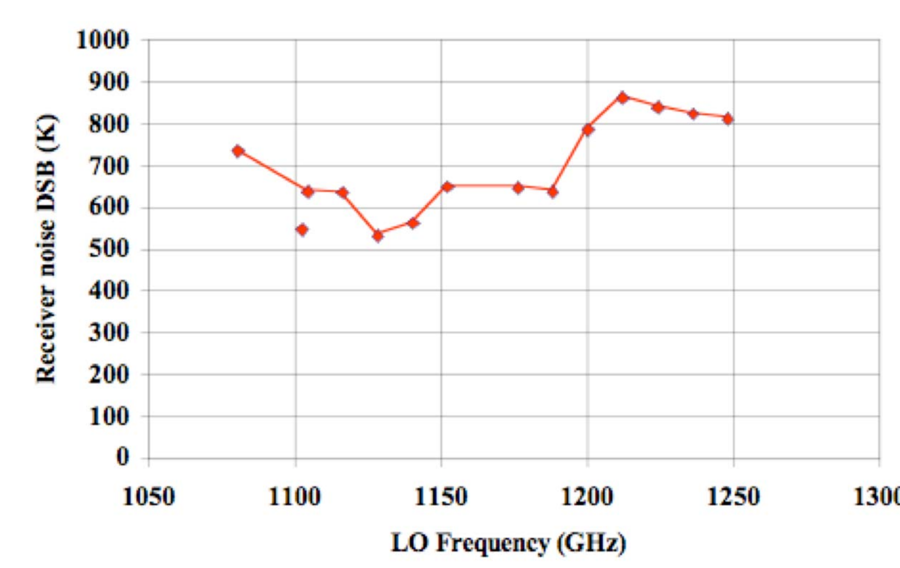


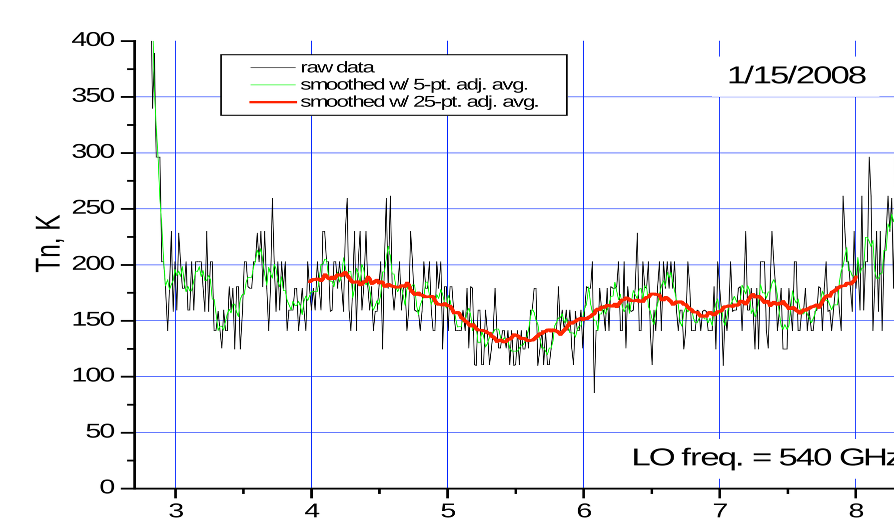
Instrument Configuration

CASIMIR embodies a versatile and modular design so it will be able to incorporate future major advances in detector, LO, and spectrometer technology. The entire instrument (left), about 1.5 m long and 1 m diameter and weighing about 550 kg, mounts on the SOFIA SI flange. Two cryostats each holds two mixers so up to four mixers are available on each flight. The cryostats are supported by a box containing the relay optics and calibration systems. This box is open to the telescope cavity so its interior is at the exterior pressure. Except for the cryostat windows, all the optics are reflective. The optics can accommodate the entire 8' telescope field of view. Local oscillators, bias electronics, and warm IF amplifiers are mounted in boxes attached to the cryostats. The electronics racks hold backend spectrometers, control electronics, and power supplies.

Mixers

All the CASIMIR bands use advanced Superconductor-Insulator-Superconductor (SIS) mixers fabricated with Nb/AlN/NbTiN junctions in the JPL Microdevices Lab. These planar mixers are quasi-optically coupled with twin slot antennas and silicon hyperhemispherical lenses with Parylene antireflection coatings. This mixer technology is usable up to 1.6 GHz. With ongoing development, we expect the DSB noise temperatures (below) to improve to 3 $h\nu/k$ at frequencies < 1 THz and 6 $h\nu/k$ above 1 THz.





Local Oscillators

All bands use tunerless solid state local oscillators 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 Virgina Diodes, the 1200 GHz LO was developed at JPL based on a Herschel/HIFI design, and the 750 GHz and 1000 GHz LOs are under development at U. Massachusetts. The LOs are mounted on the outside of the cryostat. The signals enter the cryostat through dedicated windows and optically couple to the mixers by mylar beam splitters.

Spectrometer

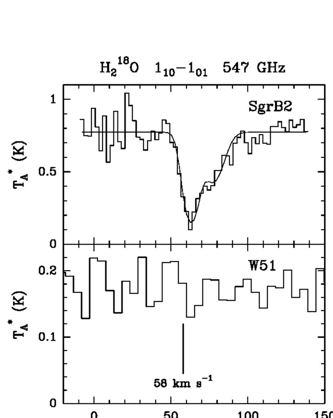
CASIMIR will use a high resolution digital FFT spectrometer developed by Omnisys. This consists of two processing modules, each with two high speed samplers and an FPGA engine. The spectrometer covers the entire 4 GHz IF bandwidth, providing 8192 channels per module and a maximum resolution 250 kHz per channel, which corresponds to a velocity resolution 75 m s^{-1} at 1000 GHz observing frequency. Lower resolution is possible by averaging adjacent channels.

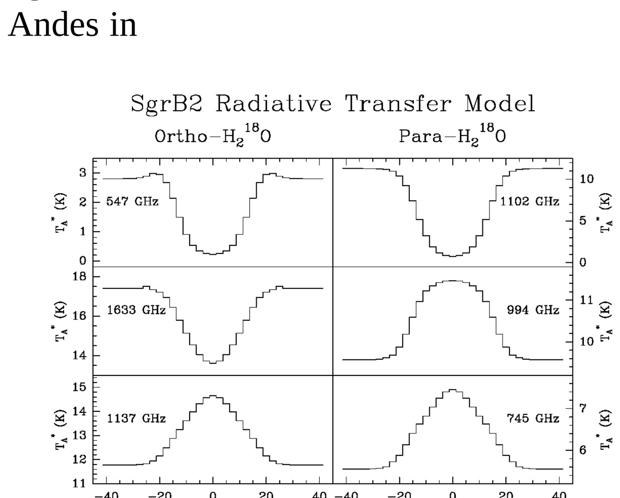
Water

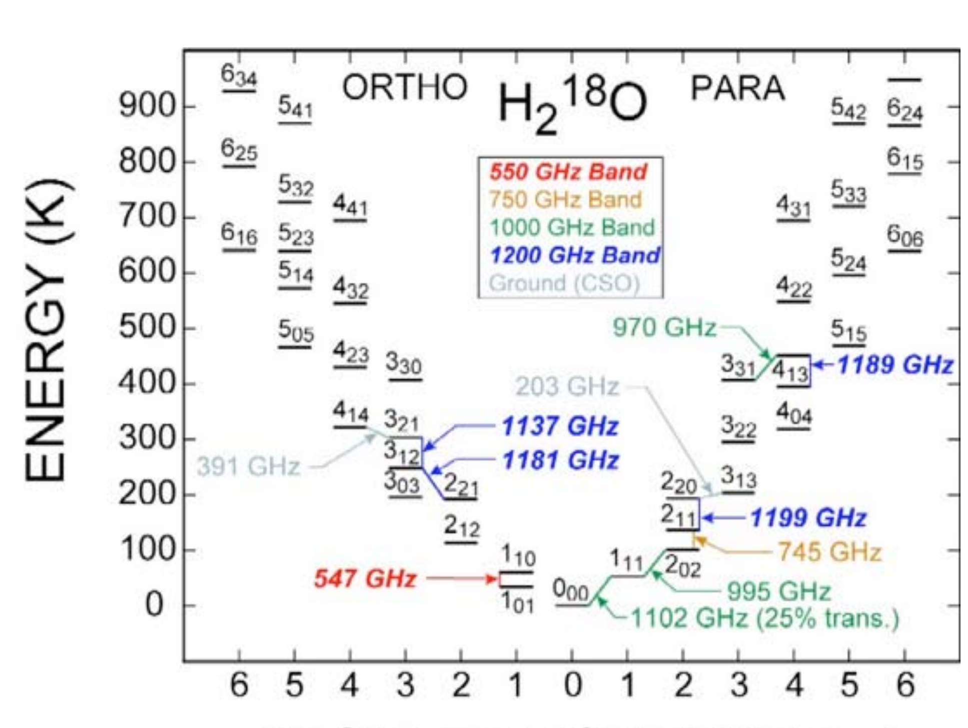
Water vapor plays an important role in the energy balance of molecular clouds by mediating radiative heating and cooling through its rotational transitions in the far infrared and submillimeter. CASIMIR will study the abundance and distribution of interstellar water with unprecedented sensitivity and 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. Instead, CASIMIR will observe rotational transitions of the rare $H_2{}^{18}O$ isotopomer, including several lines near the ground state (below center). 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 the line profiles and intensities predicted for CASIMIR on SOFIA shows the anticipated gain in sensitivity.







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

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