Status of IR Spectro-Photometric Survey Missions in Space

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Origin of IR Excess Emission?

Epoch of Reionization? Modern Galaxies form?

- Excess emission in near- & far-infrared
  - High-redshift objects: first stars or first galaxies
  - Low-redshift objects: merging galaxies or stars around galaxy

MIRIS & NISS! SPHEREx?
NISS: Near-IR Imaging Spectrometer onboard NEXTSat-1 (2018~2020)

- Wavelength range: 0.9 ~ 2.5μm
- Array format: 1024 x 1024, FoV: ~2 deg. X 2 deg. (15”resol.)
- 15cm aperture, Imaging & Low-Resolution Spectroscopy (R~20), Sensitivity ~17 AB mag. – spectrophotometric survey area ~150 deg² (2-year operation)

NISS

NEXTSat-1

290mm(L) × 270mm(W) × 392mm(H), 13.6kg

2LVFs
Passive (180K) & active cooling (80K)
Optics

- Space optics: shock/vibration, radiation, thermal-vacuum condition
- Off-axis optics / Barrel
  - Reduction of obscuration
  - Afocal system
    → independent alignment
  - Barrel: flexure / spacer
- Wide wavelength range
  - Filters
  - Coating of lens
Opto-mechanics/Structure

- Shock/vibration: FEM analysis & Support of mirrors
- Stress/Deformation for mirrors
  - 1G gravity
  - Thermal deformation
  - Mis-alignments
- Very compact dewar
- Passive/Active cooling
  - Telescope: ~180K
  - IR sensor: ~80K
Technical Developments (3/3)

- Construction of Test Facilities
  - Cryo-chamber for system calibration
  - IR collimating system for optics test
  - Monochromator system for spectral calibration
Calibration of NISS

Dark measurements

Wavelength calibration

PSF measurements

Linearity correction

After correction

Before correction
NEXTSat-1 Test

- Integration of NISS
- Thermal-Vacuum Test
- Vibration Test

Functional Test
**NISS Science Cases**

- **Near–IR Imaging Spectroscopy**
  - Large Nearby galaxies
  - Clusters of galaxies
  - Star–forming regions
  - Cosmic Near–Infrared Background

### Near–infrared spectral lines

<table>
<thead>
<tr>
<th>$\lambda$ (µm)</th>
<th>line</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.26, 1.64</td>
<td>[Fe II]</td>
<td>Emission</td>
</tr>
<tr>
<td>1.875</td>
<td>$\text{Pa}_\alpha$</td>
<td>Emission</td>
</tr>
<tr>
<td>1.96</td>
<td>[Si IV]</td>
<td>Emission</td>
</tr>
<tr>
<td>2.212</td>
<td>$\text{H}_2$ 1-0 S(1)</td>
<td>Emission</td>
</tr>
</tbody>
</table>

Kim et al. 2017, submitted
Next Schedule

- Launch @ late 2018: Falcon9 @ SpaceX
- Operation (TBD)
  - Initial operation period: ~3 months
  - Main observation: ~17 months
  - User observation: ~4 months
- New science cases: inviting!

Scientific Targets

<table>
<thead>
<tr>
<th>Category</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearby galaxy</td>
<td>~15 objects (e.g., M31, NGC628)</td>
</tr>
<tr>
<td>Cluster of galaxy</td>
<td>1~2 objects (e.g., Abell 2199)</td>
</tr>
<tr>
<td>Star-forming region</td>
<td>~6 regions (e.g., LMC, SMC)</td>
</tr>
<tr>
<td>CIB observation</td>
<td>1~3 regions (e.g., NEP, SEP)</td>
</tr>
</tbody>
</table>
One of 3 MIDEX Candidates (Aug. 2017)

August 09, 2017
RELEASE 17-069
NASA Selects Proposals to Study Galaxies, Stars, Planets

SPHEREx
An ALL-SKY Spectral Survey

July 18, 2016

SPHEREx
An ALL-SKY Spectral Survey

NASA has selected six astrophysics concept study proposals as part of the agency's Explorers Program. The proposed studies will study various emissions from galaxies, galaxy clusters, and neutron star systems, as well as exoplanet atmospheres, as a way to fill in the gaps between the agency's larger missions. Credit: NASA

Spectro-photometry with LVF

SPHEREx (MIDEX mission)
- Korean contributions: H/W, S/W & Science
- In Phase—A study

Review for SMEX (Nov. 2016)
Failed → MIDEX
SpHEx (2022?)

- Spectro-PHotometer for the Extragalactic structure, Reionization and ices Explorer
  as a candidate of NASA MIDEX Mission: Phase-A Study
- Spectro-photometric all-sky survey: 1.4B spectral catalog (0.75 ~ 4.8μm, R=40 ~150)
  - Galaxies (Emission Line Galaxies)
  - QSOs
  - Galaxy clusters
  - Mass-losing stars
  - Brown dwarfs
  - H₂O ices, ...

- SPHEREx is the upgraded mission of the NISS
Notable Features of the SPHEREx All-Sky Survey
- High S/N spectrum for every 2MASS source
- Solid detection of faintest WISE sources
- Catalogs ideal for GMT/JWST observations
- Redshifts for other surveys (e.g., eRosita X-Ray survey)
- Photo baselines for wide-field transient survey
- Mapping 3D distribution of Galactic ices
- …
SPHEREx: LSS

ORIGIN OF THE UNIVERSE

Time Since Big Bang

Cosmic variance

Effective Volume, \( V_{\text{eff}} \)

[\text{Gpc}(h^3)]

\( f_{NL} \) PoS sample

BiS, Cosmo. sample

1σ errors, statistical (systematics)

| \( f_{NL} \) | 0.86 (0.15) | 0.23 (0.05) | 0.15 (0.03) |
| Euclid (GC) | 5.59 | 5.0 |
| Spectral Index \( n_s \) x 10^{-3} | 2.6 | 1.5 | 1.4 |
| Running \( \alpha_s \) x 10^{-3} | 1.0 | 1.0 | 0.49 |
| Curvature \( \Omega_k \) x 10^{-4} | 7.6 | 9.5 | 6.6 |
| Dark Energy FOM | 381 | NC | NC |

Current
- Expected Lyman EOR features, with SNR >100 on the RMS fluctuations
- Faint EOR signal using distinctive spectral features and cross-correlations.
- Minimum EOR signal
- Line Intensity Mapping: Amplitude of linear clustering in multiple lines
Abundance and composition of biogenic ices (H₂O, CO₂, CO, XCN and CH₃OH) in dense molecular clouds and protoplanetary disks.
KASI’s Contribution @ MIDEX

- Data reduction pipeline (L0 & L4)

- Science (especially extragalactic science)
  - 2018 Science Workshop @ CfA, Boston
  - Pre-study with NISS

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

- **L0 & L1**: System calibration data sets
- **L2 ~ L4**: Sequential release in public
  - **L2**: Calibrated Spectral Images
  - **L3**: All-Sky Spectral Catalog
  - **L4**: Scientific Research – Intensity mapping
    - **L4-IC**: Cosmological Parameters
    - **L4-GI**: Galactic Ice Parameters
    - **L4-GF**: Galaxy Formation Parameters
NISS (2018)
- Full development in Korea: limited resources & manpower!
- Technical demonstration: spectro-photometry with LVFs
- Spectro-photometric survey > 150 deg$^2$
- Launch @ late 2018: Falcon9 @ SpaceX → 2-yr operation
- New science cases: inviting!

Contributing sources to CIB?

SPHEREx (MIDEX mission): all-sky spectro-photometric survey @ 2022?