1. Science aim/goal: MIR spectroscopy of rest-frame optical lines to estimate the metallicity of early galaxies and follow its evolution over cosmic times.

2. Description

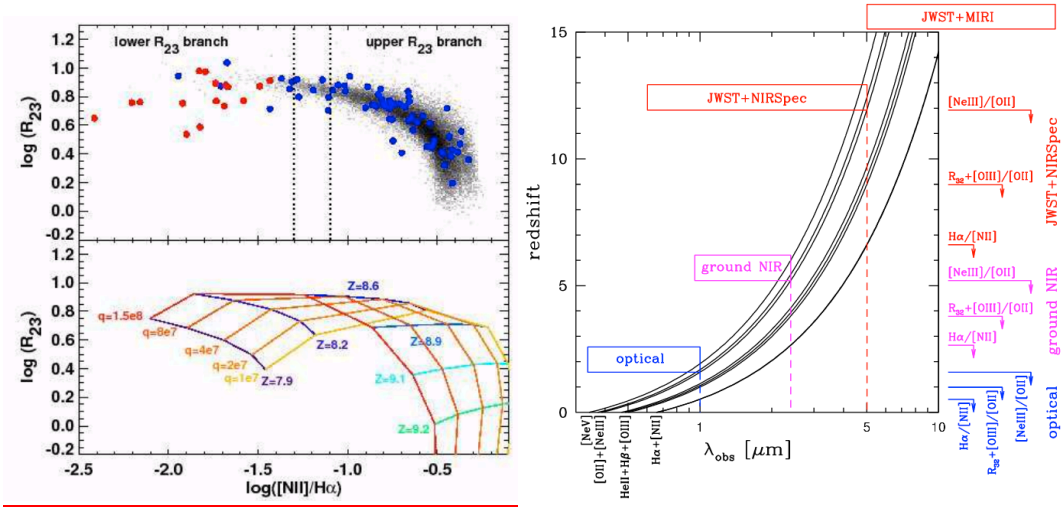
(i) Scientific Importance: The MIR range (5 to 35 μm) is important for several of the top 14 OST sciences cases. Here, we will more specifically see why it is very relevant to study the objects in the early universe at $z > 5 - 6$, i.e., the first Gyr of the universe. Measuring the abundances of metals is crucial to understand the evolutionary history of the galaxy and cosmologically, of the evolution of the universe itself. However, metallicity measurements in galaxies are not simple: an information on the gas temperature is required for a precise determination of the gas metallicity. In general, we rely on relations between the gas metallicity and the flux ratios of strong emission-lines to estimate the gas metallicity in most galaxies.

(ii) OST Observations Required: The R_{23} = [F([OII]λ3727) + F([OIII]λ4959) + F([OIII]λ5007)] / F(Hβ) line ratio (Pagel et al. 1979) is considered as a useful tool. But, unfortunately, this indicator suffers from a degeneracy and for a given ratio, we have two solutions one at low-metallicity and one at high metallicity. To rise this R_{23} degeneracy, several methods make use of the Hα and [NII]λ6548 and [NII]λ6584 lines (Left Fig). This is quite efficient (because all these optical lines are bright) But the main drawback is that, at high redshift, these lines shift outside the spectral bands accessible from optical and Near-IR telescopes and become unavailable beyond $z \sim 0.5$ or so. Other indicators are needed (Right Fig. from Nagao et al. 2006). JWST/NIRSpec will allow to use these same optical lines to $z \sim 5$ - 6. Beyond, JWST/MIRI might only detect the brightest galaxies. The sensitivity of OST/MISC (Sect. 5) could reach 10^{-21} W/m^2 in about 3h, much deeper than JWST/MIRI and could detect galaxies up to $z > 10$. Besides, for very low-metallicity galaxies that we expect in the early universe, the metallicities from MID-IR lines seems to saturate while they keep decreasing from the above optical lines (see OST Case #19), improving the complementarity with other OST instruments for Case #19 (Rise of Metals). At very low metallicity, the metallicity measured from optical lines keeps decreasing. This is very useful because most of the galaxies in the first Gyr of the universe are likely to be metal-poor or even metal-free.

(iii) Uniqueness to OST 5μm to 700 μm wavelength facility: Even though JWST/MIRI (and SPICA?) will offer us a window beyond 5μm. OST/MISC will provide the best opportunity to follow these well-known bright optical lines to the highest redshifts (Sect. 5). Beside the metallicity, the star formation rate and the dust attenuation via the Balmer line scan be estimated. No other facility will combine the MIR range to a ~10-m telescope in space. These data used in conjunction with other telescopes at lower redshifts (e.g. E-ELT, JWST) and the complementarity with the information that OST itself will get at redder wavelengths will leave an exceptional legacy over a long period.

(iv) Longevity/Durability: (with respect to expected 2025-2030 facilities) No telescope on the ground or in space under study (to our knowledge although projects have been submitted in Japan, Europe and in the US) is able to meet this objective.

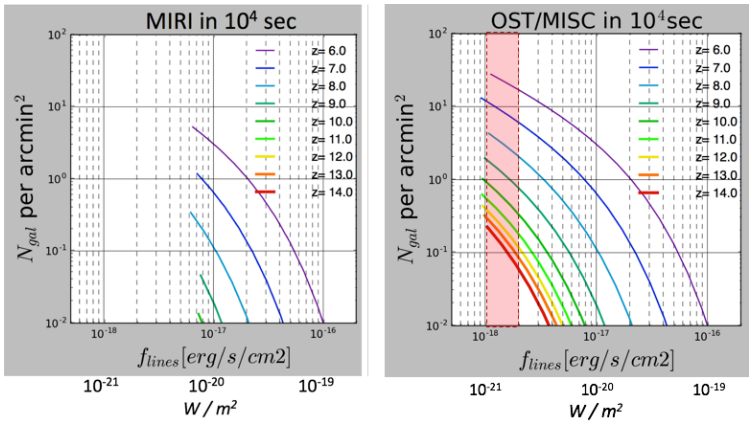
3. Figure: Left from Kewley et al. (2008): [NII]/Hα and [NII]/[OII] values are used to break the R_{23} degeneracy in a model-independent way. Right from Nagao et al. (2006). Schematic view of the availability of various metallicity diagnostics for each redshift. The black solid curves indicate the effect of redshift for some of the diagnostic lines. The colored boxes indicate the wavelength coverages of optical spectrometers (blue), of ground-based near-IR spectrometers (magenta), and of NIRSpec/MIRI on board of JWST (red). The marks on the right of the diagram indicate the maximum redshift at which some of the metallicity diagnostics can be used with the various facilities.



4. Table:

Mid-Infrared Imager Spectrometer and Coronagraph (MISC) Modes	Check all that apply to your program
MIR Imaging	✓
MIR Low Resolution Spectroscopy	✓
MIR Medium Resolution Spectroscopy	✓

5. Descriptions of an observing plan: Predicted Galaxy Number Counts at high z detectable by JWST/MIRI and OST/MISC at SNR = 10 in 10 000 sec. OST/MISC could reach about 10^{-21} W/m^2 in 3h. The complementarity with ELTs on the ground and JWST in space will allow to use the same metallicity indicator over most of the lifetime of the universe. Using a **WF Integral-Field Unit** is an interesting option.



6. Key references:

- Pagel et al. 1979
- Nagao et al. 2006
- Kewley et al. 2008