The LAPYUTA (Life-environmentology, Astronomy, and PlanetarY Ultraviolet Telescope Assembly) Mission

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The LAPYUTA (Life-environmentology, Astronomy, and PlanetarY Ultraviolet Telescope Assembly) is an ultraviolet space telescope mission scheduled for launch in the early 2030s. LAPYUTA has four scientific objectives. Objective 1 will focus on the boundary region between space and planets/moons in the solar system. We will perform continuous monitoring of water plumes erupted on the surface of Jupiter's icy moons and auroral emissions on the icy moons and the planet to elucidate the material and energy supply processes in the moons. The global distributions of water and greenhouse gases in the upper atmosphere of Mars and Venus enables us to uncover how these gases diffuse into space through the coupling between the lower and upper atmospheres and responses from the solar wind and solar activity. Objective 2 is characterization of atmospheres of exoplanets in the habitable zone and to estimate the surface environment of the planets. For cosmology and astronomy, Objective 3 is to test whether the structures of present-day galaxies contain ubiquitous Lyα halos and to reveal the physical origins of Lyα halos, and Objective 4 elucidates the heavy element synthesis process from observations of ultraviolet radiation from hot gas immediately after neutron star mergers. The main scientific payload is a Cassegrain-type telescope with a 60 cm diameter primary mirror. Two main UV instruments are installed in the focal plane of the telescope: a spectrograph and a slit imager. The spectrograph will have a spectral resolution of 0.02 nm and a field of view of 100 arcsec. The UV slit imager will consist of imaging optics, multiple bandpass filters with a rotating wheel, and a UV detector. To achieve a high spatial resolution of 0.1 arcsec, a target monitoring camera is installed at the slit imager and the 0th order position inside the spectrometer for attitude control and image correction.

Goals & Objectives

Goal1: habitable environments in the universe

(Objective 1) habitable environments in the solar system
- Current geological activity of icy moons
- Atmospheric evolution of terrestrial planets

(Objective 2) Exoplanet atmosphere
First Detection of Upper Atmosphere of an Earth-like Planet

Elements for the habitable environment
Hydrogen, Oxygen, Carbon → Advantage of UV spectroscopy

(Objective 3) Formation of present-day galaxy
- Ubiquitousness of Lyα halos
- The physical origins of Lyα halos (the Cold Streams)

(Objective 4) Origin of The heavy element
- The heavy element nucleosynthesis by neutron star mergers & Understanding of the final stage of massive star evolution

UV astronomy

Goal2: the origin of matter and space in the universe

Mission Features

EUV spectroscope HISAKI (2013-2023)
Time variable features of Mars/Venus/Jupiter

Hubble Space Telescope (STIS:1997-, COS:2009-)
Leading the ultraviolet astronomy

Limitation: Sensitivity & spatial resolution
Difficult to observe
- Spatial distribution of planetary atmospheres
- Exoplanets
- Small bodies (such as moons around Jupiter)

Limitation: Low altitude & Machine time
- Influence of geocorona: H Lyα, O 1304nm, etc.
- Not suitable for "Target of Opportunity" observation and long-term continuous observation

LAPYUTA
- Focus on Hydrogen, Oxygen and Carbon
- x 100 sensitivity and spatial resolution of HISAKI
- Target tracking capability like HISAKI

By resolving the previous constraints, LAPYUTA will explore
- Habitable Environment of the Solar System and Beyond
- Unsolved problems in ultraviolet astronomy

Habitable Environment of the Solar System and Beyond

[1-1] Icy moons of giant planets: A second habitable environment
- Physical properties of water plumes and auroras
- Current geological activity of icy moons
- Supply of chemical energy to moons

[1-2] Atmospheric escape of Venus & Mars: Atmospheric evolution

Global observations of H, O, and C
Ongoing atmospheric escape & response to Sun and atmospheric variability
Atmospheric escape under past solar conditions
Extension the knowledge to exoplanet

[2] Exoplanetary Atmospheres: Planets in the habitable zone Earth-like?

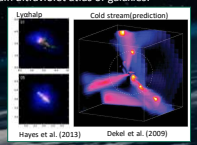
Transit observation with Ultraviolet Spectroscopy: Detection of upper atmosphere of terrestrial planets
(1) First detection of expanded upper atmospheres (O)
→ Discovery of habitable planet candidates
(2) First detection of large outflow atmosphere (H, O, C')
→ understanding of planetary evolution (runaway greenhouse, etc.)
(3) High-energy radiation from central stars (stellar flares, CME, etc.)
→ understanding of direct effects on atmospheres

Unsolved problems in ultraviolet astronomy

[3] Formation of present-day galaxy

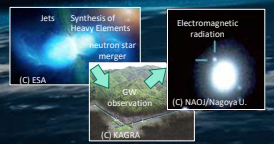
Ubiquitousness of the Galactic Lyα Halo
- Presence of the Lyα halo in galaxies today?

Large-Scale Structure of the Universe
~First Detection of "Cold Streams" in Galaxies
- Physical origin of the galactic Lyα halo.
- Basic structure of the material around galaxies.
- Verification of the galaxy formation process.
- Obtain ultraviolet atlas of galaxies.



[4] Origin of The heavy element

Era of "Multi-messenger Astronomy"
Observation of total spectral distribution of the radiation and its time evolution from neutron star mergers (within 3 hours from discovery)
- Understanding the Origin of Heavy Elements
- Overall Picture of the Synthesis of Heavy Elements



What's LAPYUTA ?

- Earth orbiting ultraviolet (UV) space telescope (ϕ60cm)
- Selected as a candidate of 6th JAXA M-class mission
- Target launch year: 2032

Four Scientific Objectives
(1) Habitable environments in the solar system
Jupiter's icy moons & Mars/Venus
(2) Exoplanet atmosphere
(3) Formation of present-day galaxy
(4) Origin of The heavy element

Specifications

Focal Plane Instruments
UV spectrograph (option: echelle spectrograph)
UV slit imager

Type	Cassegrain telescope (F32)
Primary mirror	60 cm (Diameter)
Effective area	>350 cm^2
Spatial resolution	(spectral) 0.1 arcsec
	(imaging) 0.2 arcsec
Spectral range	110 - 190 nm
Spectral resolution	0.02 nm (option: 0.003nm)
Field of view	(spectral) 100 arcsec
	(imaging) 3 arcmin x 3 arcmin
Bus system	SPRINT bus
Apogee altitude	~1,000km x 2,000 km

High sensitivity approaching to HST (2.4m) and WSO-UV (1.7m) while keeping JAXA M-class (0.6m)
- Minimization of the number of optical elements
- Improving of high efficiency optical elements

Technology Deployment
- High resolution small space telescope
- Participation in the NASA 6-m Telescope (Habitable World Observatory) ex) Large format detector

Time allocation plan

Baseline
- **Solar system bodies**: optimized by solar separation angle
  - Jupiter & Mars: around oppositions
  - Venus: around maximum solar elongation angle
- **Exoplanets** & **Astronomical targets**
  - Unsuitable periods for the solar system bodies
- **Neutron star mergers**, **Supernova** & **stellar flares**
  "Target of Opportunity"
  with 24-hour operation campaign (3 months/year)
- **Public slot** (~2 months/year)

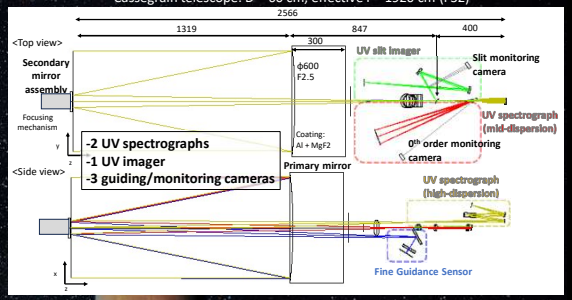
Primary mission period : 3 years
The mission period will be extended up to 9 years if the instruments are in good health.

Time allocation plan

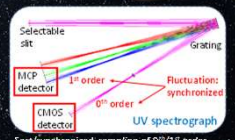
- Solar system bodies
- Exoplanet
- Astronomical object
- Public slot
- ToO

Preliminary optical design

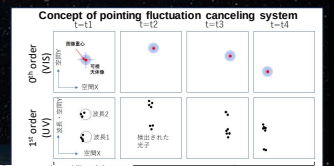
Cassegrain telescope: D = 60 cm, effective f = 1920 cm (F32)



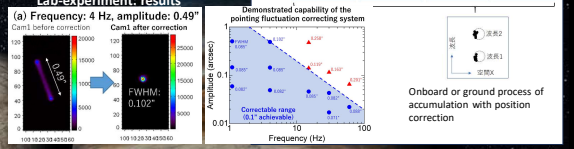
Key technology: Pointing fluctuation cancelling system



Fast/synchronized sampling of 0th/1st order



Lab-experiment: results



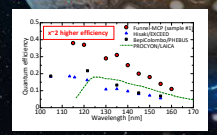
Onboard or ground process of accumulation with position correction

Key technology: MCP detector for UV

1. High efficiency: funnel-type MCP

2. Large format: MCP-array

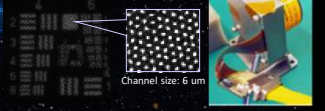
Goal: 3 x 3 array with □70 x 70 mm funnel MCPs to achieve >200 x 200 mm format



Test model (ϕ40mm) achieved 2 times higher efficiency than Hisaki (to be used for WSO-UV/UVSPEX)

3. High dynamic range and resolution: CMOS-coupled MCP

Test model achieved dynamic range of >10^{11} and MCP-channel resolution (6 um) (to be used for WSO-UV/UVSPEX)
CMOS: CMOSIS CMV4000 (baseline)



Key technology: UV mirror coating

UV mirror coating: Al + MgF2
Improvement/optimization of evaporation process
- Optimized MgF2 thickness for λ = 130 nm
- Evaporation method
- Substrate temperature
- Process Speed

Option: Al + LiF、Al + Al2F3

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