PAHST

POLYCYCLIC AROMATIC HYDROCARBONS SPACE TELESCOPE

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Abstract

Star formation in the early Universe remains unobserved in the far-infrared (FIR) domain, which motivated us to design a new space telescope: the Polycyclic Aromatic Hydrocarbon Space Telescope (PAHST). PAHST will use PAH emission lines redshifted to 30-200 µm to provide an unprecedented view of star formation at z = 4.5-6.0. The mission will also investigate the formation of high-density ridges from filaments in the interstellar medium (ISM) and the nature of cool brown dwarfs and their surrounding dusty disks. PAHST can achieve its science objectives with an 8-metre diameter primary mirror cooled to 4 K coupled to a high sensitivity photometer and spectrometer operating at Lagrange point L2. The potential ESA L-class mission is compatible with the Ariane 6 launch vehicle. PAHST is the result of the ESA/FFG Alpbach Summer School 2017 on the topic of "dust in the Universe" and the follow-up Post-Alpbach Event.

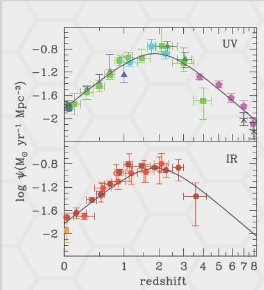


Figure 1 (left): Star formation rate density (Ψ) versus redshift (z) from various galaxy surveys up to z = 8 in the UV (upper panel) and IR (lower panel) (Madau & Dickinson, 2014).

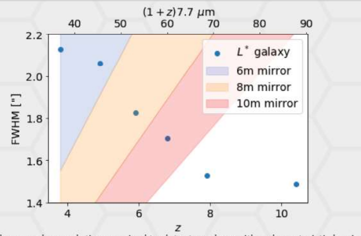


Figure 2 (top): Blue circles: angular resolution required to detect a galaxy with a characteristic luminosity L^*_{FIR} above the confusion limit as a function of redshift (primary x-axis). Lower edges of coloured regions: angular resolution of mirrors of various diameters as a function of observed wavelength of the redshifted 7.7 µm PAH feature (secondary x-axis).

Primary science objective

We will probe star formation (SF) in distant galaxies using interstellar PAH (Polycyclic Aromatic Hydrocarbon) emission at rest-frame mid-IR (MIR) wavelengths. At redshift z ≥ 4, these wavelengths fall in the FIR.

There is a gap in the evolution of the star formation rate (SFR) in FIR measurements for z ≥ 4 (see Figure 1). Only IR observations of obscured star formation at high z can test the current theory of SFR in the early Universe. An effective way to infer the SFR at high-z is to use emission from interstellar dust grains (e.g., Kennicutt, 1998). PAH molecules are an important component of dust models (e.g., Léger & Puget, 1984), and Peeters et al. (2004) showed that the intensity of PAH emission can be used as a proxy of SFR in SF dominated galaxies. Some of the well-known PAH features at 6.2, 7.7, 8.6 and 11.3 µm dominate the MIR (Tielens, 2008). Variations in the strength of these features reflect variations in the physical properties of the dust, for example the ionization state in the ISM of galaxies (Petric et al. 2011).

Our primary science requirements are shown in Figure 2. Assuming ten beams per source are required to resolve a galaxy against the background, the angular resolutions required to resolve individual sources at the characteristic magnitude are plotted at different redshifts. They are then compared with the diffraction limit at the redshifted 7.7 µm PAH feature for various mirror diameters. Two areas were selected for these observations: HDFN/-GOODS-N and CDFS/GOODS-S fields. An initial photometric survey will be performed in three bands centred at ~ 50, 90 and 150 µm using scan-mapping mode. Objects with photometry observations in the PAH wavelength range (3 – 30 µm, rest frame) will be selected for spectroscopic follow-up to detect PAH features and derive SFR estimates.

Secondary science objective

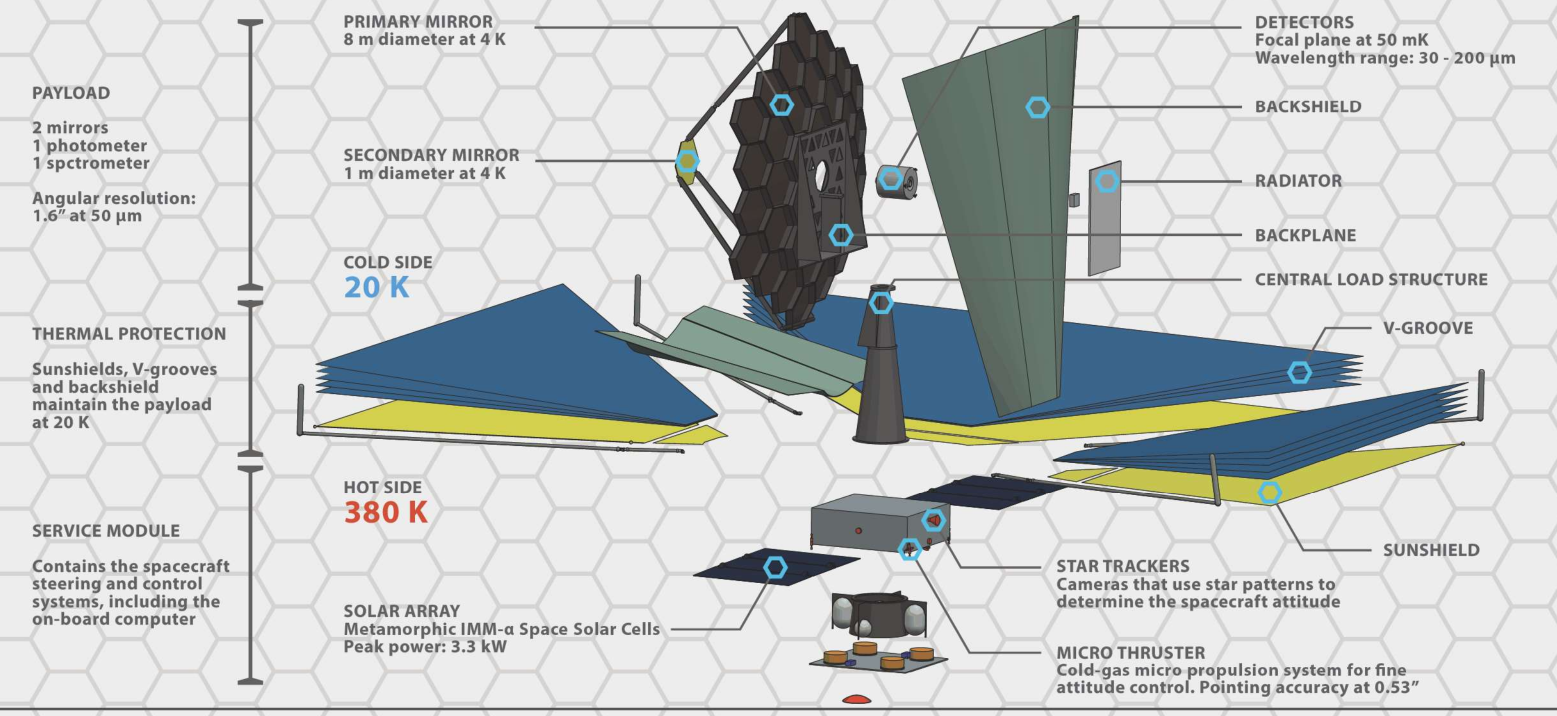
We wish to understand better the importance of dense interstellar filaments in high-mass star formation (see e.g., Motte et al. 2017), and characterise the inner structures of the highest column density (> 10^{23} cm^{-2}) dust filaments in molecular clouds of the Galactic ISM up to ~ 3 kpc distances.

The formation of high-mass stars ($M^* > 8\ M_{Sun}$) is less understood, albeit they play a major role in the energy budget and enrichment of galaxies. These stars may form in massive and dense interstellar filaments, where the filament-creating large-scale converging flows may provide the necessary conditions for clustered high-mass star formation. This objective requires photometric mapping of elongated dense structures in the PAHST mission's longest wavelength channel (~ 150 µm).

Tertiary science objective

Using PAHST's high sensitivity in the MIR and FIR, we aim to study dusty disks around brown dwarfs and survey the class Y types, which are the coolest and most recently discovered group of brown dwarfs.

Brown dwarfs are sub-stellar objects ($M < 0.08\ M_{Sun}$) which cannot fuse hydrogen, but only lithium. They may be the link between giant gas planets and very low-mass stars. They can even form dusty disks, which have been observed in the NIR (Muench et al., 2001). However, we are lacking observations probing the disks' outer, cooler regions. Cushing et al. (2011) confirmed the existence of an extremely cool (T ≈ 300 K) type of brown dwarfs, called type Y. The NH_3 lines at 40 and 42 µm can be used to distinguish between Y class and the warmer T class (Delorme et al., 2008). With our high-sensitivity spectroscopy, Y type dwarfs can be detected in the MIR up to ~ 30 pc from the Sun, and also at ~200 um, exceeding the survey distance and wavelength coverage of the WISE mission (Kirkpatrick et al. 2012).



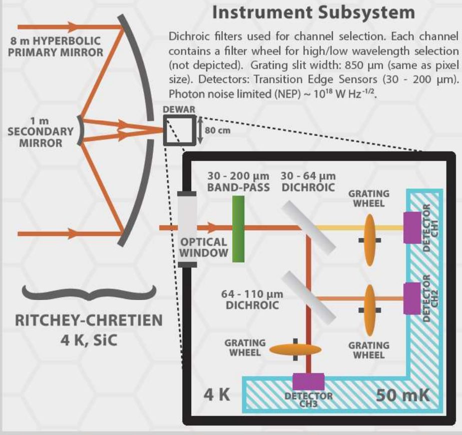
Thermal Subsystem

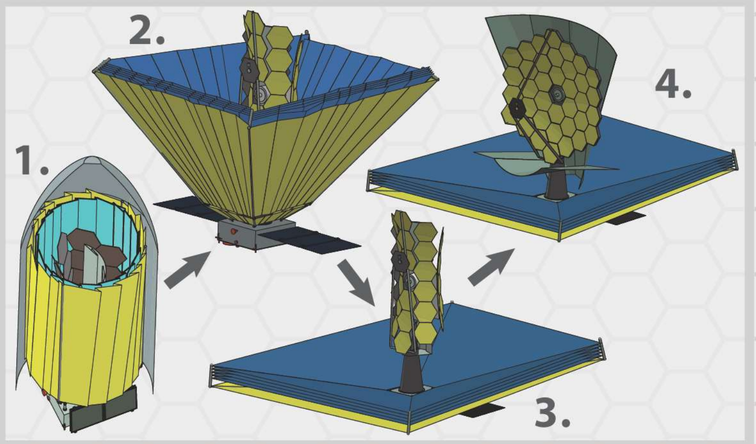
The spacecraft is split into a hot section (service module and sunshield), and cold section (telescope, active cooling system, backshield, and V-groove radiators). The required temperatures are 50 ± 1 mK for the detector focal plane, 4 ± 0.1 K for the mirror, and 4 ± 1 K for surfaces in view of the instrument focal plane.

Three stages of cooling are used: passive cooling, incorporating the sunshield and three V-groove radiators, to achieve ~ 80 K, a chain of pulse-tube and Joule-Thompson crycoolers to achieve 4 K, and an adiabatic demagnetization refrigerator to achieve 50 mK. The total mass and peak power for the thermal control subsystem are 916 kg and 620 W.

Instrument Subsystem

Dichroic filters used for channel selection. Each channel contains a filter wheel for high/low wavelength selection (not depicted). Grating slit width: 850 µm (same as pixel size). Detectors: Transition Edge Sensors (30 - 200 µm). Photon noise limited (NEP) ~ 10^{18} W Hz$^{-1/2}$.





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