ORIGINS Space Telescope

From the first stars to life

National Aeronautics and Space Administration

Origins Space Telescope: Heterodyne Receiver for OST (HERO)

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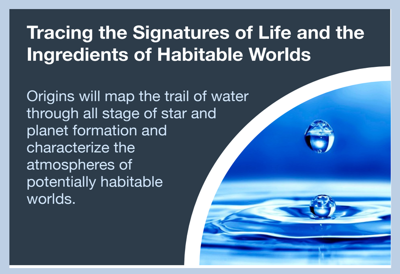
Introduction:

The Origins Space Telescope (OST) is a mission concept for the Far-Infrared Surveyor, one of the four science and technology definition studies selected by NASA Headquarters for the 2020 Astronomy and Astrophysics Decadal survey. The OST study will encompass two mission concepts (poster by A. Cooray). Concept 1 is an extremely versatile observatory with 5 science instruments, of which the HEterodyne Receivers for OST (HERO) is one.

HERO is designed to cover observations requiring extremely high spectral resolution ($\lambda/\Delta\lambda > 10^6$) at the submm/farIR wavelength range. HERO exploits Herschel/HIFI heritage, but has a larger frequency coverage and up to 128 pixel focal plane arrays.

Science:

HERO's main targets are high spectral resolution observations ($\lambda/\Delta\lambda$ up to 10^7 or $\Delta v = 0.03$ km/s) in all four astronomical topics of the OST:

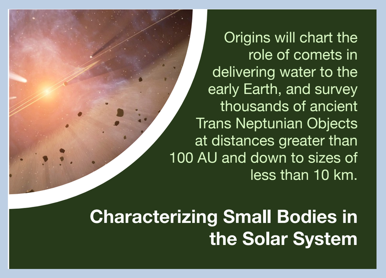


- Observe water in the ISM to follow its trail from dense filaments to YSOs envelopes and protostellar disks.
- Study water Content of Planet forming disks and locate the snow line.
- Determine protoplanetary disk masses using HD.

- Trace turbulence in the ISM and determine its role in star formation.
- Determine the cosmic-ray flux in the Milky Way and nearby galaxies
- Study the dynamic ISM as a tracer of galactic evolution.

- Follow in detail the birth path of dust around evolved stars in our Galaxy.

- Investigate the thermo-chemical history of comets and water delivery to Earth.



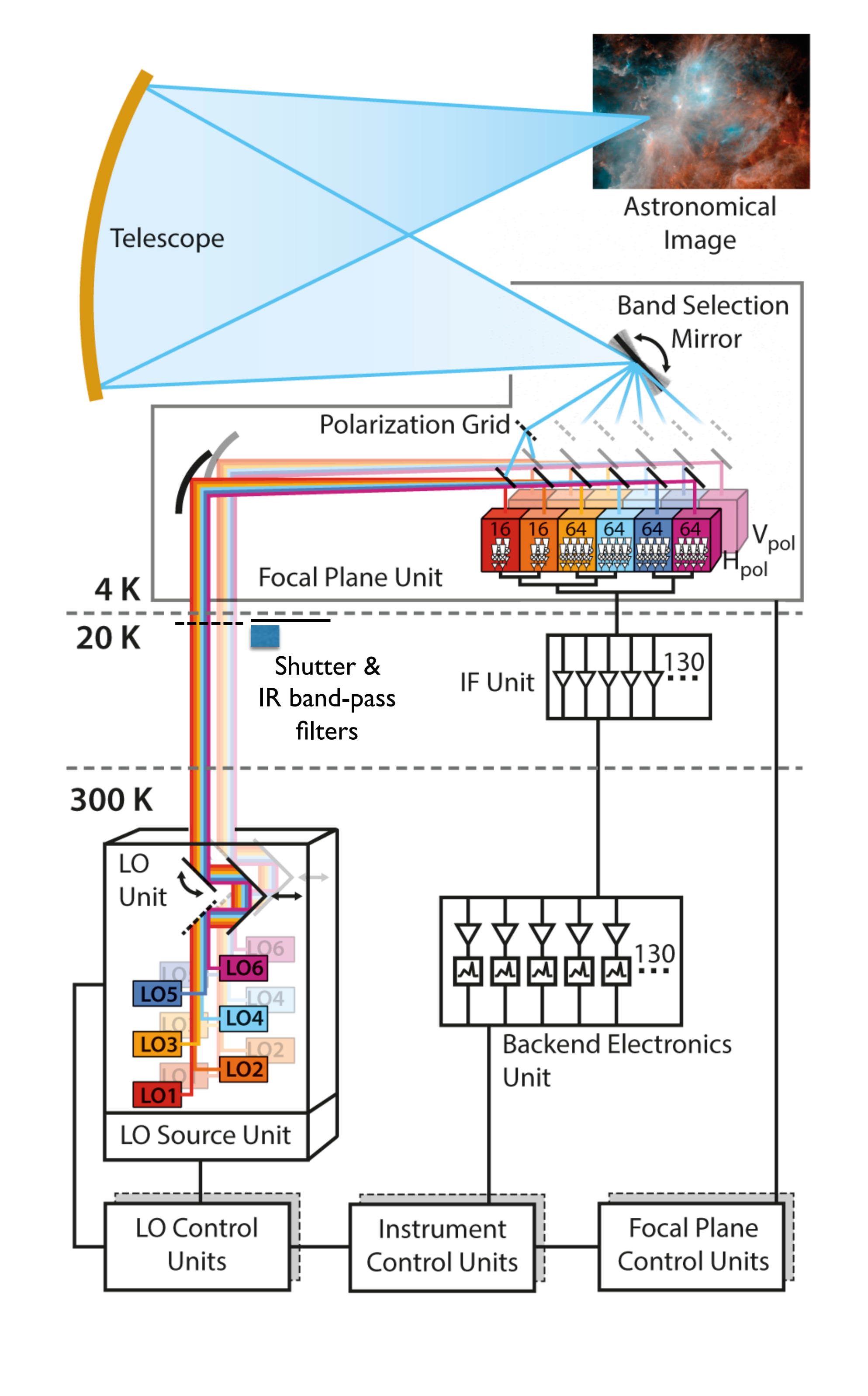


Figure1 Schematic of the HERO instrument.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Band	ν_{min}	ν_{max}	λ_{max}	λ_{min}	Max $\lambda/\Delta\lambda$	IF BW2	Mixer	# pixels	# pixels	Trx	Beam	T_{rms}	Line Flux	Line flux per time
	GHz	GHz	mm	mm		km/s	Type	Fall-back	Goal	K (DSB)	arc sec	mK in 1h, $\lambda/\Delta\lambda$ $=10^6$	W/m^2, $\lambda/\Delta\lambda=10^6$, ⌀9m, 1h	W/m^2, $\lambda/\Delta\lambda$ $=10^6$⌀9m, 5σ
1	468	648	641	463	10^7	4301	SIS	2x4	2x16	40	15.2	1.78	2.85E-21	1.62E-19
2	648	900	463	333	10^7	3101	SIS	2x4	2x16	80	10.9	3.03	6.71E-21	3.82E-19
3	900	1260	333	238	10^7	2222	HEB	2x4	2x64	110	7.9	3.53	1.09E-20	6.20E-19
4	1242	1836	241	163	10^7	1559	HEB	2x4	2x64	200	5.6	5.37	2.42E-20	1.35E-18
5	1836	2700	163	111	10^7	1058	HEB	2x4	2x64	300	3.8	6.64	4.40E-20	2.45E-18
6	4536	4752	66	63	10^7	517	HEB	2x4	2x64	500	1.8	7.73	9.75E-20	5.84E-18

Table 1 Fact Sheet for the HERO instrument (Table key in right block)

Instrument:

HERO is a heterodyne array camera with up to 128 pixels covering a very wide frequency range of 470 GHz to 4.7 THz (640 to 63 µm) in 6 frequency bands (see Table 1).

Figure 1 shows a schematic of the instrument: The radiation from the sky is collected by the telescope and directed to one of the 6 receiver bands. The sky signal is split in its two linear polarizations by a polarization grid and sent to the units, H_{pol}, V_{pol} mixer arrays in the Focal Plane Unit, An artificial, monochromatic reference signal (the LO signal) is also directed to the mixer array passing through band pass infrared filters and a shutter. Sky and LO signal are mixed and the beat frequency is created. This much lower beat or intermediate frequency (IF) is amplified at 4K and again in the IF Unit at 20K. In the warm space bus the IF signal is amplified further and analyzed by spectrometers, that send the spectra to the instrument control unit. An internal two-temperature black body source is used for accurate calibration.

Compared to other previous and existing heterodyne receivers, HERO is special as it has very large arrays of 2 x 16 pixels for the two lower frequency bands, and 2 x 64 pixels for the four upper frequency bands, which will facilitate obtaining maps of spectra of relatively large areas of the sky (> 1 square degrees).

For low heat dissipation, HERO employs newly developed SiGe amplifiers in the 4 and 20K stages. HERO has low power consuming amplifier multiplier chains as Local Oscillator and low power consuming digital Fourier transform spectrometers (FFTS) both using the newest CMOS or FPGA technologies.

Summary:

An international team of experts with the help of the OST STDT and the NASA engineering team has designed HERO. HERO builds on the successful Herschel/HIFI heritage but carries it well beyond HIFI limits in sensitivity, spectral and spatial coverage by exploiting the most promising R&D work in the field.

Table key:

Col. 6 Max $\lambda/\Delta\lambda$ max. resolution achievable, technically higher resolution can be reached easily if desired
Col. 7 Instantaneous bandwidth in km/s (it is assumed that we have 8 GHz IF bandwidth at all bands)
Col. 9, 10 The pixels will be arranged in 2 x NxN arrays, e.g. for 32 pixels there are 2 x 4x4 arrays. The two NxN arrays are overlaid at two different linear polarization.
Col 11 Relatively conservative receiver sensitivity estimate
Col 12 Diffraction limited beam size for 9m telescope
Col 13 Line sensitivity at 1 sigma, a factor of 2 has been taken into account to convert from DSB to SSB, however no factor for on/off has been taken into account.
Col 14 Assumed is 9m dish with 0.8 aperture efficiency, resolution $\lambda/\Delta\lambda = 10^6$, and 5σ for 1h
Col 15 Assumed is 9m dish with 0.8 aperture efficiency, resolution $\lambda/\Delta\lambda = 10^6$, and 5σ per unit time

The **Origins Space Telescope** is the mission concept for the **Far Infrared Surveyor**, a study in development by NASA in preparation for the *2020 Astronomy and Astrophysics Decadal Survey*.

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Secret OST Word: Water