

PROCEEDINGS OF SPIE

Adaptive Optics Systems VII

Laura Schreiber
Dirk Schmidt
Elise Vernet
Editors

14–22 December 2020
Online Only, United States

Sponsored and Published by
SPIE

Volume 11448
Part One of Two Parts

Proceedings of SPIE 0277-786X, V. 11448

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

The papers in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. Additional papers and presentation recordings may be available online in the SPIE Digital Library at SPIDigitalLibrary.org.

The papers reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from these proceedings:

Author(s), "Title of Paper," in *Adaptive Optics Systems VII*, edited by Laura Schreiber, Dirk Schmidt, Elise Vernet, Proceedings of SPIE Vol. 11448 (SPIE, Bellingham, WA, 2020) Seven-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510636835

ISBN: 9781510636842 (electronic)

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time) Fax +1 360 647 1445

SPIE.org

Copyright © 2020, Society of Photo-Optical Instrumentation Engineers.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$21.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/20/\$21.00.

Printed in the United States of America by Curran Associates, Inc., under license from SPIE.

Publication of record for individual papers is online in the SPIE Digital Library.

SPIE. DIGITAL LIBRARY

SPIDigitalLibrary.org

Paper Numbering: *Proceedings of SPIE* follow an e-First publication model. A unique citation identifier (CID) number is assigned to each article at the time of publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online and print versions of the publication. SPIE uses a seven-digit CID article numbering system structured as follows:

- The first five digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc. The CID Number appears on each page of the manuscript.

Contents

Part One

ASTRONOMY WITH AO

- 11448 08 Planet formation with all flavors of adaptive optics: VLT/MUSE's laser tomography adaptive optics to directly image young accreting exoplanets [11448-3]
- 11448 09 Constraining orbits and masses of stellar companions with SCExAO imaging and REACH spectroscopy [11448-4]

PROCESSING TECHNIQUES FOR AO CORRECTED DATA I

- 11448 0A Review of PSF reconstruction methods and application to post-processing (Invited Paper) [11448-5]

UPGRADES AND NEW AO INSTRUMENTS IN DEVELOPMENT

- 11448 0D MAVIS: the adaptive optics module feasibility study [11448-9]
- 11448 0E Keck all sky precision adaptive optics [11448-11]

PROCESSING TECHNIQUES FOR AO CORRECTED DATA II

- 11448 0G Precise photometry and astrometry in the core of the globular cluster NGC 6121 using PSF-R techniques [11448-13]
- 11448 0H Starfinder2: a software package for identification and analysis of point-like sources in adaptive optics images with spatially variable PSF [11448-15]

STATUS OF AO PROJECTS I

- 11448 0K Overview of AO activities at Subaru Telescope (Invited Paper) [11448-19]
- 11448 0N Status of the SCExAO instrument: recent technology upgrades and path to a system-level demonstrator for PSI [11448-22]

MODELLING OF AO SYSTEMS

- 11448 0O Challenges in simulating advanced control methods for AO [11448-334]
- 11448 0P Overcoming the effect of pupil distortion in multiconjugate adaptive optics [11448-23]

NEW AO SYSTEMS ON SKY

- 11448 0T First light with adaptive optics: the performance of the DKIST high-order adaptive optics (Invited Paper) [11448-27]
- 11448 0U Prediction of the planet yield of the MaxProtoPlanetS high-contrast survey for H-alpha protoplanets with MagAO-X based on first light contrasts [11448-28]
- 11448 0V MUSE+GALACSI: the first years [11448-29]
- 11448 0W Design and performance of the PALM-3000 3.5 kHz upgrade [11448-31]

AO INSTRUMENTS ON ELTs

- 11448 0Y MAORY: the adaptive optics module for the Extremely Large Telescope (ELT) [11448-33]

WAVEFRONT SENSING FOR ELTs

- 11448 12 Petalometry for the ELT: dealing with the wavefront discontinuities induced by the telescope spider [11448-39]

REAL-TIME CONTROLLERS FOR ELTs

- 11448 14 Real-time control (RTC) systems and hardware considerations for next generation adaptive optics (AO) RTC (Invited Paper) [11448-41]
- 11448 15 Hard real-time core software of the AO RTC COSMIC platform: architecture and performance [11448-172]

WAVEFRONT SENSING

- 11448 19 First on-sky results of the CAWS wavefront sensor on the CANARY experiment [11448-48]

WAVEFRONT CORRECTORS

- 11448 1B Overview on wavefront corrector technologies for astronomy and solar adaptive optics systems (Invited Paper) [11448-49]
- 11448 1D TMT deformable mirror prototype testing and verification [11448-51]
- 11448 1E A new adaptive secondary mirror for astronomy on the University of Hawaii 2.2-meter telescope [11448-52]

MACHINE LEARNING IN AO

- 11448 1G Deep learning-based focal plane wavefront sensing for classical and coronagraphic imaging [11448-56]
- 11448 1H Convolutional neural networks for object-agnostic wavefront sensing in the presence of noise [11448-325]

TURBULENCE CHARACTERIZATION AND FORECASTING

- 11448 1J Turbulence nowcast for the Cerro Paranal and Cerro Armazones observatory sites [11448-59]
- 11448 1K Comparison of atmosphere profilers at Paranal and atmosphere parameters statistics: AOF-profiler, STEREO-SCIDAR, MASS-DIMM, LGS-WFS [11448-60]

PROGRESS OF UPCOMING SYSTEMS

- 11448 1L Development and status of MAPS, the MMT AO exoPlanet characterization system [11448-61]
- 11448 1M SHARK-NIR, toward the installation at the Large Binocular Telescope [11448-62]
- 11448 1O ULTIMATE-START: Subaru tomography adaptive optics research experiment project overview [11448-64]
- 11448 1P TROIA adaptive optics system for DAG Telescope [11448-65]

NEW IDEAS

- 11448 1Q The use of random phase patterns composed of huge number of elements for wavefront reconstruction in adaptive optics [11448-66]

11448 1T **Using the generalised-optical differentiation wavefront sensor for laser guide star wavefront sensing [11448-69]**

LASER GUIDE STARS II

11448 1U **Australia's first laser guide star: design and telescope integration at Mount Stromlo Observatory [11448-73]**

11448 1V **The use of sodium layer density anisotropies to fully measure the atmospheric turbulence, including tip-tilt, focus, and higher order aberrations [11448-74]**

TURBULENCE CHARACTERIZATION

11448 1W **Correction of finite spatial and temporal sampling effects in stereo-SCIDAR [11448-75]**

PATHFINDERS

11448 1Z **Validating advanced wavefront control techniques on the SCExAO testbed/instrument [11448-78]**

POSTER SESSION: CONTROL AND CALIBRATION

11448 29 **An advanced SCAO control concept based on mechanical mirror modes for METIS [11448-88]**

11448 2A **Identification and model predictive control of an experimental adaptive optics setup utilizing Kautz basis functions [11448-90]**

11448 2C **Predictive learn and apply: MAVIS application - learn [11448-93]**

11448 2E **ALIOLI: presentation and first steps [11448-95]**

11448 2H **GPI 2.0: optimizing reconstructor performance in simulations and preliminary contrast estimates [11448-100]**

POSTER SESSION: REALTIME CONTROLLERS

11448 2K **A feasibility study of the open source DARC RTC software as a baseline for a generic Gemini AO RTC [11448-142]**

11448 2L **Predictive learn and apply: MAVIS application - apply [11448-143]**

- 11448 2M **MAVIS real-time control system: a high-end implementation of the COSMIC platform** [11448-144]
- 11448 2N **Adaptive optics real-time control with the compute and control for adaptive optics (Cacao) software framework** [11448-145]
- 11448 2O **Implementation and initial test results of the new Keck real time controller** [11448-146]

POSTER SESSION: AO MODELING, ANALYSIS, AND SIMULATION

- 11448 2S **MAORY AO performances** [11448-162]
- 11448 2V **Design of a performance verification unit for the MAORY system** [11448-166]

POSTER SESSION: ASTRONOMY WITH AO

- 11448 2W **MAORY science preparation status** [11448-167]

POSTER SESSION: ELTS PROJECT STATUSES

- 11448 2X **The Giant Magellan Telescope high contrast phasing testbed** [11448-149]
- 11448 2Y **InfraRed Imaging Spectrograph (IRIS) on TMT: OIWFS opto-mechanical design update** [11448-150]
- 11448 30 **MAORY calibration unit design status** [11448-153]
- 11448 32 **MAORY main structure design: general overview** [11448-156]
- 11448 34 **MAORY: optical configuration and expected optical performances** [11448-158]
- 11448 35 **Optomechanical design of MAORY post focal relay optics** [11448-159]

POSTER SESSION: PROCESSING OF AO CORRECTED DATA

- 11448 37 **MICADO PSF-reconstruction work package description** [11448-169]

POSTER SESSION: REALTIME CONTROLLERS

11448 39 MAORY RTC, a status update [11448-173]

POSTER SESSION: WAVEFRONT SENSING

11448 3I Evaluating the performance of an Ingot wavefront sensor for the ELT: good news from simulations [11448-194]

11448 3N Design study for a three-sided reflective pyramid wavefront sensor for Shane AO [11448-200]

Part Two

POSTER SESSION: AO MODELING, ANALYSIS, AND SIMULATION

11448 3R MAVIS: system modelling and performance prediction [11448-103]

11448 3S The adaptive optics simulation analysis tool(kit) (AOSAT) [11448-104]

11448 3T A versatile turbulence simulator for high-resolution imaging studies of astronomical targets [11448-105]

11448 3V Operational forecast of the PSF figures of merit [11448-341]

11448 3W New concepts in vector-apodizing phase plate coronagraphy [11448-109]

11448 3Z Analytical model-based analysis of long-exposure images from ground-based telescopes [11448-111]

11448 42 On the sequence of deformable mirrors in MCAO: findings from an on-sky, closed-loop experiment [11448-114]

POSTER SESSION: MACHINE LEARNING IN AO

11448 49 Self-optimizing adaptive optics control with reinforcement learning [11448-205]

11448 4A Non-parametric point spread function modelling for adaptive optics systems [11448-206]

11448 4C Wavefront prediction using artificial neural networks with CANARY telemetry [11448-209]

11448 4E Statistical learning as a new approach for optical turbulence forecasting [11448-213]

- 11448 4F **Neural network wavefront sensor for the Large Binocular Telescope Observatory** [11448-214]
- 11448 4G **Improved training for the deep learning wavefront sensor** [11448-215]
- 11448 4H **Wide-field wavefront sensing with convolutional neural networks and ordinary least squares** [11448-324]
- 11448 4J **Denosing wavefront sensor images with deep neural networks** [11448-327]

POSTER SESSION: NEW AO SYSTEMS ON SKY

- 11448 4L **MagAO-X first light** [11448-218]
- 11448 4M **Multi-core fibre-fed integral-field unit (MCIFU): overview and first-light** [11448-219]

POSTER SESSION: PROGRESS OF UPCOMING SYSTEMS

- 11448 4R **Optical design of the adaptive optics system for DAG, the new 4 m Turkish telescope** [11448-293]
- 11448 4U **Calibrating ERIS data: as-built capabilities and performances of the instrument's inner calibration unit** [11448-296]

POSTER SESSION: ASTRONOMY WITH AO

- 11448 4V **Finding exoplanets in the habitable zone with light echoes** [11448-118]

POSTER SESSION: PROCESSING OF AO CORRECTED DATA

- 11448 4Z **The power spectrum extended technique applied to images of binary stars in the infrared** [11448-123]
- 11448 50 **Post-AO image reconstruction with the PSE algorithm** [11448-124]
- 11448 53 **High resolution residual wavefront reconstruction for closed-loop adaptive optics systems** [11448-129]
- 11448 54 **Incorporating adaptive optics controls history in post-processing of ground-based coronagraph models** [11448-132]
- 11448 56 **Real-time PSF estimation with GIRMOS** [11448-135]

- 11448 59 **Analyzing long-term performance of the Keck-II adaptive optics system** [11448-138]
- 11448 5A **Exoplanet imaging data challenge: benchmarking the various image processing methods for exoplanet detection** [11448-321]

POSTER SESSION: STATUS OF CURRENT AO PROJECTS

- 11448 5E **Multi-cascade image correction system for the Large Solar Vacuum Telescope** [11448-178]
- 11448 5H **The ORP on-sky community access program for adaptive optics instrumentation development** [11448-181]
- 11448 5I **Enhanced seeing mode: a technique for improving wide-field angular resolution in the near-infrared using adaptive optics** [11448-182]
- 11448 5J **Design and development of a high-speed visible pyramid wavefront sensor for the MMT AO system** [11448-332]

POSTER SESSION: WAVEFRONT CORRECTORS

- 11448 5K **GMT adaptive secondary mirrors subsystem final design** [11448-183]
- 11448 5L **Laboratory testing and calibration of the upgraded MMT adaptive secondary mirror** [11448-331]
- 11448 5N **Research on the large adaptive deformable mirror base on giant magnetostrictive material actuators** [11448-224]
- 11448 5O **Adaptive secondary mirrors performance and reliability improvements at the Large Binocular Telescope** [11448-225]
- 11448 5Q **High precision shape control of large deformable mirrors for adaptive optics** [11448-227]
- 11448 5R **Performance analysis of the adaptive secondary mirror for the UH2.2 telescope** [11448-229]
- 11448 5S **Photo-controlled deformable mirror based on silicon photoconductor** [11448-230]
- 11448 5T **Adaptive secondary mirrors upgrades at the Large Binocular Telescope** [11448-232]
- 11448 5U **Developing adaptive secondary mirror concepts for the APF and W.M. Keck Observatory based on HVR technology** [11448-233]
- 11448 5V **Performance of large-format deformable mirrors constructed with TNO variable reluctance actuators** [11448-234]

POSTER SESSION: WAVEFRONT SENSING

- 11448 60 **Aligning and testing the ingot wavefront sensor in the lab** [11448-241]
- 11448 61 **Test bench demonstration of the geometric wavefront sensor** [11448-242]
- 11448 62 **Wind estimates from layer-oriented MCAO telemetry: working towards wavefront prediction** [11448-243]
- 11448 65 **Measurements of image quality and surface shape of microlens arrays for Shack-Hartmann wavefront sensors** [11448-247]
- 11448 68 **Ingot wavefront sensor: from the Fourier End2End numerical simulation to the LOOPS test bench** [11448-250]
- 11448 6D **Focal plane wavefront sensing on SUBARU/SCEXAO** [11448-255]
- 11448 6G **Injecting pupil binary intensity map into the laboratory adaptive optics bench using phase-only LCoS-SLM device** [11448-258]
- 11448 6H **Fast pixel difference algorithm for determining piston step between optical mirror segments** [11448-259]
- 11448 6J **GPI 2.0: design of the pyramid wave front sensor upgrade for GPI** [11448-262]

POSTER SESSION: LASER GUIDE STAR SYSTEMS

- 11448 6S **Alignment and tolerancing of a mirror relay system for a newly upgraded LGS system on Subaru Telescope** [11448-273]

POSTER SESSION: PATHFINDERS, NEW PROPOSED SYSTEMS, AND CONCEPTS

- 11448 6W **MAVIS adaptive optics module optical design** [11448-280]
- 11448 6Y **Optical design and preliminary results of NEW EARTH, first Canadian high-contrast imaging laboratory test bench** [11448-282]
- 11448 6Z **Development of an experimental optical adaptive optics for small telescopes** [11448-283]
- 11448 71 **Dimensioning adaptive optics for future VLTI projects** [11448-286]
- 11448 72 **The multi-object adaptive optics system for the Gemini infra-red multi-object spectrograph** [11448-287]

- 11448 73 **Upgrading the Gemini Planet Imager calibration unit with a photon counting focal plane wavefront sensor** [11448-288]
- 11448 74 **Ground-based adaptive optics observations with orbiting nanosatellite (GO-ON)** [11448-290]
- 11448 75 **RISTRETTO: a pathfinder instrument for exoplanet atmosphere characterization** [11448-329]

POSTER SESSION: STATUS OF CURRENT AO PROJECTS

- 11448 76 **Developing the prototype adaptive optics system for the Gemini infra-red multi-object spectrograph** [11448-297]
- 11448 77 **Development of multi-conjugate adaptive optics system for monitoring of solar system planets** [11448-298]
- 11448 78 **Extremely high-contrast, high spectral resolution spectrometer REACH for the Subaru Telescope** [11448-299]
- 11448 7C **New NIR spectro-polarimetric modes for the SCExAO instrument** [11448-304]
- 11448 7D **Wavefront correction using MEMS deformable mirror for Earth observation satellite with large segmented telescope** [11448-305]
- 11448 7F **Potential optical design of a multi-conjugate adaptive optics instrument based on a modified Offner concentric relay for Gemini North** [11448-322]
- 11448 7G **KaIAO the swift adaptive optics imager on the 1.2m Euler Swiss telescope in La Silla, Chile** [11448-328]
- 11448 7H **On-sky performance and recent results from the Subaru coronagraphic extreme adaptive optics system** [11448-330]

POSTER SESSION: TURBULENCE CHARACTERIZATION, MEASUREMENT, AND MODELING

- 11448 7K **Turbulence monitoring at Calern observatory with the generalized differential image motion monitor** [11448-310]
- 11448 7L **The effect of intermittency of the jitter of astronomic images in the high-altitude observations** [11448-311]
- 11448 7O **Which isoplanatic patch size for high angular resolution techniques?** [11448-314]
- 11448 7P **Atmospheric turbulence profiling with a Shack-Hartmann wavefront sensor** [11448-315]
- 11448 7Q **Toward an optimal prediction of atmospheric turbulence by means of WRF model** [11448-316]

- 11448 7T **A program to monitor and improve routine AO operations [11448-320]**
- 11448 7U **Gaussian phase autocorrelation as an accurate compensator for FFT-based atmospheric phase screen simulations [11448-323]**