Infrared Imaging Spectroscopic Missions: NISS & SPHEREx

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Infrared Spectro-Photometric Survey?

- Wide-field Imaging + Wide-\(\lambda\) Range Spectroscopy
- No moving part: reliable observations
- High throughput & survey efficiency
- Technically demonstrated through NISS mission (2018)

Linear Variable Filter
Launch of NISS / Initial Operation

- Near-Infrared Imaging Spectrometer (NISS) onboard NEXTSat-1
- Spectro-photometric survey: ~100 deg² during 2-yr operation

- Infrared imaging spectroscopy (0.95~2.5 μm, R~20)

- Operation: ~2 years
  - Initial operation period: 3 months
  - Main observation: 18 months
  - User observation: 3 months

- Launched (Dec. 04) by Falcon9, SpaceX

- Dimensions: 290mm(L) × 270mm(W) × 392mm(H), 13.6kg
Optics
- Optical design & analysis
- Mirrors & lens

Opto-mechanics, Structure
- Mechanical design & analysis
- Barrel, structure
- Passive & active cooling system

Electronics
- Operation of IR sensor
- Data transfer

Calibration & Operation
- Test, Cal., DR
- Operation
Operations in Space

- Cooling Time (Op-TA)
  - Telescope: ~2 day (~1 day)
  - IR sensor: ~24 hrs (~12 hrs)
- Telescope: 220 – 230K
- IR Sensor: 88 – 96K

Background variation

1 μm          1.6 μm        1.9 μm

Actual PSF
Images from Initial Operations

HST vs NISS

M33

Orion

2MASS vs NISS
**Developments of Space IR Instruments**

- Study of diffuse components from MIRIS & NISS
  - EBL Study: near Ecliptic poles observed by AKARI
  - Star formation & ionized diffuse gas: Galactic plane

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIRIS (2014)</th>
<th>NISS (2018)</th>
<th>SPHEREx</th>
</tr>
</thead>
<tbody>
<tr>
<td>FoV</td>
<td>3.6×3.6 deg.</td>
<td>2×2 deg.</td>
<td>3.5×11.3 deg.</td>
</tr>
<tr>
<td>Aperture of Telescope</td>
<td>8cm</td>
<td>15cm</td>
<td>20cm</td>
</tr>
<tr>
<td>Spectral Coverage</td>
<td>1.1 &amp; 1.6 (1.87)μm</td>
<td>0.95 ~ 2.5μm</td>
<td>0.75 ~ 5μm</td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>5 (45)</td>
<td>20</td>
<td>40 - 150</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>51.6&quot;</td>
<td>15&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>Coverage (Deep fields)</td>
<td>~3,000 deg²</td>
<td>150 deg²</td>
<td>All-sky</td>
</tr>
<tr>
<td>Depth</td>
<td>18 AB mag.</td>
<td>17 AB mag.</td>
<td>19 AB mag.</td>
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</table>
SPHEREx: An All-Sky Spectral Survey

Designed to Explore
- The Origin of the Universe
- The Origin and History of Galaxies
- The Origin of Water in Planetary Systems

The First All-Sky Near-IR Spectral Survey
A Rich Legacy Archive for the Astronomy Community with 100s of Millions of Stars and Galaxies

Low-Risk Implementation
- Single Observing Mode
- No Moving Parts
- Large Technical & Scientific Margins

Finally Selected!
**Major Scientific Goals**

**Cosmology**

SPHEREx will probe the 3D Large scale structure today to gain insight into the earliest epochs of the universe. Measure $\sigma f_{NL}$ to high accuracy.

**Galaxy Formation and Evolution**

**Biogenic Ices**

SPHEREx will measure the $H_2O$, $CO$, $CO_2$, $CH_3OH$ ice content in clouds and disks, determining how ices are inherited from parent clouds vs. processed in disks.

**SPHEREx extragalactic background light measurements determine the total light emitted by galaxies**

NASA MIDEX Mission
SPHEREx Creates an All-Sky Legacy Archive

<table>
<thead>
<tr>
<th>Detected</th>
<th>Medium-Accuracy Spectra</th>
<th>High-Accuracy Spectra</th>
<th>Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1 billion</td>
<td>&gt; 100 million</td>
<td>10 million</td>
<td>25,000</td>
</tr>
</tbody>
</table>

**Galaxies**
- Main Sequence Spectra: > 100 million
- Dust-forming: 10,000
- Brown Dwarfs: > 400
- Cataclysms: > 1,000

**Stars**
- Quasars: > 1.5 million
- Quasars z > 7: 1 – 300?
- Asteroid & Comet Spectra: 10,000

**Other**
- Galactic Line Maps: PAH, HI, H$_2$

A spectrum for every 6” pixel on the sky
NEP/SEP: 100 + 100 sq. deg.
  - AKARI Deep Fields (NEP/SEP)
  - Average 60x deeper than all-sky survey
  - Spatially not uniform, but include Euclid Deep Fields (eROSITA)
NEP: 5.4 deg.$^2$ by IRC (Near- & Mid-IR 9 bands)
SEP(ADF-S): 12 deg.$^2$ by FIS (FIR 4 bands)

Ancillary Data (undergoing)
- Optical data: Subaru(N), KMTNet(S)
- NIR: Kitt Peak FLAMINGOS – NEP
  VISTA - SEP
- MIRIS (I & H): up to 10 x 10 deg.
- Spec: MMT/Hectospec
  & WYIN/Hydra – NEP, AOmega - SEP
- FIR-Submm: Herschel PACS & SPIRE
- Submm: SCUBA-2, (ALMA)
- mm: AzTEC – SEP, (ALMA)
Expecting Synergy with KASI’s Facilities

- Korea Microlensing Telescope Network (KMTNet)

- Access to foreign facilities
  - EAOs: JCMT, ALMA, ...
  - Mid-sized optical telescopes: Gemini-S/N, MMT, UKIRT, ...

- GMT, LSST, ...
Data reduction pipeline: experience from NISS

Science (especially extragalactic science)
  - Pre-studies with NISS: operation from 2018
  - Multi-wavelength surveys for NEP/SEP regions

Ground support equipment for characterizing the instrument (cryo. Chamber, integrating sphere, ground station electronics)
  - Re-design of cryo. chamber
  - Test items: optics & system
Phase Studies (10 yrs)

- Phase-A (2018): Conceptual design

- Development Phase (2019 ~ 2022)
  - Detailed design, Assembly & preparation of DR
  - Preparation of Science Cases

- Operational Phase (2023 ~ 2025)
  - Constructs test calibration facilities & Calibration
  - All-sky survey & evaluation of PV data

- Science Phase (2025 ~ 2028)
  - Research activities with legacy science data
  - Revision of DR for Science Enhancement Options (SEO)
Collaborations in Science

- Cosmology: 3D large-Scale structure

- Galactic Sciences
  - Ice Features from YSOs & IRDCs
  - Exploring unshocked SN ejecta in young SNs
  - Deep ecliptic patrol of the southern sky: DEEP-South
  - Transient objects (stars, SNs, ...)

- Extragalactic Sciences
  - SF properties of near-by galaxies
  - Near-by and high-z AGNs & AGNs
  - Properties of High-z emission line galaxies
  - Origin of Cosmic Infrared Background

NISS
Summary

- Space instruments developed by KASI
  - Technical demonstration: imaging spectroscopy with LVFs
  - Imaging spectroscopic survey: Nearby galaxies, star-forming regions, low-background regions ...

- SPHEREx
  - KASI’s contribution
  - Galactic / Extragalactic Sciences
  - Synergy with other Facilities (KMTNet, GMT, GEMINI, MMT ...)
  - More science cases from Korean community
  - Need more manpowers

- Contributing sources to CIB?
  -> Extragalactic Sciences with NEP/SEP Regions