Wide-field Imaging Surveyor for High-Redshift
WISH

Proposal for JAXA ISAS Working Group

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WISH Team

WISH Conceptual Study Team

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1 Abstract: What is WISH

WISH is a space science mission whose primary goal is to reveal the first-generation galaxies in the early young universe. We launch a 1.5m-aperture telescope equipped with 0.5-degree-diameter wide-field NIR camera by middle of 2010's in order to conduct ultra-deep and wide-area sky survey with the depth that cannot have been achieved by previous ground-base telescopes. WISH should be a very powerful and unique facility not only for the search for first-generation objects but also for study of dark energy and many other fields in astronomy.

Observations in NIR wavelength (1-5μm) is essential to detect the red-shifted light from the objects in the very early universe. While ground-based observations are very much limited in sensitivity by the atmospheric airglow and thermal background radiation at this wavelength range, the observations from space with the appropriately cooled telescope achieve much better sensitivity. Furthermore, wide-area capability with 0.5-deg diameter field of view also brings a uniquely large survey power in this wavelength. The main scientific goals of WISH mission are as follows.

[1] Search for the most-distant first-generation galaxies and revealing the galaxy distribution and properties in the era of cosmic re-ionization

[2] Study of the expansion history of the universe and properties of dark energy by using a very large sample of high-redshift Type-Ia Supernovae

[3] Extensive study of galaxy formation and evolution utilizing the unique wide-area NIR observations from space.

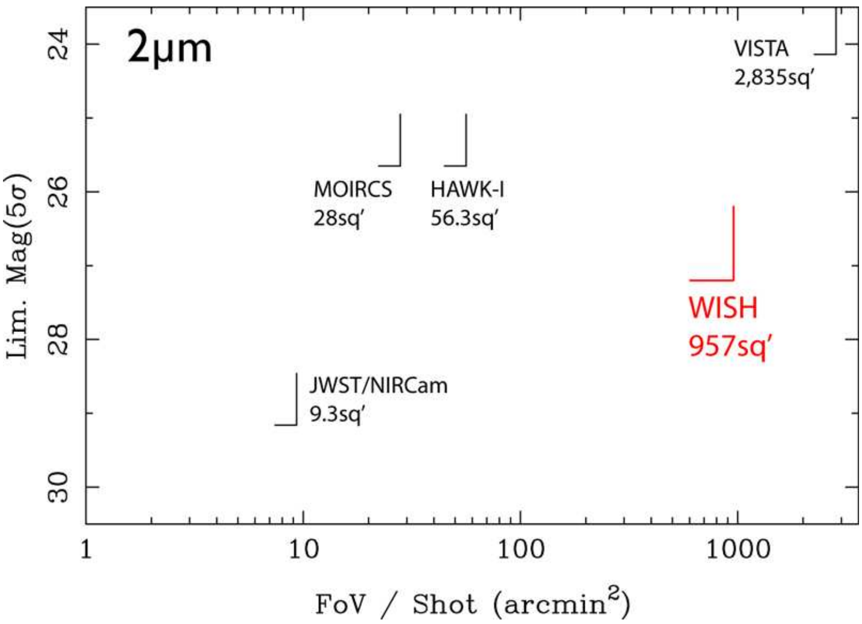
These scientific goals are indeed among the most important questions in modern astronomy, and at the same time, they are improvement or extension of what achieved by the current, world-leading Japanese facilities, such as Subaru 8.2m telescope. It is indeed an effort for Japanese astronomers to seek the cutting-edge frontier fields in astronomy. On the other hand, the concept of WISH, namely the very field-field (0.5-deg) FoV camera working at 1-5 μm is unique and powerful among the various on-going or approved missions. We thus propose to found the WISH Working Group under JAXA ISAS.

WISH is very much complementary in wavelength, observational technique, and science goals, to other very large projects planned in Japan, such as SPICA mission or ground-based Thirty-Meter Telescope (TMT). It even has very strong synergy with them. On the other hand, it can be very important step for Japanese optical/NIR astronomers who mainly have worked with the ground-based telescope to the era of space science.

1.1Basic Specification

Telescope	
Primary Mirror diameter	1.5m
Wavelength Range	1μm – 5μm
Field of View	~1000 square arcmin (or 35' diameter)
Temperature (FP)	Less than 100K (goal: ~40K) Passive Cooling
Wide-Field NIR Camera	
Detector	HgCdTe (18μm/pixel is assumed)
Sampling	0.15"/pix
Operation Temperature	80K Passive Cooling
Filter	5 broad-band filters covering 1μm to 5μm Narrow-band filters / slitless spectroscopy (TBD)
Spacecraft / Launcher	
orbit	SE-L2 (TBD)
rocket	HIIA (TBD)
Total weight	1.3t (matched to HIIA dual launch)
others	
Mission life time	5 years

1.2 Survey Power : comparison with other NIR imagers

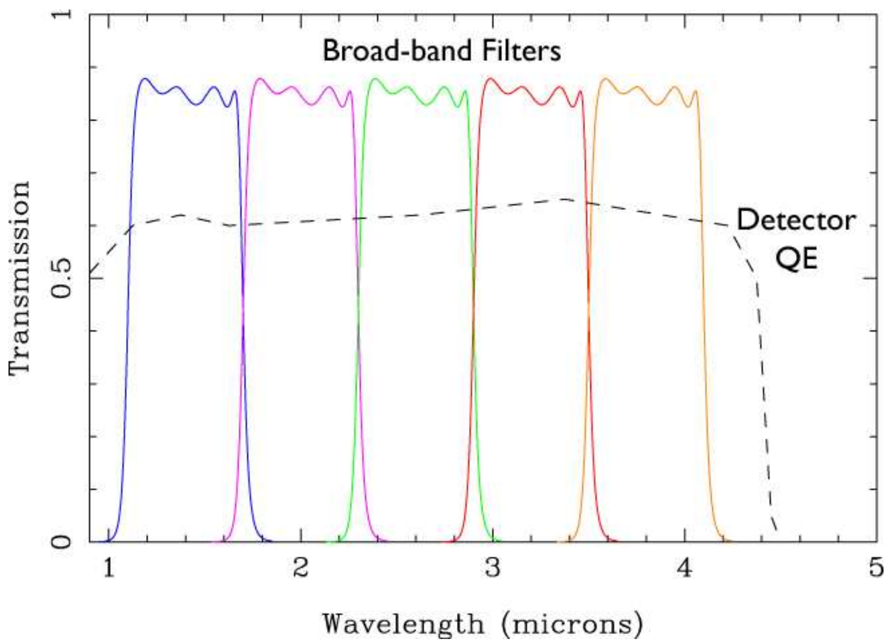


[Fig 1-1: Detection limit and instrument FoV of WISH compared with those of the current wide-field NIR cameras on 8m-class ground-based telescopes (Subaru MOIRCS and VLT Hawk-I), a 4m-class NIR survey telescope (VISTA), and JWST NIRcam. The detection limits are those at around 2μm.]

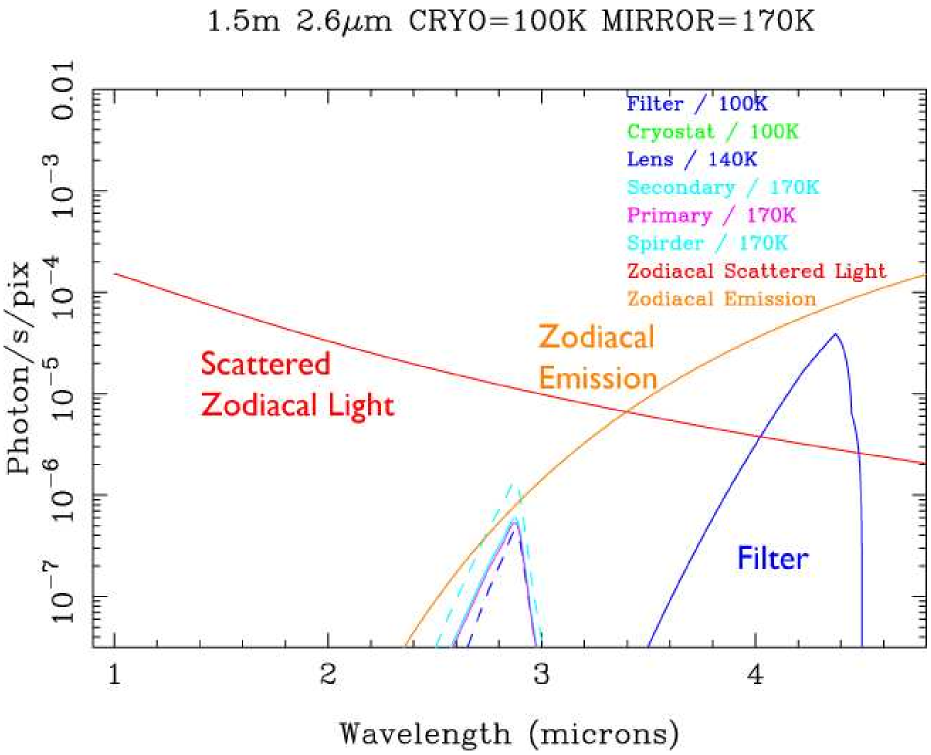
It is useful to compare the goal sensitivity (survey detection limits) and instrument field of view of WISH with those of other current and near-future NIR wide-field imager to understand the uniqueness of WISH. The survey detection limit of WISH is far below those with ground-based facilities and the field of view is much larger than those of 8m-class telescopes. NIRcam on JWST with 6.5m-diameter can go much deeper than WISH but the instrument field of view is much smaller.

1.3 Sensitivity

While the filters of the ground-based telescope cameras are optimized to the wavelength of atmospheric windows, for space telescopes we can make filters without wavelength gap. For a simple example, we consider 5 broad-band filters (FWHM~0.6μm) covering from 1 to 4.1 μm homogeneously. As we show below, the longest wavelength which can be used depends on the temperature (cooling) and here we assume the case filters are cooled to 100K.

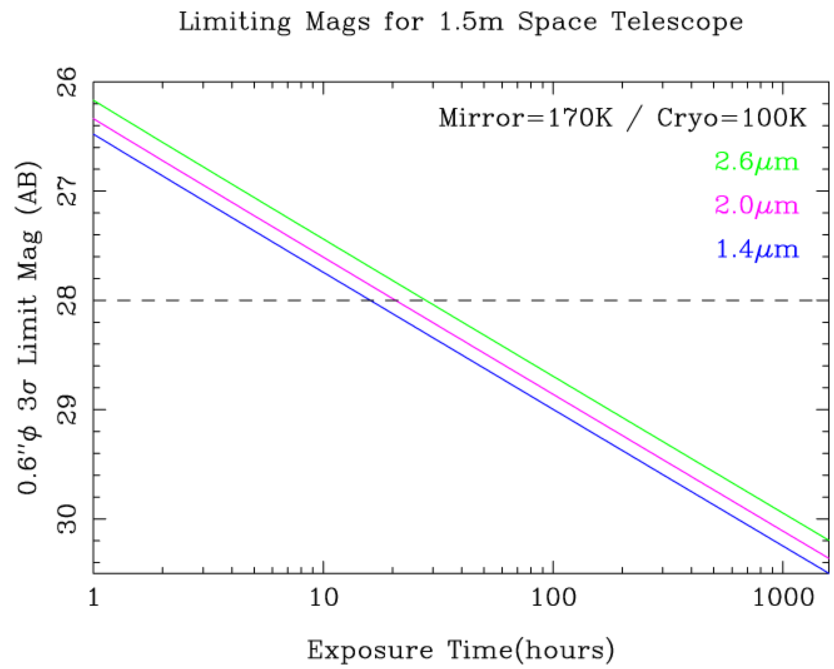


[Fig1-2:Filters and detector QE curve which is used in the following sensitivity evaluation.]

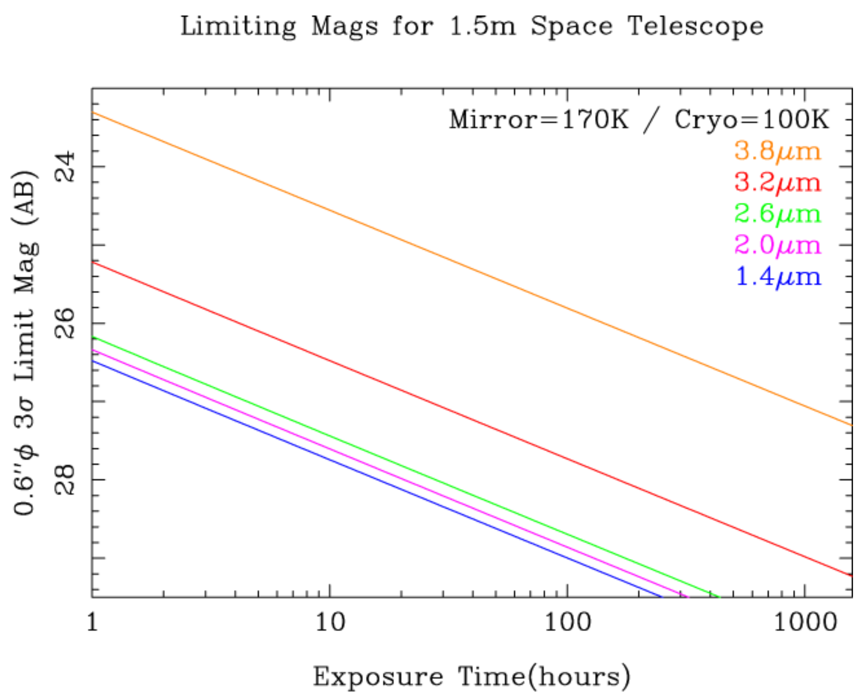


[Fig 1-3: Flux of background radiation from zodiacal light and thermal background. The pixel scale is 0.15". Telescope temperature is 170K, and the filters are assumed to be colder, 100K.]

In the case that the primary mirror and telescope structures are 170K, corrector lenses are 140K, and filters are 100K, the number of the photons of background radiation per pixel is shown in the figure above. In this calculation, filters are placed just in front of the detector and their thermal radiation may be the dominant background source. However, it is less than zodiacal light if cooled below 100K and is no more the dominant background source.



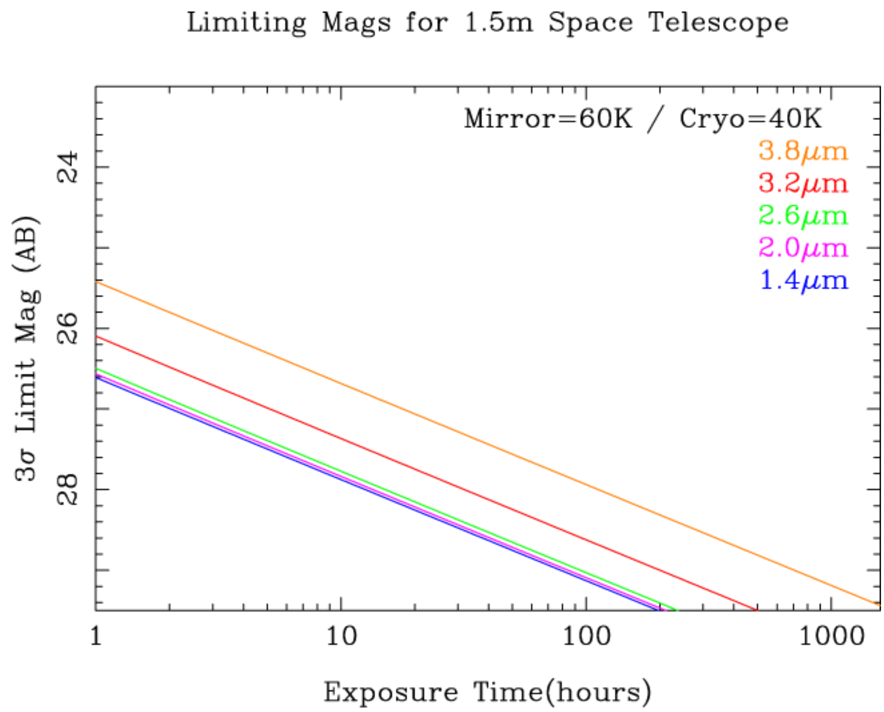
[Fig1-4: Detection limit as a function of exposure time. Three filters at shorter wavelength.]



[Fig1-5: Detection limit as a function of exposure time. At the longer wavelength, the detection limit is shalower due to the effect of thermal noise.]

At the shorter wavelength, WISH reaches the limiting magnitude 28 mag (AB, 3 σ), which cannot be achieved from the ground, thanks to much less background noise. At the longer wavelength, with the assumed temperature, it is shallower due to the thermal radiation. Yet it already reaches 26AB at 3μm and 25AB at 4μm, which cannot be achieved by the ground-based telescopes.

If we adopt the SE-L2 orbit, it is possible to cool the telescope and filters to 30-40K. The detection limit in this 'cold' case is shown in the next figure. Compared to the previous case (100K), we can reach the depth of 27AB in 20-30h integration even at the longer wavelength. It should be however noted that the technical difficulty increases in this case since the end-to-end test with cooled telescopes/filters on the ground becomes much difficult. We should carefully consider the optimum choice in operation temperature for the best scientific outputs.



[Fig1-6: Detection limit as a function of exposure time for the 'cold' case, 60K at the telescope and 40K at the filters.]

Thus, WISH can achieve sufficiently deep sensitivity limit even at the reasonable thermal condition realized by passive cooling.

1.4 Survey Plan

Survey plan is considered based on the total available observation time in 5 years, the nominal lifetime of the WISH mission. For the main survey project which aims the detection of the first-generation galaxies at very high redshift and systematic study of the era of re-ionization, we consider Ultra-Deep Survey (UDS), covering 100 deg^2 down to AB 28 mag in the 3 bands. As the depth is achieved by recurrent exposures, the survey for variable objects such as SNe Ia can be done simultaneously. A part of the sky in UDS can be intensively observed in all the bands (MBS). The other survey is Ultra-Wide Survey (UWS) covering 1000 deg^2 at the shallower depth within several month, which aims to study structure formation, galaxy evolution, high-redshift quasars, Galactic objects, and weak lensing.

- Ultra Deep Survey (UDS)
  3 Bands, 100 deg^2, Detection limit: 28AB

- Multi-Band Survey (MBS)

5Bands, Selected area in UDS, Detection limit: 27-28AB

- Ultra-Wide Survey (UWS)
  2-3 Bands, 1000deg^2, Detection limit: 24-25AB