

SPICAが目指すサイエンス: Science cases that SPICA challenges

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Abstract

How our Universe has evolved since the Big Bang and how our Solar system became the habitable environment it is in the present-day Universe are among the most fundamental questions ever posed by human beings, and questions that modern astronomy strives to answer. SPICA will unveil the nature of star-forming galaxies at around the peak of the cosmological star formation activity (at redshifts between 1 and 3) and reveal the processes of the galaxy evolution and the heavy element enrichment in the Universe. SPICA will also study the properties of the gas, ice, and dust in protoplanetary and debris disks, where planets are being formed, revolutionizing our understanding of the observed diversity of exoplanets and the evolutionary route to our Solar system. **SPICA's major goal is to reveal the process that enriched the Universe with metals and dust, leading to the formation of habitable worlds.**

Major questions SPICA challenges

- What physical processes shape the galaxy mass function and regulate evolution since reionization (fig. 1)?
- What causes the peak in the SFRD at $z \sim 2$ and the sharp drop-off at later times (fig. 2)?
- How and why do galaxies evolve on and off the star-forming "main sequence" and what is its physical significance (fig. 3)?
- How does the SMBH – stellar mass relation develop over cosmic time (fig. 4)?
- How does the gas in and outside of galaxies get enriched with metals over time (fig. 5)?
- How is water delivered to the planets (fig. 6)?
- How do solids evolve from pristine dust to differentiated bodies, and what is the link with our sown Solar System (fig. 7)?
- When does the gas supply exhaust during the planet forming phase (fig. 8)?
- How does gas dissipation and photo-evaporation set the clock for planet formation (fig. 9)?

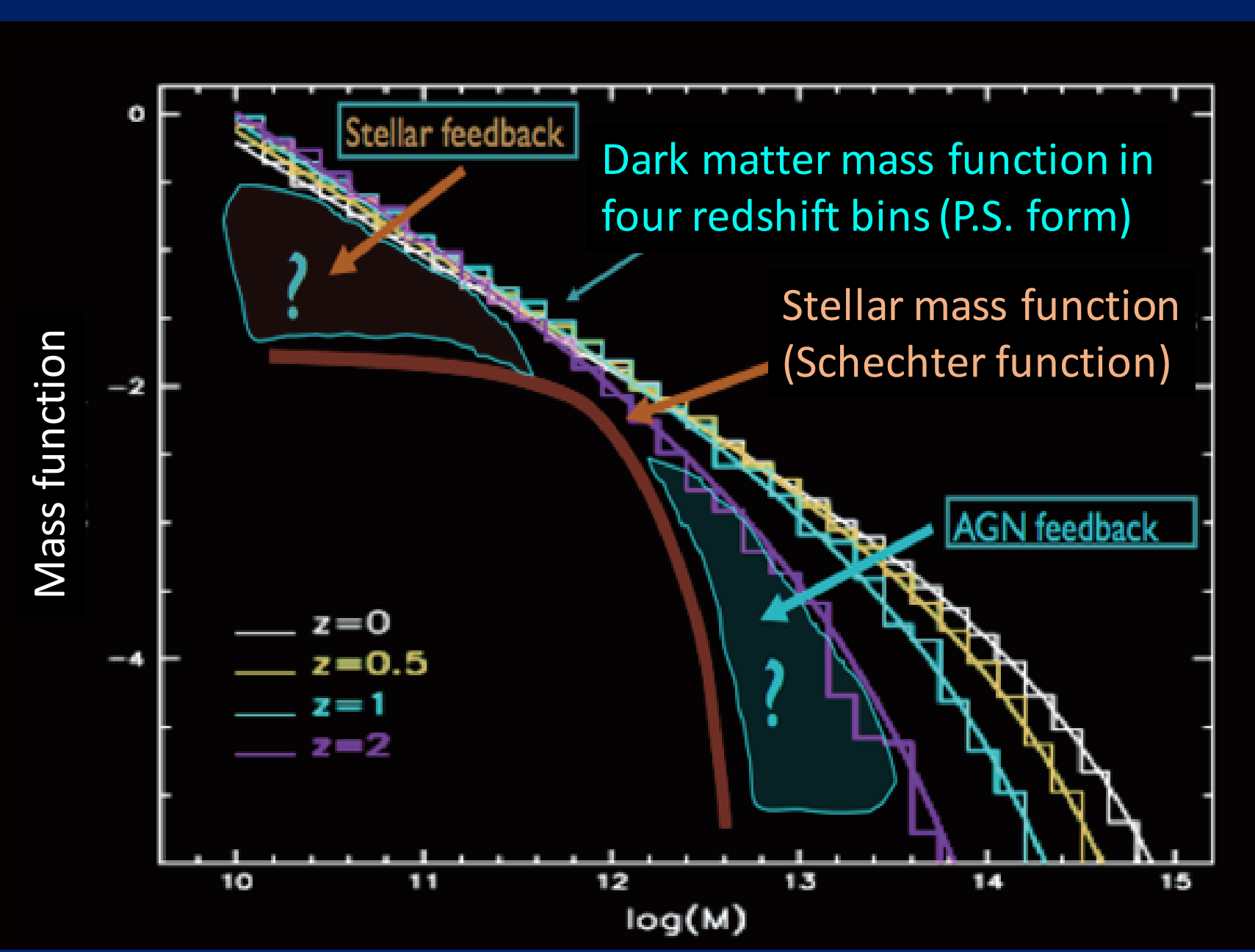


Fig. 1: Mass functions of stellar mass (brown) and dark matter (other colors). As a first approximation, stellar mass increases with dark matter halo mass. Deviations at both ends of the stellar mass function suggest that feedback mechanisms play a significant role in regulating evolution of the Universe, which will be thoroughly studied by SPICA spectroscopy.

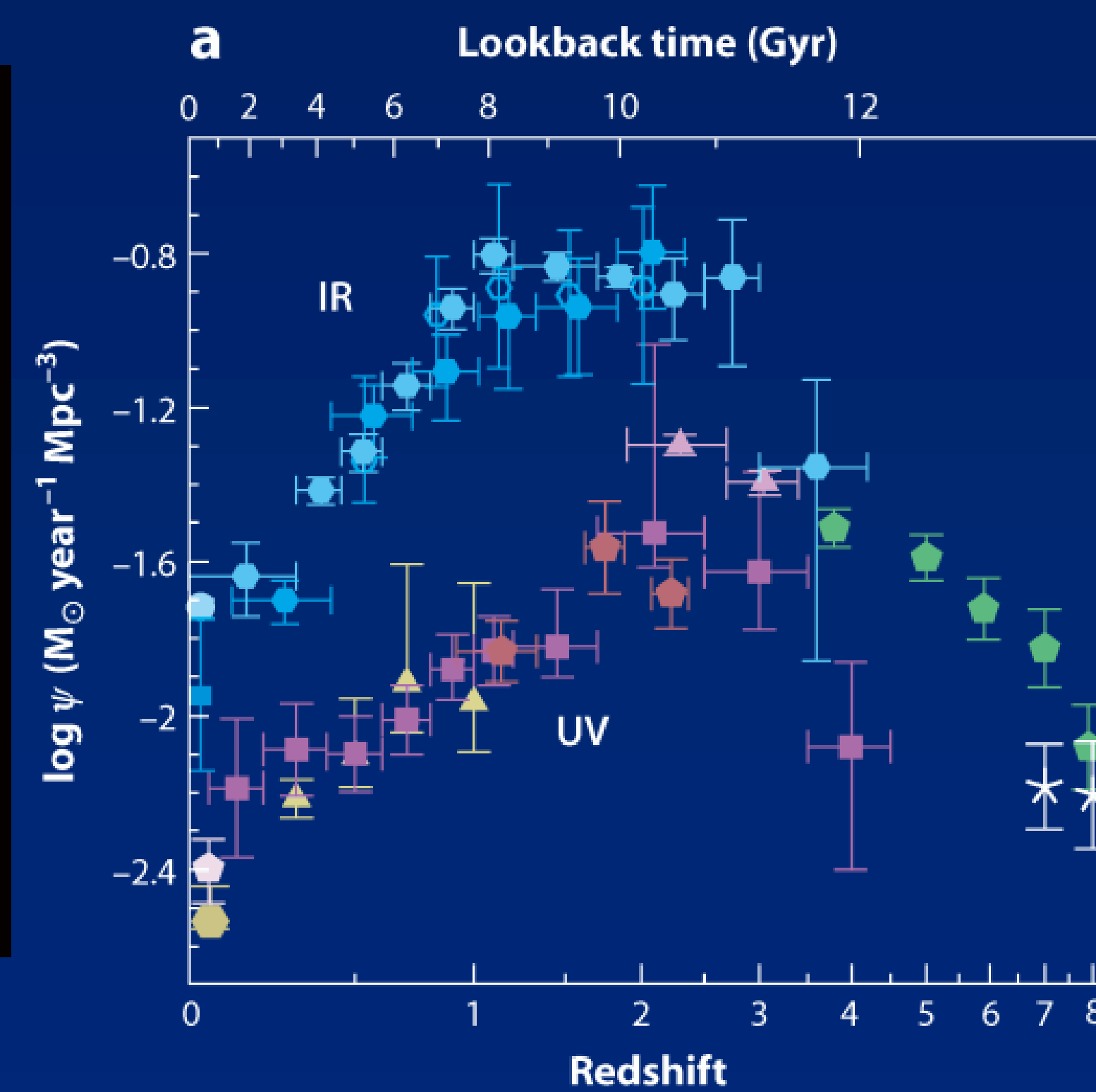


Fig. 2: Cosmic star formation rate density (SFRD) peaks at around $z \sim 2-3$, where a large fraction of UV light is attenuated and SFRD is dominated by infrared light (Madau & Dickinson 2014). Infrared observations are indispensable to understand the cosmic SFRD evolution.

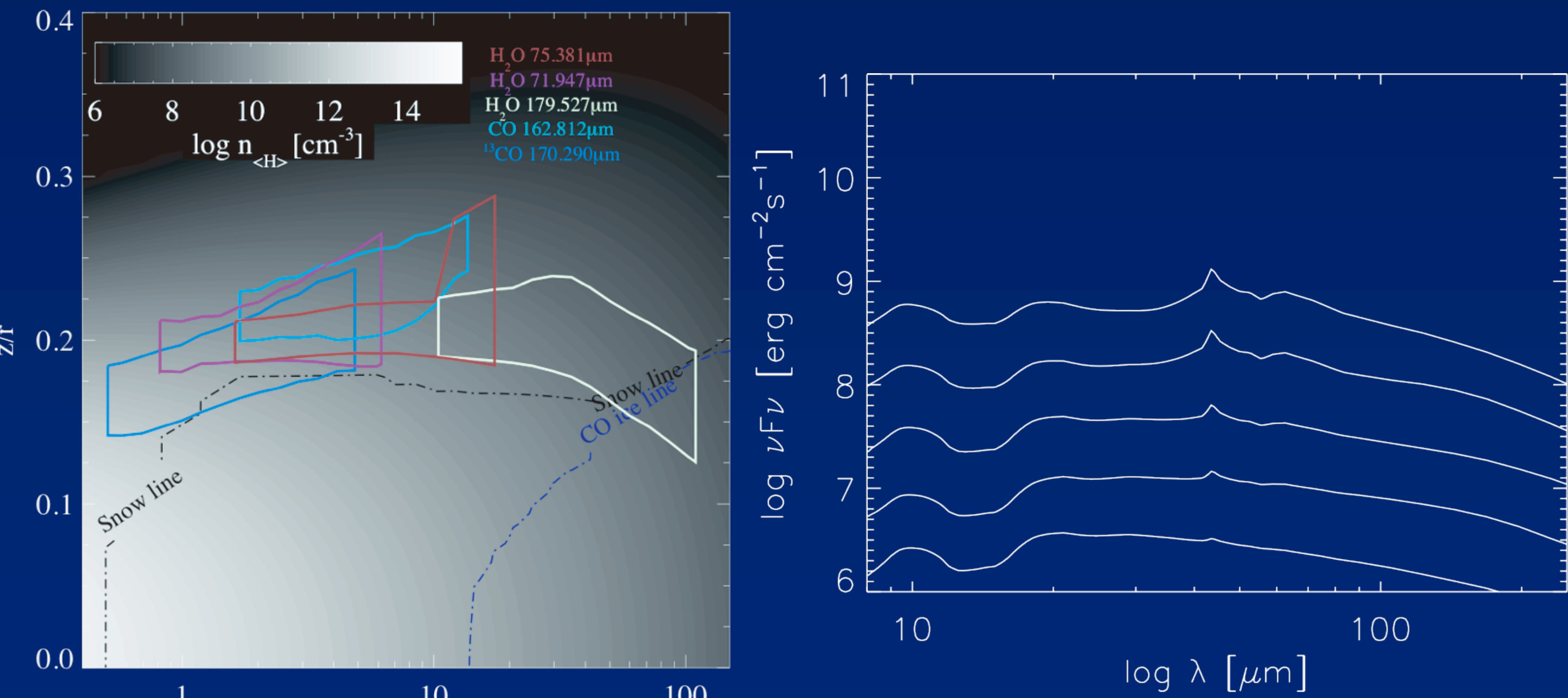


Fig. 6: Left figure shows a typical T Tauri disk model. Water gas lines scan the disk surface above the snow line (black dashed line); color boxes outline the region from which 50% of the line flux originate. Right figure shows simulated SEDs for T Tauri disks with varying fraction of icy grains (from bottom to top: 5, 10, 20, 50, and 100%). Various water vapor lines and water ice bands in the SPICA spectral range enable us to track the water trail in planet-forming disks for the first time.

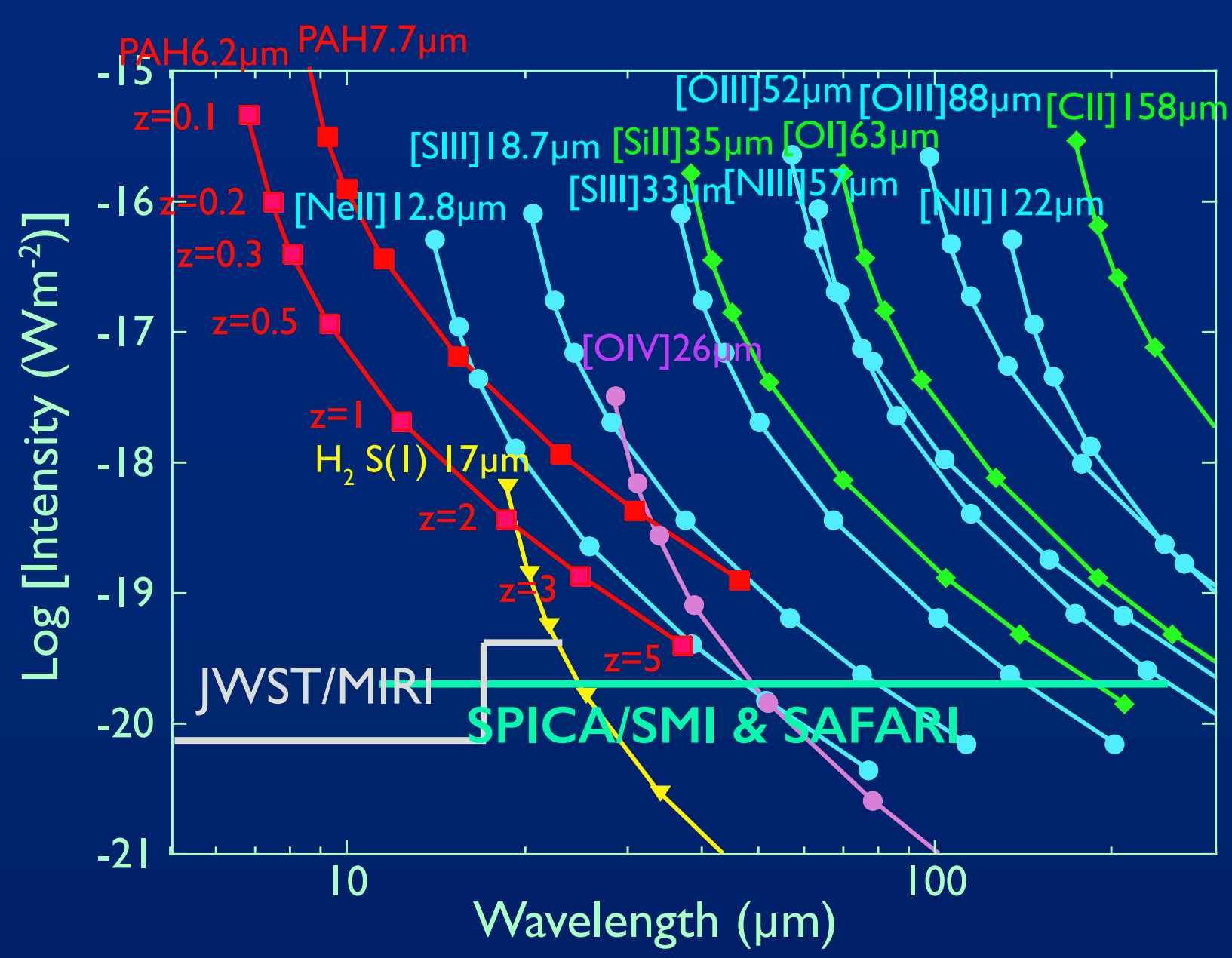


Fig. 3: SPICA has unprecedented sensitivity to detect major diagnostic emission lines both from star-forming main-sequence galaxies and AGNs ($L_{IR} = 10^{12} L_{\odot}$) at the peak of cosmic SFRD and unveil their true nature. PAH bands are strong and will be a very useful means to investigate galaxies even up to $z=5$ and to make efficient selection of objects for detailed spectroscopy. Line diagnostics will also be applied to spatially resolved data of nearby galaxies that will be a base for distant galaxies.

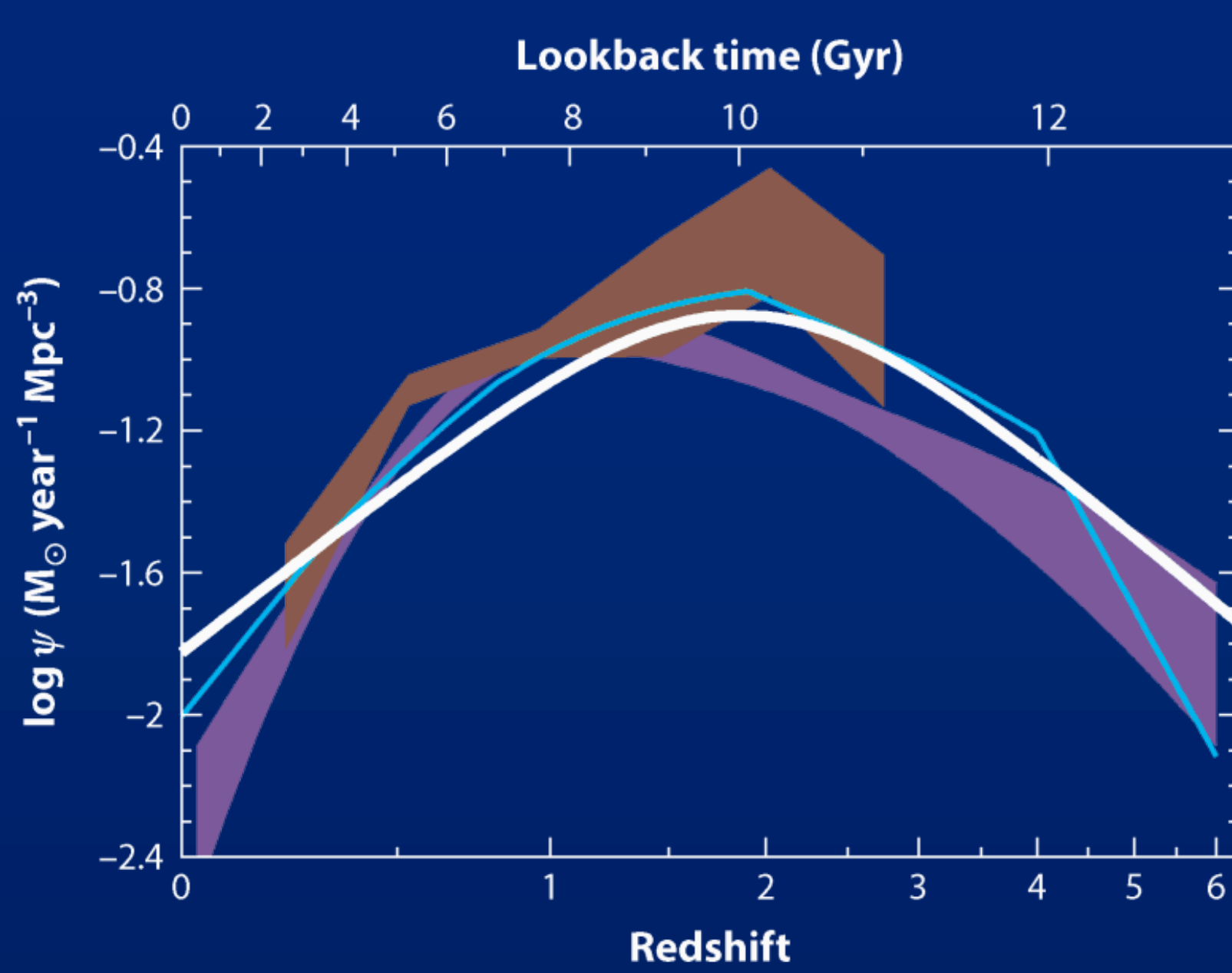


Fig. 4: Massive black hole accretion history from X-ray (blue line and purple shading) and SFRD from infrared data (brown shading), both of which show similar evolution. The accretion rates are scaled by a factor of 3300 to facilitate visual comparison to SFRD (white line) (Madau & Dickinson 2014). SPICA detects highly obscured AGNs to complete AGN census and revolutionizes the study of co-evolution.

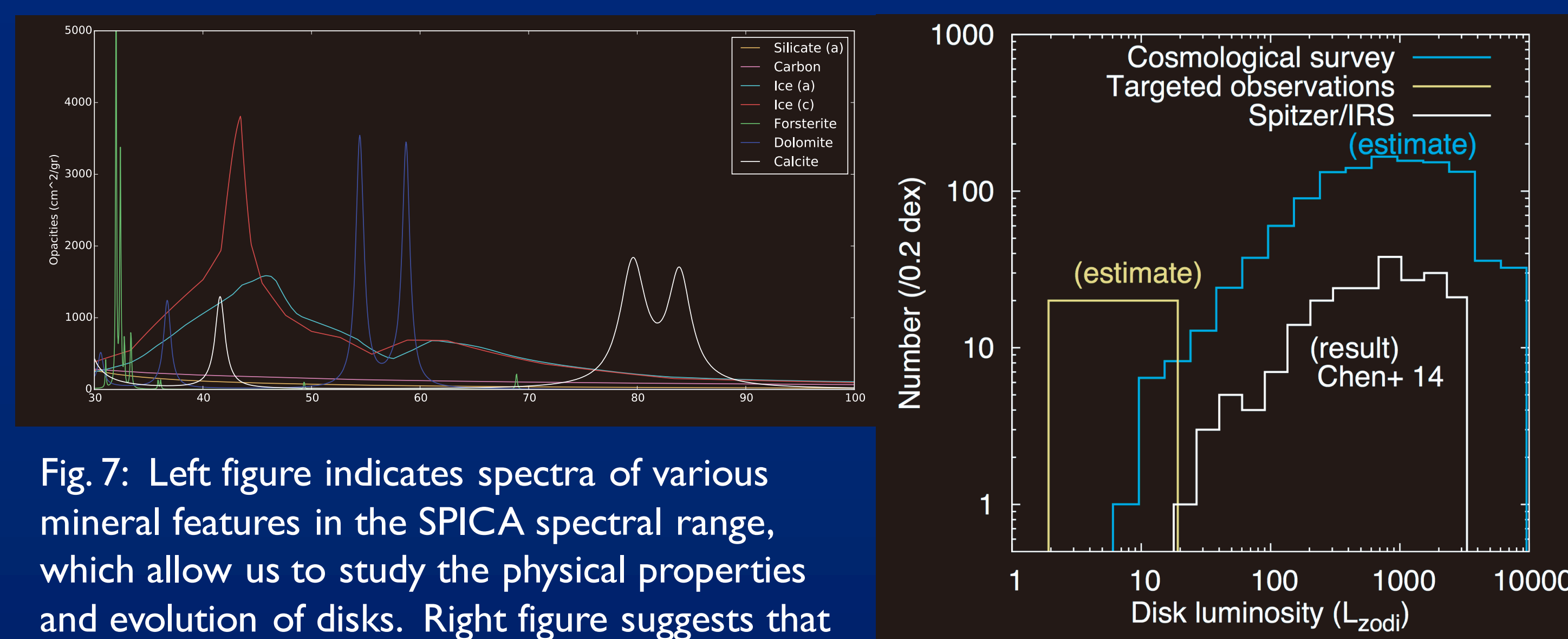


Fig. 7: Left figure indicates spectra of various mineral features in the SPICA spectral range, which allow us to study the physical properties and evolution of disks. Right figure suggests that SMI/LRS survey will have a potential to detect exo-zodiacal light down to a level similar to our Solar System, providing us with the first opportunity to study the origin and evolution of our Solar System in a wider Galactic context.

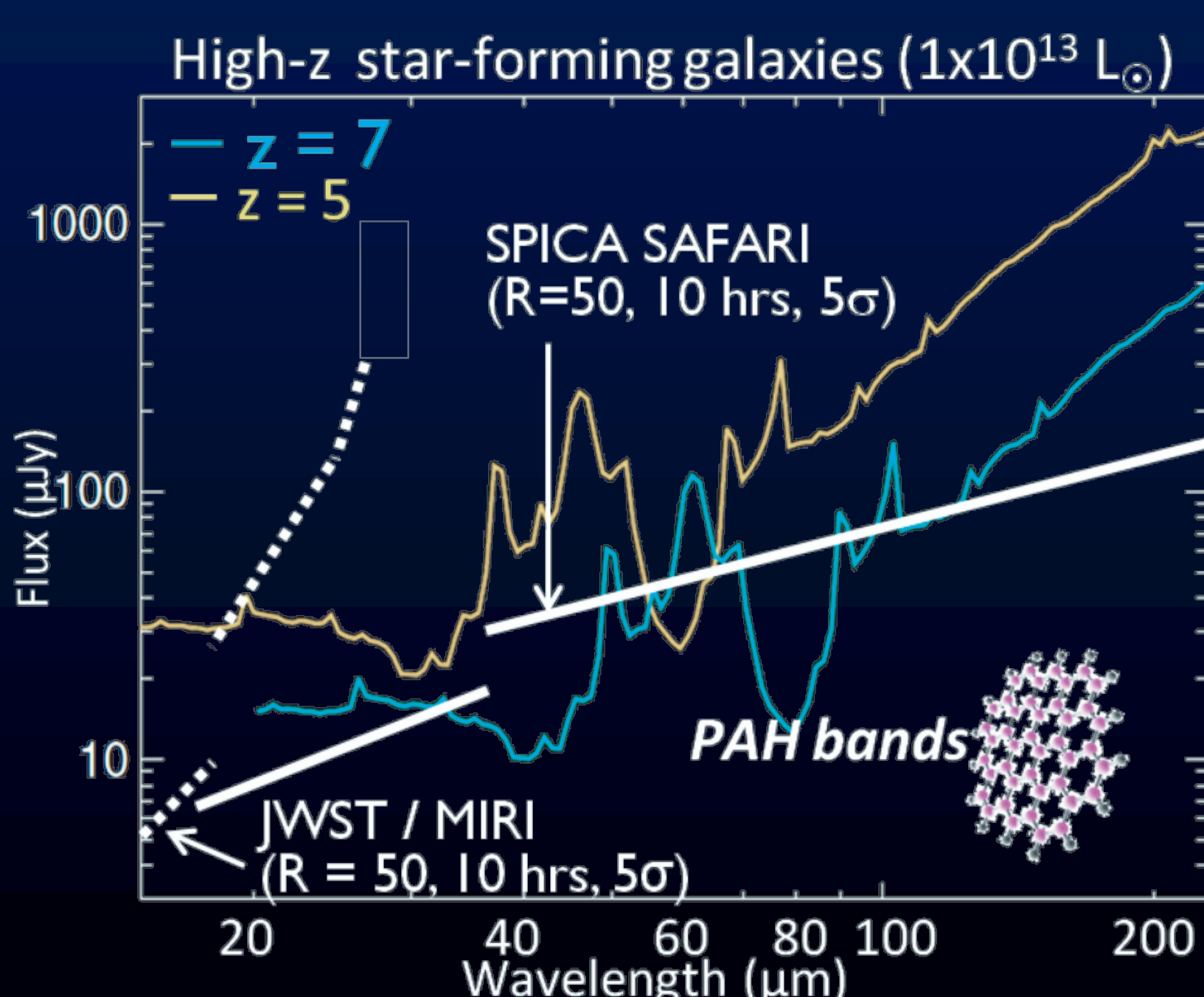


Fig. 5: SPICA has a capability to detect band emission from dust grains even at $z > 7$. Dust grains are cosmic reservoirs for heavy elements and important to understand the history of metal enrichment in our Universe.

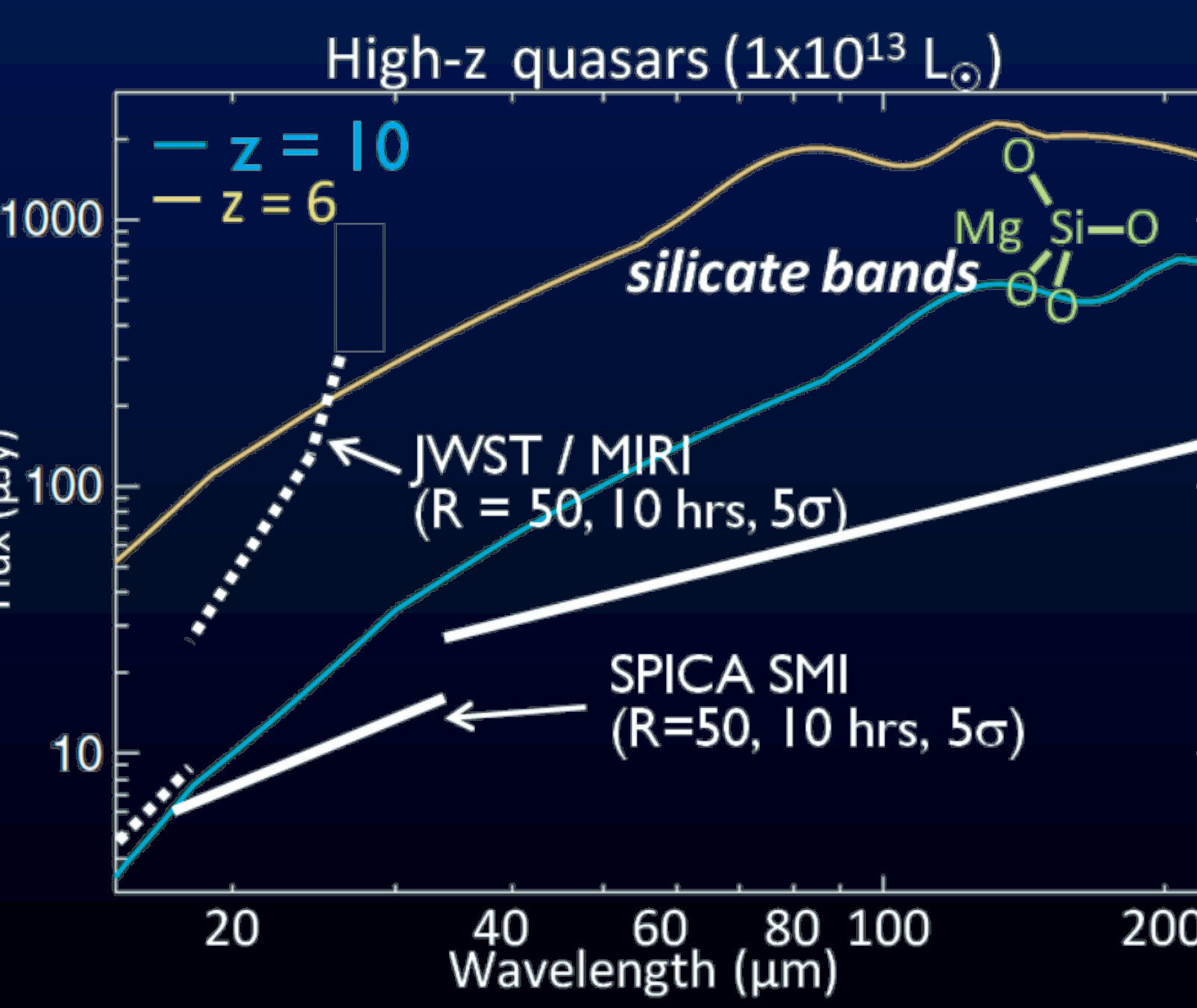


Fig. 8: Differentiated HD line ($J=1-0$ and $2-1$) fluxes in a typical T Tauri disk model at 140 pc as a function of gas temperature. HD traces warm ($\sim 50-100$ K) gas more reliably and accurately than H_2 and CO line emission and allows us to study the true warm gas content and dissipation, which play a crucial role in planet formation and atmospheric composition of the forming-planet.

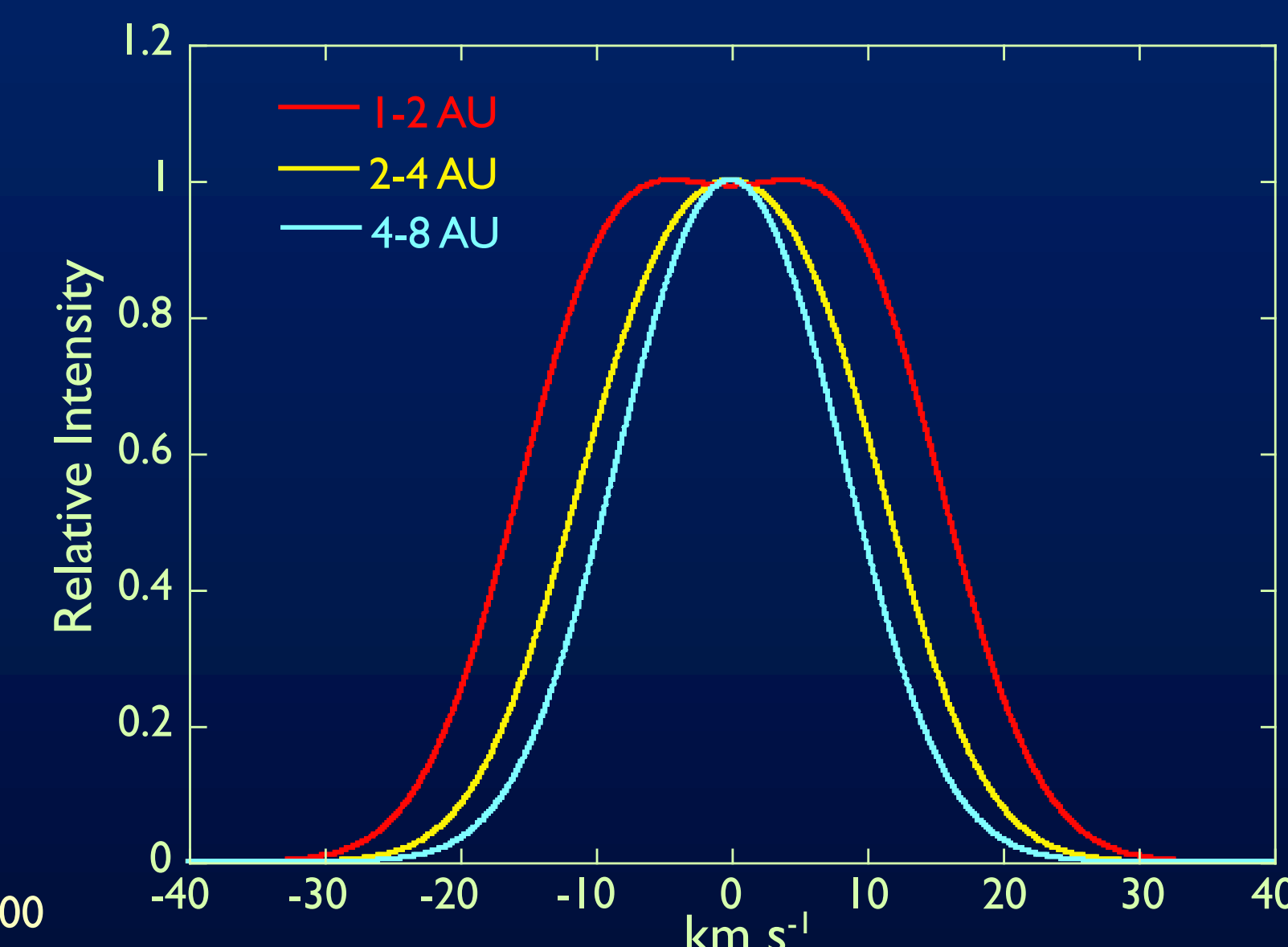


Fig. 9: Simulation of $H_2 S(2)$ line emission for a typical T Tauri disk. SPICA SMI/HRS has a sufficient spectral resolution and sensitivity to distinguish emission from the terrestrial planet forming region (1-2AU) from the outer regions to study the gas dissipation process in the innermost region of the disk in detail.

Acknowledgement

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