Naoyuki Tamura
(Kavli Institute for the Physics and Mathematics of the Universe, the University of Tokyo)

Title: **Prime Focus Spectrograph (PFS): Overview of the instrumentation and its current status**

Abstract: PFS (Prime Focus Spectrograph), a next generation facility instruments on the Subaru telescope, is a very wide-field, massively multiplexed, and optical & near-infrared spectrograph. Exploiting the Subaru prime focus, 2400 reconfigurable fibers will be distributed in the 1.3 degree-diameter field of view. The spectrograph system has been designed with 3 arms of blue, red, and near-infrared cameras to simultaneously deliver spectra from 380nm to 1260nm in one exposure. The instrumentation has been promoted by the international collaboration under the initiative of Kavli IPMU. The team are actively integrating and testing the hardware and software of the subsystems. Last year in 2018, we managed to deliver one of them, Metrology Camera System, to the observatory at the summit of Maunakea, and subsequently tested it on the telescope in the nighttime. The development of the other subsystems is steadily progressing, aiming at starting engineering observation in 2020, and science operation from 2022. We are also making substantial simulation efforts to develop a survey plan in the framework of Subaru Strategic Program (SSP). In this presentation, we will give an overview of the instrumentation, current status and future perspectives.
Title: Prime Focus Spectrograph (PFS): The metrology camera system

Abstract: The metrology camera system (MCS) serves as the optical encoder of the fiber motors for the configuring of fibers in PFS. MCS provides the fiber positions within a 5 microns error over the 45 cm focal plane. The information from MCS is fed into the fiber positioner control system for the closed loop control. MCS locates at the Cassegrain focus of Subaru telescope in order to cover the whole focal plane with one 50M pixel Canon CMOS camera. It is a 380mm Schmidt type telescope which generates a uniform spot size with a ~10 micron FWHM across the field for reasonable sampling of the point spread function. The positions of all fibers can be obtained within 0.5s after the readout of the frame. This enables the overall fiber configuration to be less than 2 minutes. The system was completed in early 2018 and delivered to Subaru telescope in April 2018.

In this report, we will present the major components for MCS and the latest test results of MCS during the engineering run with Subaru telescope.
Title: Prime Focus Spectrograph (PFS): The status of integration and testing of Prime Focus Instrument

Abstract: The prime focus unit of PFS called Prime Focus Instrument (PFI) provides the interface with the top structure of Subaru telescope and also accommodates the optical bench in which Cobra fiber positioners are located. In addition, the acquisition and guiding cameras (AGCs), the optical fiber positioner system, the cable wrapper, the fiducial fibers, illuminator, and viewer, the field element, and the telemetry system are located inside the PFI. The mechanical structure of the PFI was designed with special care such that its deflections sufficiently match those of the HSC’s Wide Field Corrector (WFC) so the fibers will stay on targets over the course of the observations within the required accuracy. The PFI structure and component was delivered in 2017 and the integration of PFI started in 2018. The integration of the Cobra modules started in 2019. In this report, the latest status of PFI development will be given including the procedure of the PFI integration, the integration and testing results.
Daniel Reiley  
(Caltech)

Title: Prime Focus Spectrograph (PFS): Delivery of subassemblies from Caltech

Abstract: The team in Pasadena, including Caltech, JPL, and LNA, have completed all assemblies for the Prime Focus Instrument (PFI) subsystem of Prime Focus Spectrograph (PFS). These items include mechanical, electrical, and optical subassemblies and subsystems. By far the largest task was the delivery of 44 Cobra modules, each of which integrates 57 fibers, microlenses, and positioners, as well as mechanical support and electrical drive electronics. Quality of these assemblies was controlled via detailed work instructions and was monitored via metrology of many performance characteristics. One of these characteristics, beam angle, is shown in detail.
Title: Prime Focus Spectrograph (PFS): FRD testing of individual Cobras and Cobra modules

Abstract: Focal ratio degradation (FRD) is a degradation in angular distribution of light exiting an optical fiber, relative to its angular distribution at the fiber’s input. This effect is important to the Subaru PFS because it affects the point spread function in the spectrographs, thereby affecting the fidelity of sky subtraction. Caltech has completed detailed studies on FRD in fibers, with precise measurements on the fiber level, detailed system-level simulations, and preparation for module-level measurement in production.
David Le Mignant
(Laboratoire d'Astrophysique de Marseille (LAM, Aix-Marseille Université, CNRS))

Title: **Prime Focus Spectrograph (PFS): integration and performance tests of the spectrograph modules**

Abstract: The spectrograph modules for the Prime Focus Instrument are now in the phase of assembly, integration and tests, fully verified first in France, then at Subaru telescope in Hawaii. In this poster, we report on the assembly, integration and tests of the first two spectrograph modules at Laboratoire d'Astrophysique de Marseille (LAM, Marseille, France). We briefly present the hardware configuration, the functional performance and alignment procedures. We then present and discuss the image quality results (ensquared energy, spectral resolution, scattered light, etc.). The 2019-2021 schedule for the integration & tests for the 4 spectrograph modules, leading to the Subaru spectrograph readiness is also presented.
Title: **Prime Focus Spectrograph (PFS): Fiber Optics System**

Abstract: The fiber optic system to be used in the PFS project was divided into three parts being called; Cable A, Cable B, and Cable C. When A, B, and C cables are connected they will form a cable with a 65-meter cable. We have chosen two types of optical fiber manufacturer, Fujikura, and Polymicro so we could get better performance. Each of these parts makes a connection using connectors that have been developed to connect 651 optical fibers at once time. The fibers start at Cable C where we have the light input, it passes through the connectors, Cable B, and ends in the slit, Cable A, where we have the light output being analyzed by 4 spectrographs in the total of 2394 fibers. We describe and show how each of these parts is assembled. Also, we describe the type of polish for optical fibers and the assembly of fibers terminations.
Graham J. Murray
(Durham University)

Title: Fibre Cables from FMOS to PFS and beyond - Development of a Unique Fibre Cable Manufacturing Process for Subaru MOS Projects.

Abstract: For integral-field and multi-object astronomical spectroscopy, fibres offer unique flexibility by enabling spectrographs to be located remotely from the telescope focal plane. Photon-starved observations demand optimum optical efficiency, so fibre losses must be minimised. In addition to intrinsic absorption in the fibre, another loss mechanism, so-called “focal ratio degradation” (FRD) must be considered. A fundamental cause of FRD is stress, therefore low stress cables that impart minimum fibre FRD are essential. FMOS for Subaru Telescope employed a highly effective cabling solution developed at Durham University in collaboration with the company PPC Broadband Fiber Ltd. The manufacturing process has been improved and reapplied for PFS, thus maintaining a long and productive relationship between Durham and NAOJ Subaru Telescope. The methods have subsequently found wider application in DESI and are likely to feature in MSE, ELT-HiRES and several large format IFU schemes. The process, planetary stranding, is adapted from the manufacture of marine telecommunications cables. Fibre bundles describe helical paths through the cable, incorporating additional fibre per unit length. As a consequence fibre stress from tension and bending is minimised. This poster describes the stranding principles and the manufacturing process, incorporating the latest test data from the PFS science cables.
Title: **Prime Focus Spectrograph (PFS): Development of the 2D sky subtraction algorithm**

Abstract: Sky subtraction in 2D offers natural advantage over the subtraction in 1D as it able to account for the full complexity of the PSF, some of which is always lost when simplifying a PSF to a 1D problem. The main factors that need to be known to model individual PSFs are the optical aberrations and the illumination of the spectrograph camera. This final illumination of the camera depends on the properties of individual fibers and the vignetting at the entrance to the fiber. We have been developing an algorithm which will be able to predict the 2D PSF at any position on the detector plane and under various vignetting angles. Drawing from our experience from the HSC project, we have been analyzing the strongly defocused arc data taken at the optical bench in order to precisely characterize optical aberrations across the whole detector plane. Use of defocused images also allows us to decouple the influence of the focal-ratio degradation in the fiber and the optical aberrations on the final PSF. We plan to use this algorithm to remove the wings of the bright sky lines. We show some preliminary results demonstrating the quality of the subtraction.
Title: **Prime Focus Spectrograph (PFS): Development in flux calibration and sky subtraction**

Abstract: We report the current status of our software development on flux calibration and sky subtraction for the Subaru Prime Focus Spectrograph (PFS) data. PFS, a next generation instrument, is a very wide-field multi-object spectrograph in optical and near-infrared wavelength. PFS simultaneously observes 2394 spectra of 380-1260 nm wavelength using fibers distributed over the 1.3 deg diameter field of view. We are developing software modules for flux calibration and sky subtraction in a data reduction pipeline, taking part in an international collaboration.

The flux calibration is performed using F-type stars which are pre-selected from broadband colors (e.g., HSC-SSP). We use the AMBRE stellar model templates to type observed spectra into stellar sub-groups and produce the flux calibration vectors. In our sky-subtraction module, we adopt a 1D algorithm in contrast to the 2D algorithm being developed for the main data reduction. We presume that our module will be useful in quick analysis if we make the 1D algorithm faster than the 2D one.
Vincent Le Brun
(Laboratoire d'Astrophysique de Marseille)

Title: **Prime Focus Spectrograph (PFS) : An overview of the automatic redshift measurement and spectral analysis pipeline**

Abstract: The PFS consortium will propose a large scientific program shared between 3 large spectroscopic surveys that will gather hundreds thousands of galaxy/QSO spectra in various redshift ranges. It is therefore necessary to develop an automated redshift estimation and spectral analysis pipeline, that will also deliver a reliability level of the measurement, as well as basic spectral parameters (line fluxes, equivalent widths). This poster describes the methods we use, as well as preliminary results on the first simulated data.
Maximilian Fabricius  
(Max-Planck for Extraterrestrial Physics)

Title: **Prime Focus Spectrograph (PFS): Fiber assignment and Survey Planning**

Abstract: The galaxy evolution and galactic archeology components of the PFS survey will target the same patch of sky from several dozens to 100 times. The problem of allocating PFS’ 2394 fibers to objects over many visits of a field is a highly non-trivial optimization problem that we solve through linear programming. Our new network flow approach models the fiber allocation as a generalized network min-cost/max-flow problem inspired by SDSS, but extends this to address the variety of conditions and requirements of the the PFS survey. It offers a clear sense of an optimal solution; while it may not find a globally optimal solution in finite computational time, it generally provides a very good solution in reasonable amounts of time and gives a clear quantitative measure of just “how good it is”. Our approach generally yields higher total number of observed science objects per given number of observations than “greedy” allocation algorithms and respects constraints like the minimal number of allocated calibration fibers, and the completion of already started objects. Finally, collisions are taken into account in an iterative manner by interfacing to a python reimplementation of the fiber collision simulation code.
Title: Prime Focus Spectrograph (PFS): the SSP survey plan and simulations

Abstract: A large spectroscopic survey using Prime Focus Spectrograph (PFS) in the framework of the Subaru Strategic Program (SSP) is now under planning. The survey, which consists of 3 science topics (cosmology, galactic archaeology, and galaxy/AGN evolution), has various conditions, for instance, (1) there are different target fields widely, (2) there are targets with different exposure time and scientific priority in the same field, (3) there may be requirements on the observation season and cadence. Considering this complexity, one of the important tasks is to make one coherent survey plan maximizing the entire scientific outputs.

We are now planning a detailed survey design conducting many simulations with the survey simulator in development. The survey simulator provides the optimal observation schedule for a given list of target fields and the required observing time. We also conduct detailed end-to-end simulations by simulating the entire process from the target selection to the data quality assurance, in which software we use in the actual operation such as fiber allocation software is partly implemented. In this presentation, we report the current status of the survey design and the survey simulations in detail.
Title: **Prime Focus Spectrograph (PFS): the expected performance**

Abstract: Prime Focus Spectrograph (PFS) on Subaru Telescope has a power of conducting large spectroscopic surveys thanks to its wide field-of-view, multiplicity, and wide spectral range. The expected performance of the instrument should be defined beforehand to plan the survey design and carry out the feasibility study of targets in interest.

PFS project office presents the expected performance partly using the actual throughput measurement of some instrument components and provides some tools such as the exposure time calculator (ETC) and the spectral simulator. In this poster, we present the latest performance that we expect, showing an example of simulated spectra.

The sky subtraction capability is also critical to the performance for especially faint targets at higher redshift. We examine the possible uncertainty of the sky subtraction utilizing the ETC assuming several possible cases of the sky subtraction residual. We also examine the effect of fiber aperture by using the optical model of the telescope and instrument. In this poster, we also present the recent progress of these studies and discuss a possible impact on the scientific performance.
Masayuki Tanaka
(NAOJ)

Title: **Prime Focus Spectrograph (PFS): Science Database**

Abstract: Prime Focus Spectrograph (PFS) is going to deliver a large number of spectra with a wealth of information about emission and absorption lines of objects. In order to handle and explore the massive data efficiently, National Astronomical Observatory of Japan (NAOJ) and the Johns Hopkins University (JHU) are building a data analysis environment for PFS that serves both HSC imaging data and PFS spectroscopic data. The combination of these data sets makes it difficult to carry out science in a classic 'download-data-and-analyze-locally' way; the total data volume is too big (over several hundred TBytes) to be transferred over the network. We provide a Jupyter Notebook environment, where users can login and analyze data on a remote server, thus eliminating massive data transfer. We combine the SciServer environment developed by JHU and a number of data analysis tools developed by NAOJ to build this Jupyter Notebook environment. We are prototyping a system and iterating with science users to make the system ready for science by the time PFS starts science operation. We describe the current status and discuss future development plans.
Junko Furusawa  
(Astronomy Data Center, NAOJ)

Title: Current Status of SMOKA

Abstract: SMOKA (Subaru-Mitaka-Okayama-Kiso Archive system, URL: https://smoka.nao.ac.jp) provides to general users with public data observed with the Subaru Telescope and several optical and infrared telescopes operated by Japanese institutes. SMOKA not only promotes further utilization of observational data for research and educational activities, but also enables verification of research results. The system has been in operation since June 2001. The data size of 33TB are downloaded from SMOKA, and 14 academic papers based on the archived data came out in the last fiscal year. One of the biggest changes of the service recently made is hosting Hyper Suprime-Cam (HSC) raw data, which was started in February 2014. In particular, we have been successfully providing the raw data from the Subaru Strategic Program with HSC, synchronously with its public data releases (February 2017 and May 2019). We report developments and usage status of the SMOKA system in the past year, and discuss our future scheme of operation and improvements.
Abstract: The Subaru Strategic Program (SSP) with Hyper Suprime-Cam (HSC) is a wide-field imaging survey for covering 1400 square degree fields by five optical wavebands (g, r, i, z, y), which is cooperated by an international collaboration of Japan, Princeton University, and the Taiwan community. The project involves development of pipeline, data processing, and construction of a data archive service for products. In May 2019, we launched the second public data release (PDR2). This release includes processed images and catalogs for over 300 square degrees of multi-waveband data (March 2014 through January 2018). The data set comprises Wide (r~26) and Deep+UltraDeep (D+UD) data (r~27.5-28). The D+UD data are covered by four narrow-band (NB387, 816, 921, 1010) as well as the five broad bands. The products involves several new important features including a bug fix in PSF modeling, sky-background subtraction using a global pattern across field-of-view, scattered light subtraction in the y band, and improvement in a coaddition and source detection. The archive service provides users with useful functions to retrieve necessary data, such as catalog search, image cut-out, an interactive viewer. We will discuss the project status and plan for the future releases.
Title: Stacking the Suprime-Cam image archive at the CADC

Abstract: To increase the legacy value of the Suprime-Cam data, the CADC is calibrating and stacking the entire archive. The individual raw images are detrended (bias-subtracted and flat-fielded) using the sdfred2 software package. The images are astrometrically calibrated using GAIA and photometrically calibrated using Pan-STARRS. The individual images are then resampled and stacked using SWarp on to a grid of tiles covering the sky.
Title: **Instrument, Software, and Operation Status of the InfraRed Doppler Spectrograph (IRD)**

Abstract: InfraRed Doppler (IRD) is the high-dispersion ($R \sim 70,000$) spectrograph that works on the Subaru Telescope mainly to find and characterize exoplanets based on precision radial velocity (RV) measurements in the near-infrared. Laser frequency comb (LFC) that ranges from about 1 to 1.7 um calibrate IRD’s RV measurements, enabling the efficient RV sampling for cool objects like late-M dwarfs. The adaptive optics system, AO188, corrects the wavefront error of object light, which is then injected into optical fibers through fiber injection module and transferred to the spectrograph. IRD employs several mode-scramblers to suppress modal noise of multi-mode fibers. In future, the extreme AO system, SCExAO, can be used with IRD, allowing us to optimize the use of single mode fibers. IRD has been available for science observations since 2018, and it is now running for the Subaru Strategic Program (SSP) and open-use observations. Here, we report the latest status of IRD’s instrument, and its software for observation operation and data reduction. Our report includes the stability of our RV measurements that have been tested from our on-sky observations.
Title: **Performance of New NIR Imager/MOS Spectrograph SWIMS on the Subaru Telescope**

Abstract: SWIMS, a simultaneous-color wide-field infrared multi-object spectrograph, is one of the first generation instrument for the University of Tokyo Atacama Observatory 6.5m telescope, which is no under construction at Chile. For an initial test and performance verification, we have installed SWIMS on the Cassegrain focus of Subaru telescope and successfully carried out two engineering runs. By the data obtained, we have verified that the performances of SWIMS is as good as designed, and is capable of carrying out science observations. In this presentation, we will introduce the design and performances of SWIMS and show the future plan of its operation.
Sebastien Vievard  
(Subaru Telescope - Observatoire de Paris - Astrobiology Center)

Title: **FIRST instrument at Subaru - Status and upgrades**

Abstract: FIRST, the Fibered Imager foR a Single Telescope instrument, is an ultra-high angular resolution spectro-imager, able to deliver calibrated images and measurements beyond the telescope diffraction limit, a regime that is out of reach for conventional AO imaging.

FIRST achieves sensitivity and accuracy by coupling the full telescope to an array of single mode fibers. Interferometric fringes are spectrally dispersed and imaged on an EMCCD. An 18-Fiber FIRST setup is currently installed on the Subaru Coronographic Extreme Adaptive Optics instrument at Subaru telescope. It is being exploited for binary star system study. In 2020 it will be upgraded with delay lines and an active LiNb03 photonic beam-combining chip allowing phase modulation to nanometer accuracy at MHz.

On-sky results at Subaru Telescope have demonstrated that, thanks to the ExAO system stabilizing the visible light wavefront, FIRST can acquire long exposure and operate on significantly fainter sources than previously possible. A similar approach on a larger telescope would therefore offer unique scientific opportunities for galactic (stellar physics, close companions) and extragalactic observations at ultra-high angular resolution.
Title: A second generation astro-comb for SUBARU/HDS

Abstract: We have developed a new astro-comb operating in the visible wavelength regime for installation at SUBARU-HDS. The astro-comb with its mode spacing of 30 GHz will provide a precise wavelength calibrator for HDS to allow precision spectroscopy over a wide wavelength range covering 350-830 nm in three broadband windows. We will give an overview of the instrument and show first performance results based on an extensive test in summer 2019 at the Okayama observatory where the comb is tested on the HIDES spectrograph mounted at the 1.88m telescope.
Koki Terao  
(Tohoku University)

Title: ULTIMATE-START I: Subaru Tomography Adaptive optics Research experiment overview

Abstract: We present the current states of ULTIMATE-START (Subaru Tomography Adaptive optics Research experiment) project, which is a laser tomography adaptive optics experiment modifying the current AO188 laser guide star system. Main goal of the project is to improve the LGS AO performance and achieve AO correction in the shorter wavelength range down to 650 nm. In a single laser guide star (LGS) system, there is a "cone effect" problem that an LGS cannot cover the whole cylindrical light path of a science object. Thus, the accuracy of wavefront measurement and performance of the current LGS-AO is limited. As a method of reducing the cone effect, it has been proposed to cover the cylindrical region with multiple LGSs. Besides, the wavefront correction is performed in high precision by breaking the atmospheric turbulence in altitude direction using the tomography technique. Our LTAO system will be operated by four Shack–Hartmann wavefront sensors (WFS) and four LGSs. We are making the design of WFS systems and optimizing by numerical simulations.
Title: ULTIMATE-START II : Performance evaluation with AO simulations

Abstract: The ULTIMATE-START (Subaru Tomography Adaptive optics Research experiment) is a project led by Tohoku University in Japan to install a laser-tomography adaptive optics (LTAO) mode into AO188, which is a facility SCAO system operating at the Subaru telescope. The goal of this project is to improve the AO performance especially in visible wavelength and to demonstrate technologies for the future ULTIMATE-Subaru GLAO system. We will use 4 laser-guide stars (LGSs) and 4 Shack-Hartmann wavefront sensors (SH-WFSs) for the high-order tomographic wavefront measurement. The low-order mode is measured with one natural guide star (NGS) observed by the 2x2 SH-WFS in AO188, and the DM in AO188 applies the LTAO correction. In this presentation, we will present our performance evaluation for the LTAO system based on numerical simulations, including influences from brightness and angular distance of NGS and comparison with the current AO188 SCAO mode, under various of observation conditions and wavelengths.
Title: ULTIMATE-START III: Atmospheric turbulence profiling for a tomography AO

Abstract: We are developing a new laser tomography adaptive optics system for the Subaru telescope. In this system, tomographic estimation of atmospheric turbulence with 4 laser guide stars is going to be used in order to measure the effect of turbulence and to realize high Strehl Ratio observation in short wavelength range. The angle between two laser guide stars is only a few ten arcseconds, which makes the tomographic estimation an ill-posed inverse problem. Then, it is essential to get low resolution atmospheric turbulence profile as a prior information for tomographic estimation. In order to obtain the atmospheric turbulence profile, we are proposing to use Shack-Hartmann wavefront sensor scintillation information as a MASS (Multi Aperture Scintillation Sensor; Tokovinin 1998) measurement. The merit of the approach is the wavefront sensors in AO system can be used, and the atmospheric turbulence information in the same direction to the target can be obtained in real time. In this poster, we will report the detail of this method and current development status.
Title: ULTIMATE-Subaru: Project overview and current status

Abstract: ULTIMATE-Subaru is a Subaru’s next facility instrument project, which will provide wide-field near-infrared survey capability in late 2020s. ULTIMATE-Subaru will be equipped with a Ground-Layer Adaptive Optics (GLAO) system, which uniformly improves image quality over a wide field of view by correcting for the turbulence at the ground layer of the Earth’s atmosphere. The GLAO system consists of an adaptive secondary mirror, laser guide star facility, and wavefront sensor systems at Nasmyth IR (NsIR) and Cassegrain (Cs) foci. The telescope will be modified to have maximum FoV at Cs (~20’) and NsIR (~14’). We have successfully passed a conceptual design review of the GLAO system in 2018. Currently, preliminary design studies for GLAO and conceptual design studies for WFI and MOIRCS upgrade with GLAO are ongoing, as well as GLAO key subsystem prototyping and on-sky demonstration. In this presentation, we will provide ULTIMATE project overview and timeline. We will also introduce our current activities on the instrument design and the key technology development.
Title: **ULTIMATE-Subaru: science overview**

Abstract: We present an overview of the science goals of ULTIMATE-Subaru project - the development of ground layer adaptive optics (GLAO) on Subaru. The improved image quality (0.2" at K-band in the median conditions) over the wide FoV (~20-arcmin in diameter) will bring strong impacts on a wide variety of science fields in astronomy from studies of the very high-redshift universe to the present-day universe (including our Galaxy). In my poster, based on the extensive discussion within the ULTIMATE-Subaru science team over the last few years, we will summarize our key science goals, survey design, and the expected outcome of ULTIMATE-Subaru, including its great synergy with the other Subaru facility instruments (HSC/PFS), as well as the future space missions (JWST/WFIRST/Euclid). We hope to share the science capabilities of ULTIMATE-Subaru with all participants in the conference (including scientists from outside the current Subaru community), and to promote discussion on the wide-field strategy of Subaru during the conference.
Title: ULTIMATE-WFI: Wide Field Imager with 200 square arcmin FoV

Abstract: ULTIMATE Wide Field Imager (WFI) is a near-infrared wide field imager for Subaru GLAO system, now under conceptual design phase. WFI will be installed on the Cassegrain focus and cover FoV of 14arcmin on a side with image quality less than 0.1arcsec, to sample the 0.2arcmin image quality over 20 arcmin diameter of the GLAO system. As the diameter of the FoV is over 600mm, the optics is divided into four barrels with square field lenses under room temperature, with gaps less than 1arcmin. Each barrel has at least two filter wheels, one for broad/medium-band filters and the other for narrow-bands, and be imaged with a HAWAII-4RG 15um array. Preliminary design study of the optics shows good image quality of spot size less than 0.1arcsec over whole FoV, proving the feasibility of WFI. In this poster, we will introduce the WFI concept and its current design.
Title: Laser Guide Star Facility upgrade for ULTIMATE: SCAO, LTAO, and GLAO at Subaru

Abstract: Since its first light with 36 elements in 2002 and with 188 elements in 2006, Subaru’s AO facility has been providing excellent corrected seeing for many kinds of science for the past 17 years. In 2011, our AO system was further improved by the addition of a laser guide star facility (LGSF) which increased the sky coverage by a factor of three. In the next decade at Subaru, our AO system will step forward into the next scale by introducing laser-tomography (LT) and ground-layer (GL) AO modes, whose project names are ULTIMATE-START and ULTIMATE-Subaru. ULTIMATE-START is a milestone project toward ULTIMATE-Subaru to demonstrate a multi-laser system at Subaru where we also enhance the AO correction for observations in the visible. ULTIMATE-Subaru will develop a next facility-class GLAO system at Subaru with an adaptive secondary to strengthen the extremely wide-field capability of Subaru Telescope.

In this presentation, we focus on a LGSF upgrade aspect of ULTIMATE project for the upcoming LTAO and GLAO systems at Subaru. We expect to install the TOPTICA laser in a single-beam configuration for SCAO in 2020, a four-beam configuration for LTAO in 2022, and a wide-asterism configuration for GLAO in 2025.