Detector Development at AIP and DZA

Martin M. Roth
Deutsches Zentrum für Astrophysik
Leibniz Institute for Astrophysics Potsdam (AIP)
University of Potsdam

40 billion € transformation funds 1.3 → DZA

STOP until 2030/2038 !

Kohleausstiegsgesetz (KAusG)

effective from 14.08.2020

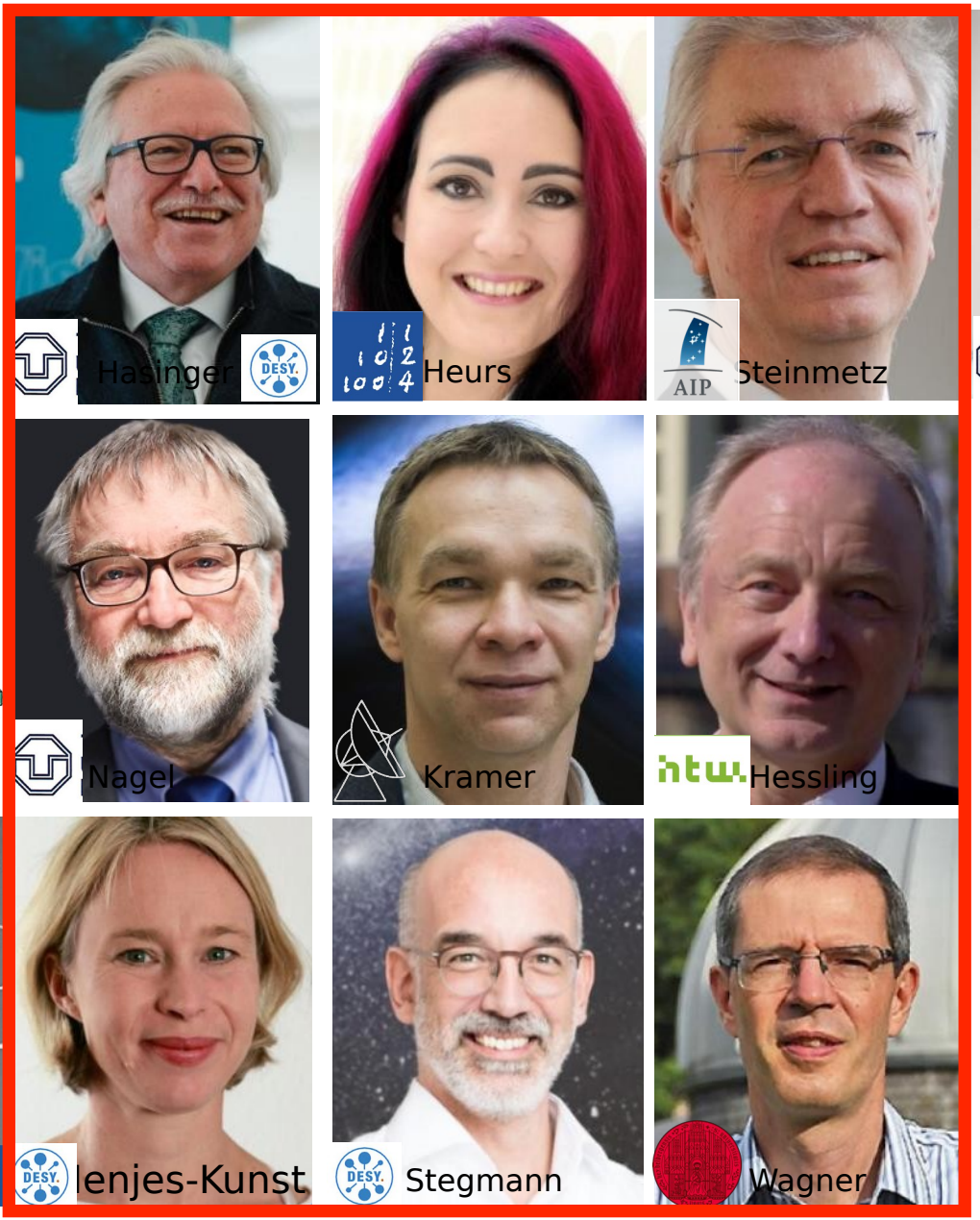
BGBl. I, S. 1818 (08.08.2020)

Forschung. Technologie. Digitalisierung.

Astrophysics and high technology in Saxony

DZA Deutsches Zentrum für Astrophysik

DZA Team and network



DZA concept : 3 pillars

Astronomy

Square Kilometre Array Observatory (SKAO)

Einstein Telescope (Low Seismic Lab)

Instruments

Developments for future astronomical experiments

Strong participation of Saxon industry

Data Intensive Computing

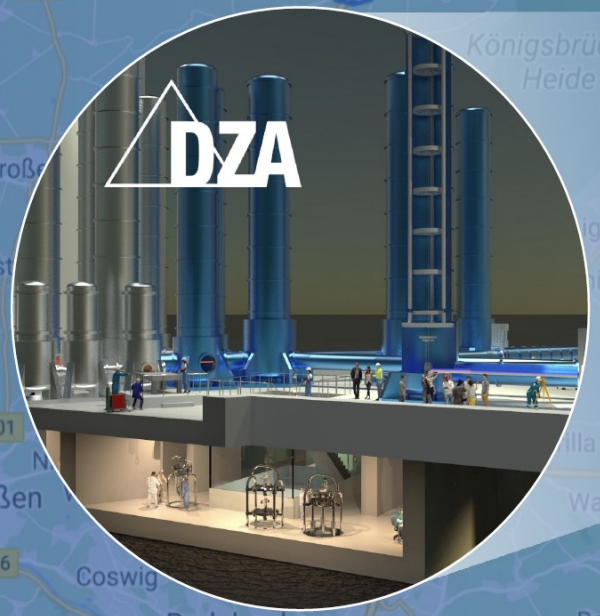
Processing huge amounts of astrophysics data from all over the world

Innovative AI based and Smart Green Computing

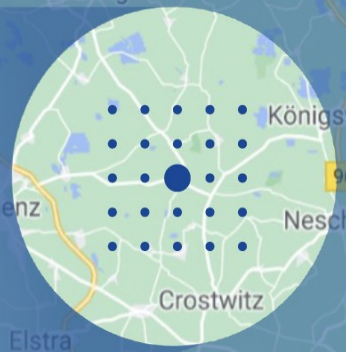
Interlocking of pillars → unique synergies


Vereinigtes Königreich
Isle of Man
Great Britain
Leeds
Liverpool
Manchester
Birmingham
Norwich
Cambridge
WALES
ENGLAND
Oxford
London
Bristol
Cardiff
Exeter
Bournemouth
Plymouth
Ärmelkanal
Guernsey
Jersey
Caen
Rouen
Paris
Versailles
Saint-Malo
Brest
Quimper
Rennes
Le Mans
Lorient
Angers
Tours
Nantes
Poitiers
Frankreich
Amsterdam
Niederlande
Rotterdam
Antwerpen
Brüssel
Belgien
Lille
Lüttich
Luxemburg
Groningen
Flensburg
Kiel
Lübeck
Hamburg
Rostock
Stralsund
Swinemünde
Koszalin
Kolberg
Danzig
Stettin
Bydgoszcz
Polen
Gorzów Wielkopolski
Posen
Płock
Łódź
Zielona Góra
Hannover
Bielefeld
Dortmund
Düsseldorf
Kassel
Deutschland
Leipzig
Dresden
Görli
Breslau
Częstochowa
Katowice
Prag
Pilsen
Tschechien
Ostrava
Brünn
Nürnberg
Karlsruhe
Stuttgart
Straßburg
Regensburg
München
Linz
Wien
Bratislava
Slowakei
Freiburg im Breisgau
Basel
Zürich
Dijon
Liechtenstein
Österreich
Graz
Schweiz
Berlin
Potsdam
Magdeburg
OpTecBB
DZA
AI
UHH
RUB
TLS
UNIVERSITÄT WÜRZBURG
EBERHARD KARLS UNIVERSITÄT TÜBINGEN
ESO
MPE
TUM
LMU
LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN
Google

Why in Saxony? Lusatia is a unique region for Astrophysics, Technology and Digitization



Location for the Low Seismic Lab



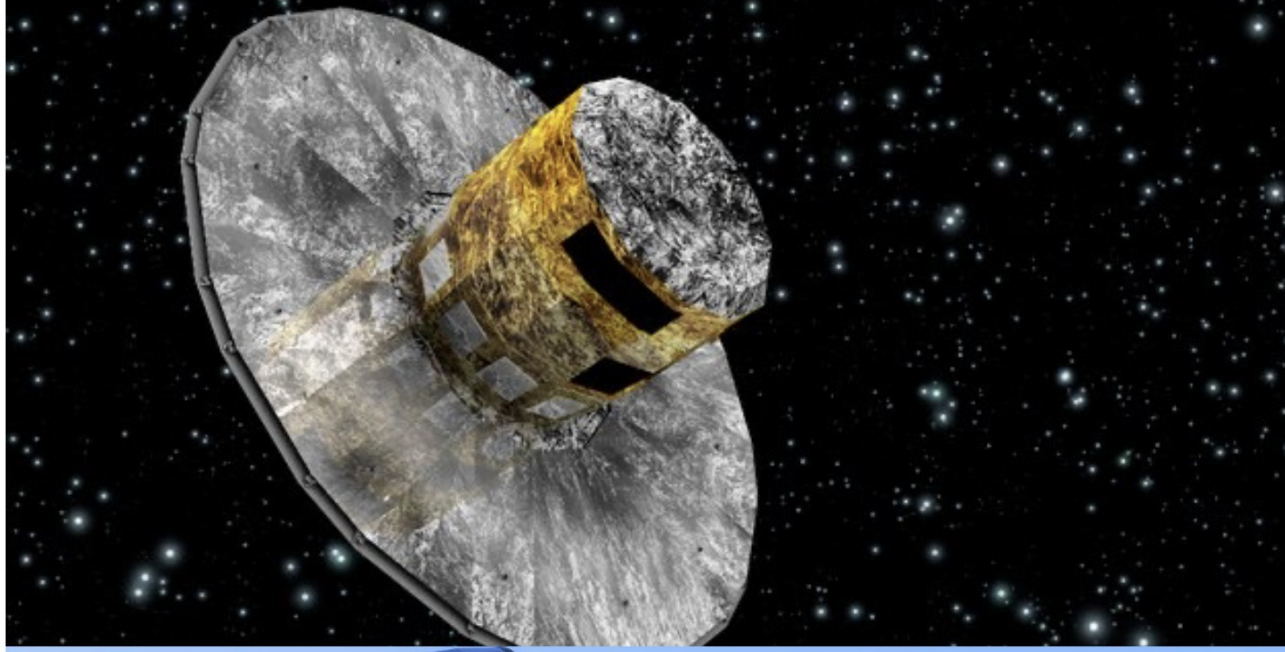
TECHNISCHE UNIVERSITÄT DRESDEN

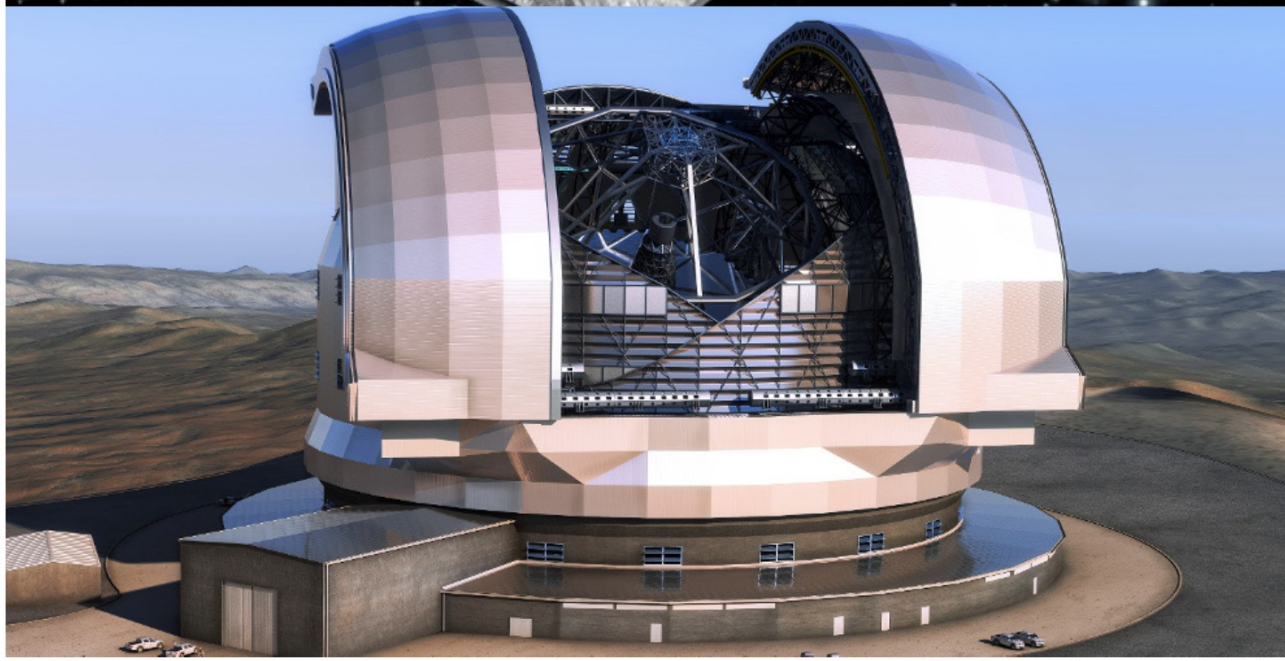
DZA

A center for astrophysics with advanced data intensive computing and technology development.

Electromagnetic sensor/optics technology (possible examples)

- detector technology through 2050 & wide field-of-view optics
- science-grade CMOS with low read noise
- curved detectors
- integrated optics (astrophotonics)
- optics for next-generation interferometry, laser frequency combs
- NIR array detectors (e.g. for GAIA-NIR)





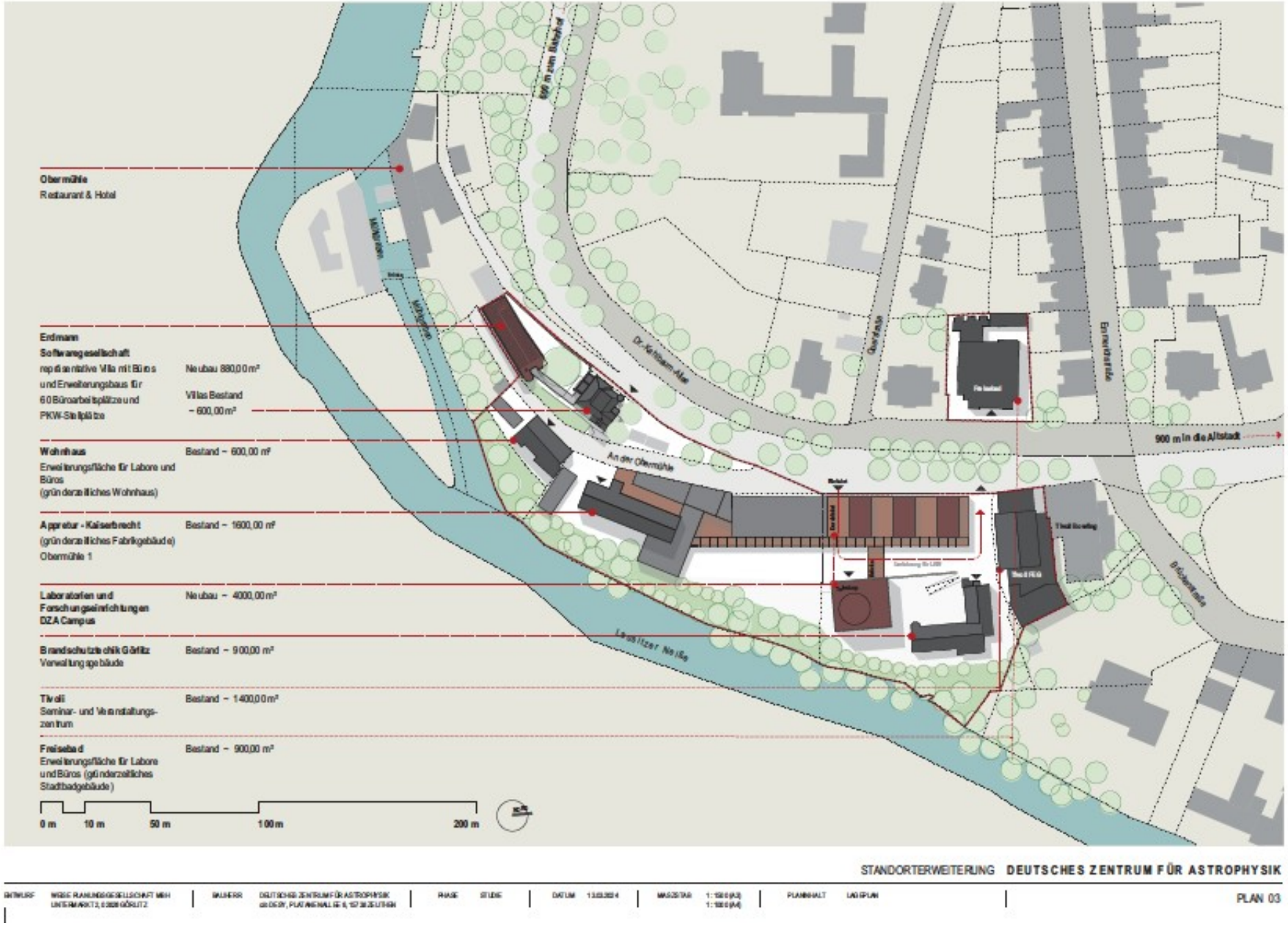
Interim ITE Labs

Interim Headquarter

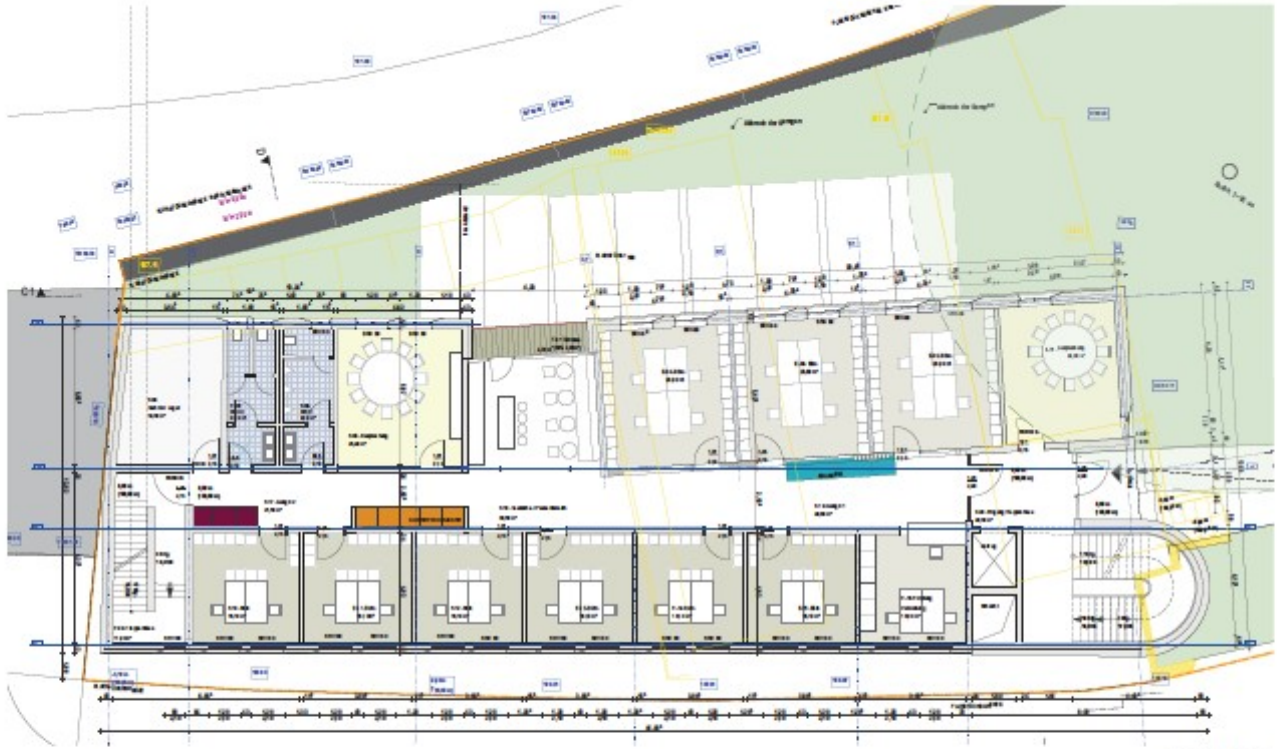
DZA Görlitz

Campus Kahlbaumareal

Planning for Technology Buildings



Planning for Technology Buildings



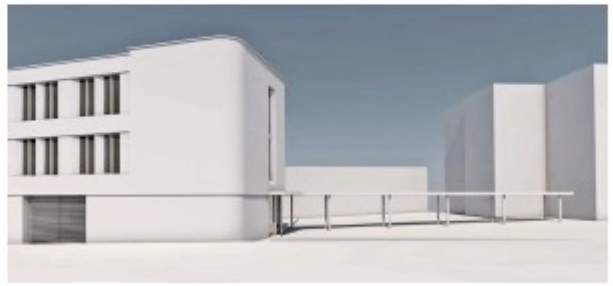
ERWEITERUNGSBAU ERDMANN SOFTWARE
DR.-KAHLBAUM ALLEE 16

BÜRO & VERWALTUNGSBAU
Baugenehmigung bereits erteilt

1. & 2. Obergeschoss - 60 Büroarbeitsplätze
Untergeschoss - 20 PKW-Stellplätze

Grundriss 1. OG

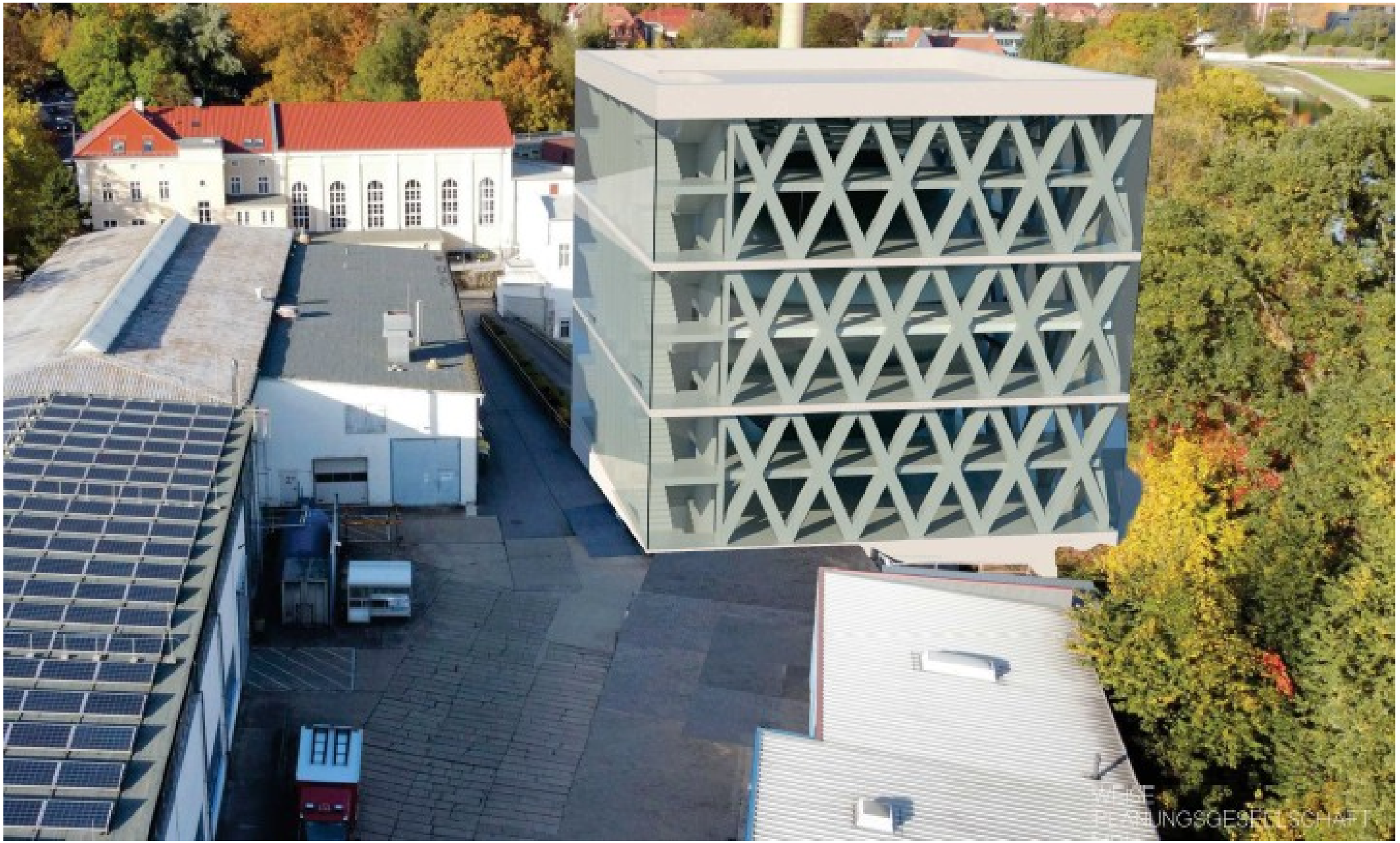
Villa Dr.-Kahlbau-Allee 16



STANDORTERWEITERUNG DEUTSCHES ZENTRUM FÜR ASTROPHYSIK

ENTWURF | BAUHERR | PHASE | STUDIE | DATUM | MAßSTAB | PLANINHALT | PLAN 04

Integration Hall

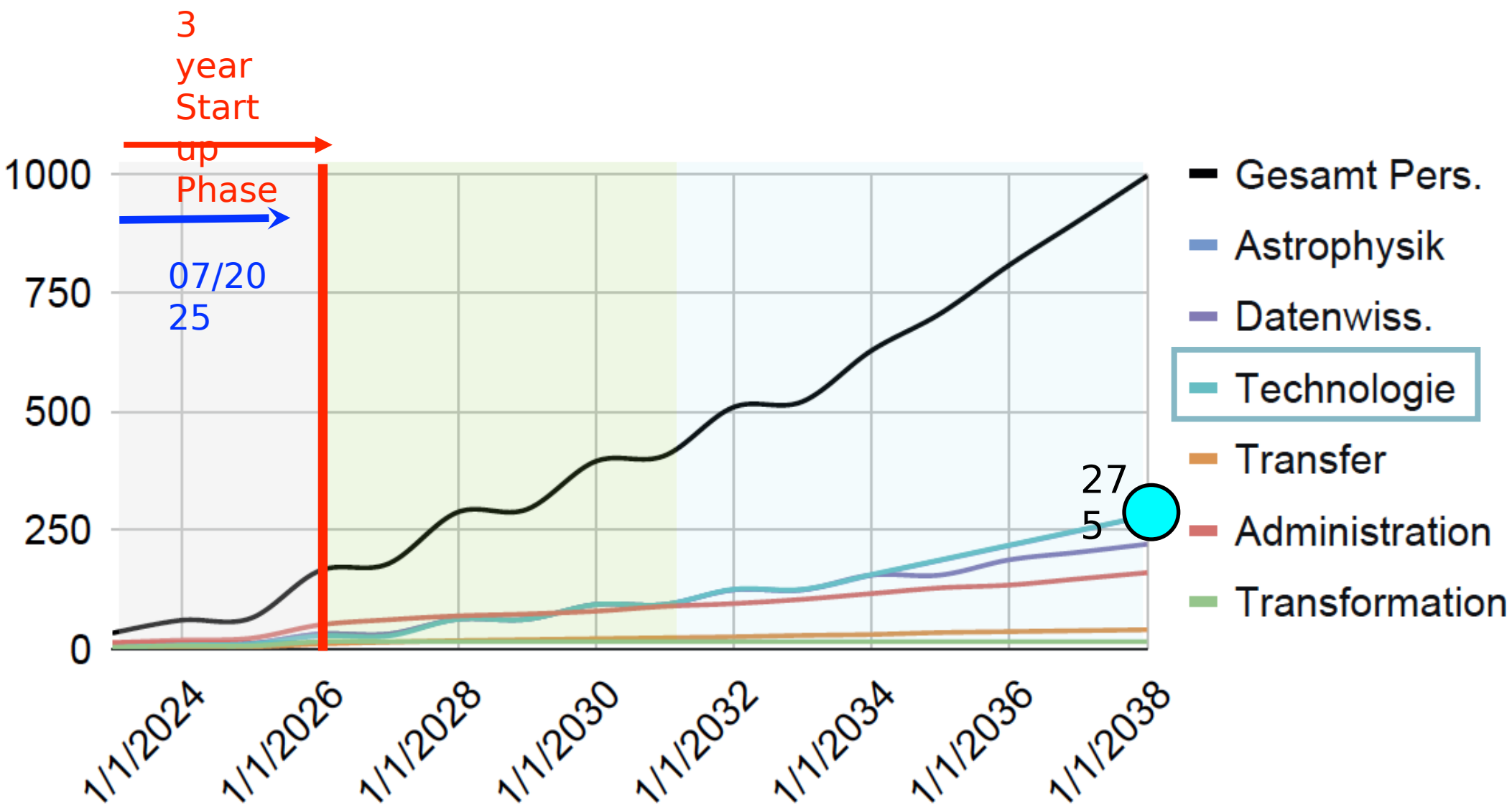


Personnel development (2023-2025)

We are hiring!

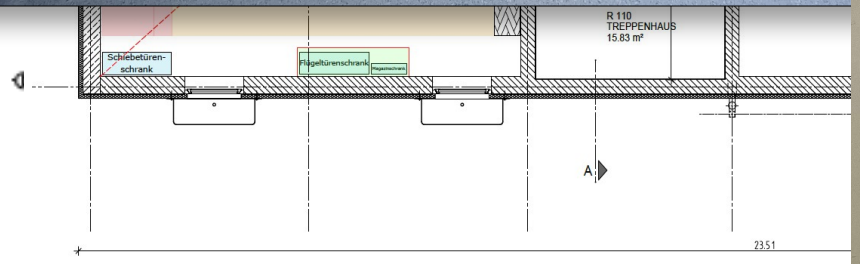
ITE Team 07/2025

Personnel development (2023-2038)



Center for Technology: provisional labs 2024-2030

Center for Technology: provisional laboratories 2023-2030



DZA-ITE
10.09.2024

Center for Technology: provisional laboratories 2023-2030

OLAB

08/2024

Center for Technology: provisional laboratories 2023-2030

OLAB

05/2025

Center for Technology: provisional laboratories 2023-2030

DLAB

08/2024

Center for Technology: provisional laboratories 2023-2030

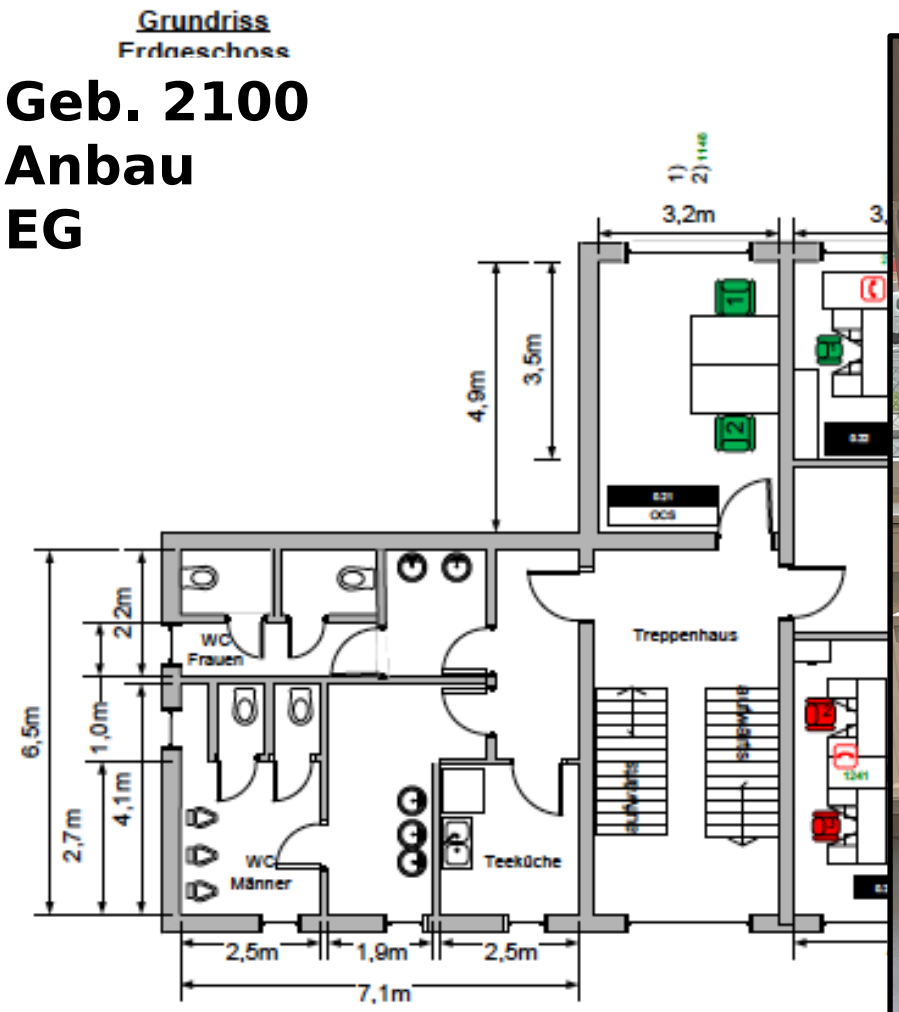
DLAB

05/2025

21 Deutsches Zentrum für Astrophysik, 12.10.

Center for Technology: provisional laboratories 2023-2030

Geb. 2100
Anbau
EG



Center for Technology: provisional laboratories 2023-2030

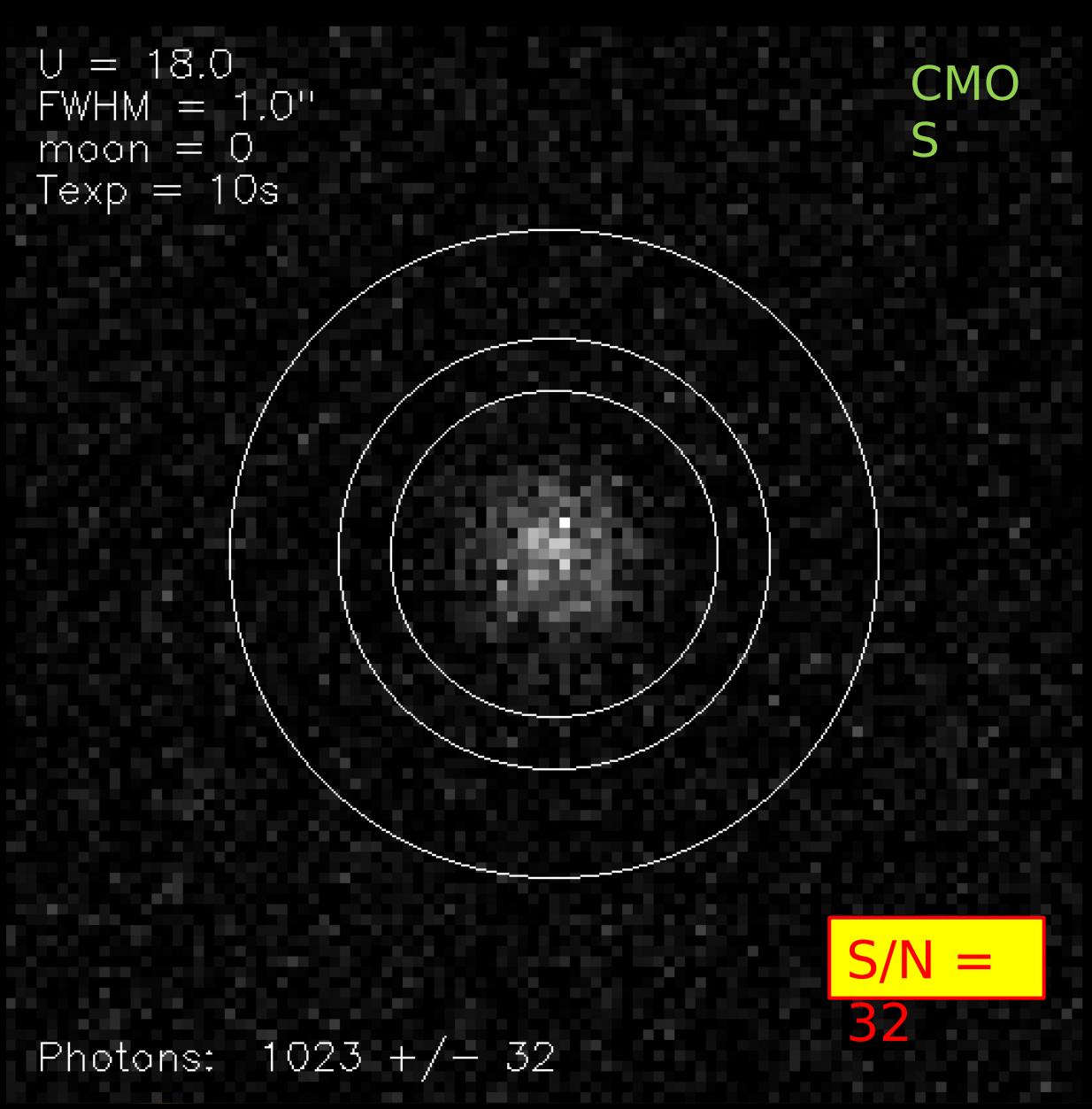
DLAB

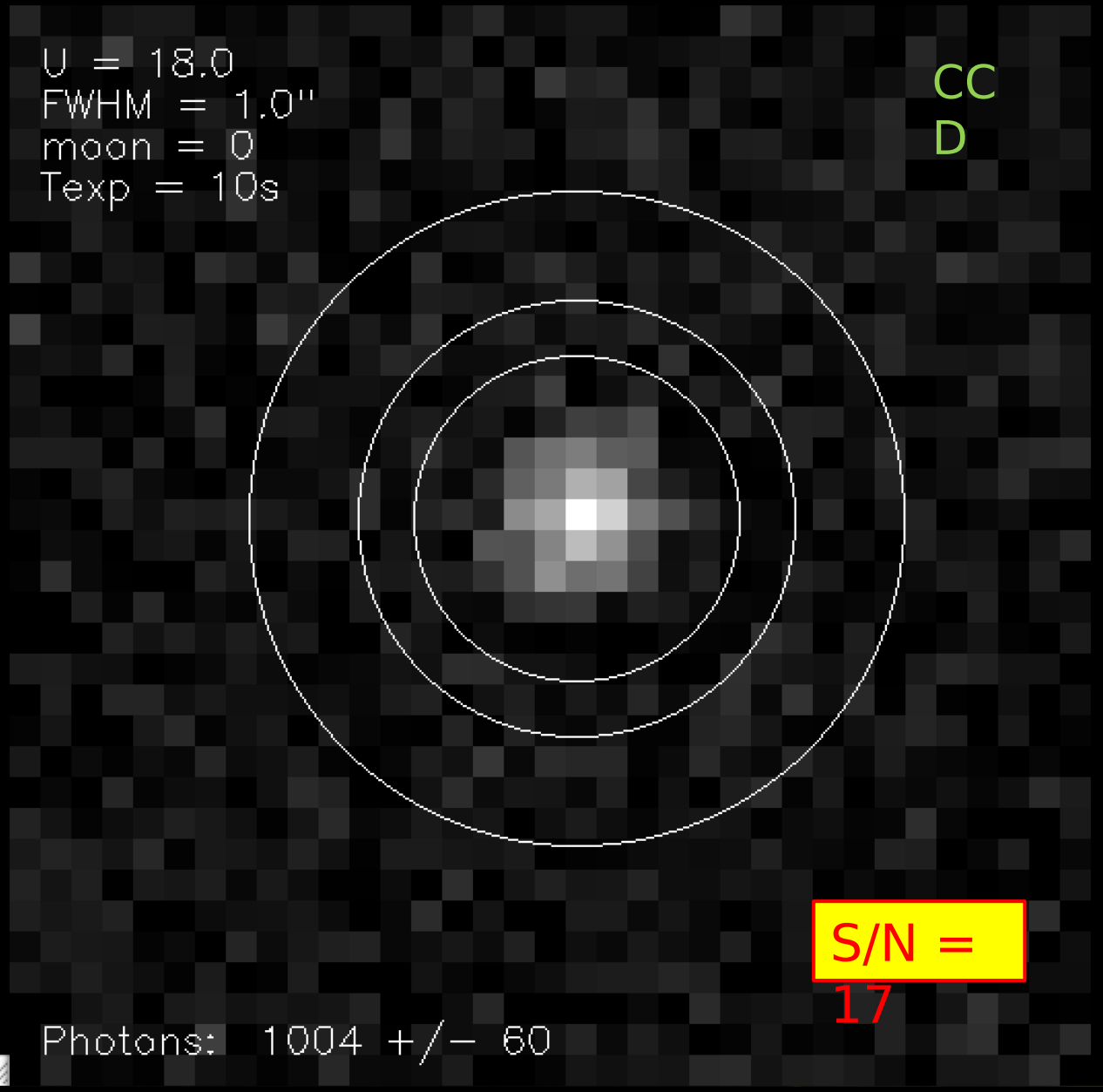
Activities since 2024

Simulations

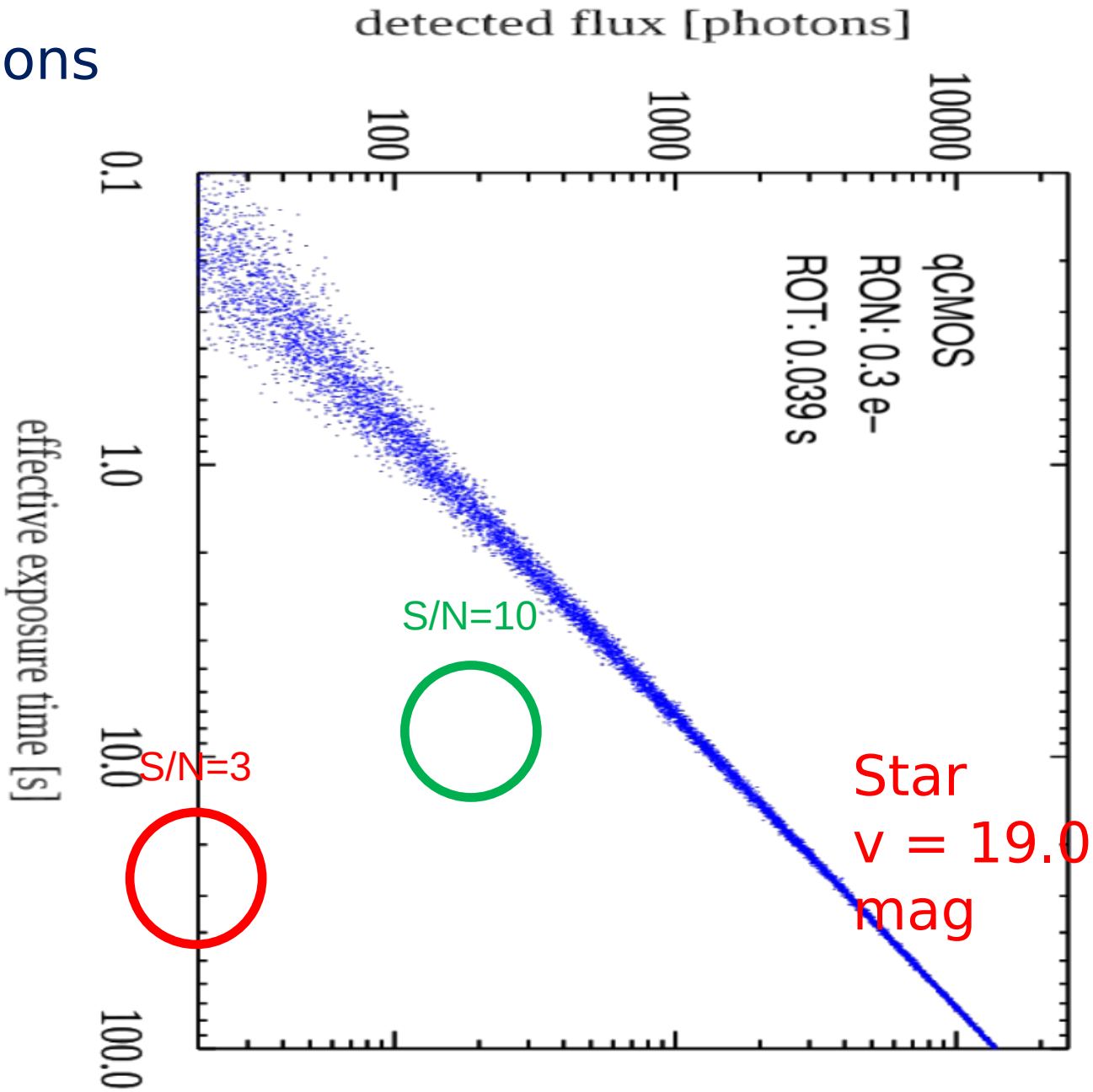
Hamamatsu ORCA-Quest 2
CMOS

ANDOR iKon-L
CCD

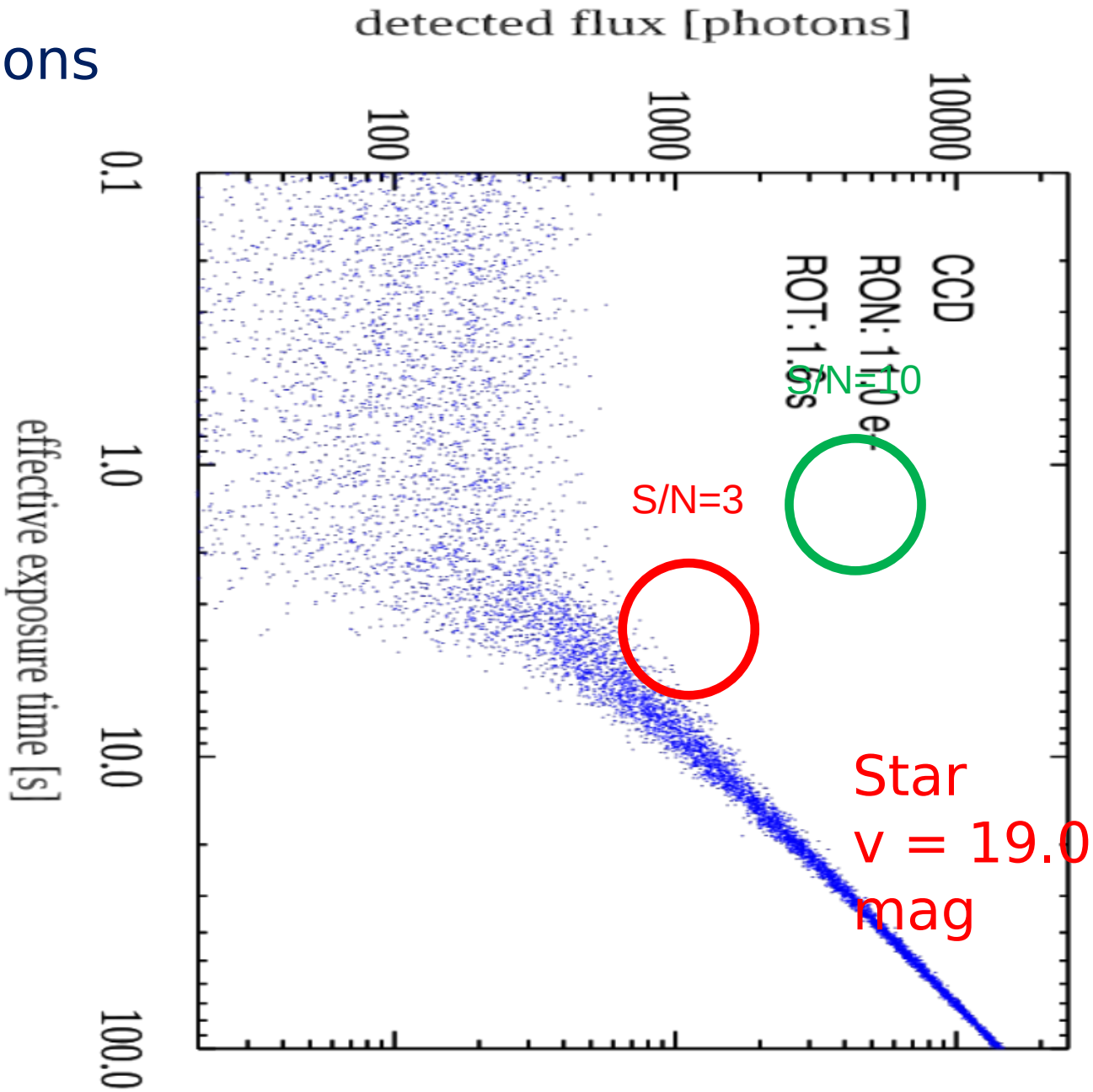

U = 18.0
FWHM = 1.0''
moon = 0
Texp = 10s
CMOS
S/N = 32
Photons: 1023 +/- 32


U = 18.0
FWHM = 1.0''
moon = 0
Texp = 10s
CCD
S/N = 17
Photons: 1004 +/- 60

(2) Simulations



(2) Simulations



Research Note published Nov 2024 at AAS

RNAAS RESEARCH NOTES OF THE AAS

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qCMOS Detectors and the Case of Hypothetical Primordial Black Holes in the Solar System, near Earth Objects, Transients, and Other High-cadence Observations

Martin M. Roth[1,2,3]

Published November 2024 • © 2024. The Author(s). Published by the American Astronomical Society.

Research Notes of the AAS, Volume 8, Number 11

Citation Martin M. Roth 2024 *Res. Notes AAS* **8** 282

DOI 10.3847/2515-5172/ad90a8

Figures ▾ References ▾

▲ Hide article and author information

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Article metrics

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Executive Summary: ORCA-TWIN Experiment

The ORCA-TWIN Experiment is a proof-of-concept to explore time domain astronomy with a novel CMOS sensor technology that offers low readout noise and very short readout times. The qCMOS technology developed by Hamamatsu is commercially available and comes as a turnkey ready camera system called ORCA-Quest2.

Key features are: 4096 x 2304 pixels^2, 4.6μm square pixels, QE_{max} = 85% at 450nm, readout noise 0.3 e$^-$, frame rate up to 125 fps.

Numerical simulations show that this camera is far superior to CCD cameras in terms of signal-to-noise ratio for time series observations with time steps below 10s (Roth 2024[1]). This capability opens the door to novel applications in time domain astronomy. Science cases include, but are not limited to:

- fast moving solar system objects, especially near-earth objects
- high precision asteroid tracking to search for primordial black holes
- space debris
- exoplanet transits in M stars with flare activity
- rapid follow up to high-energy transients

DZA has procured two ORCA-Quest2 cameras and intends to perform a proof-of-concept experiment with two remote 1m-class telescopes aiming at synchronized high speed imaging of such targets. Besides unprecedented time resolution, the remote twin configuration offers opportunities to suppress errors induced by atmospheric turbulence and extinction, and to triangulate nearby objects with high precision. Calar Alto Observatory in southern Spain and STELLA at the Teide Observatory, Tenerife, are ideal locations to implement the experiment.

[1] Roth, M.M. 2024, *qCMOS detectors and the case of hypothetical primordial black holes in the solar system, near earth objects, transients, and other high cadence observations*, Res. Notes AAS 8, 282

8.6 Fast-cadence high-contrast Bayesian imaging with photon counting camera

PI: Prof. Dr. Torsten Enßlin (DZA)

Direct imaging of exoplanets is challenging due to the high brightness contrast between a star and its exoplanets at very small angular separations, just a few times wider than the largest telescopes' diffraction limit, aggravated by atmospheric turbulence that distorts the incoming wavefront.

While extreme adaptive optics (ExAO) partially compensates for these distortions, residual spatiotemporal variations create a complex speckles pattern, changing on a few millisecond timescale, that obscures fainter companions (Fig 1, left panel). To enhance contrast, data post-processing techniques, such as ADI, PCA-ADI, and newer methods, leverage field rotation to model and subtract the central star's light and speckles, mitigating residual noise and improving detection capabilities.

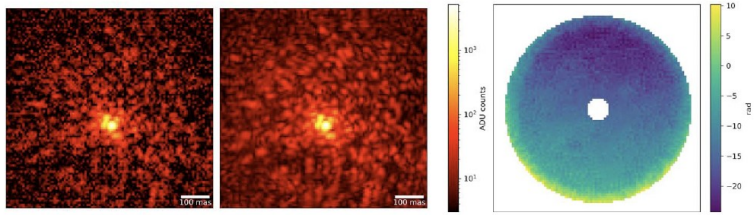


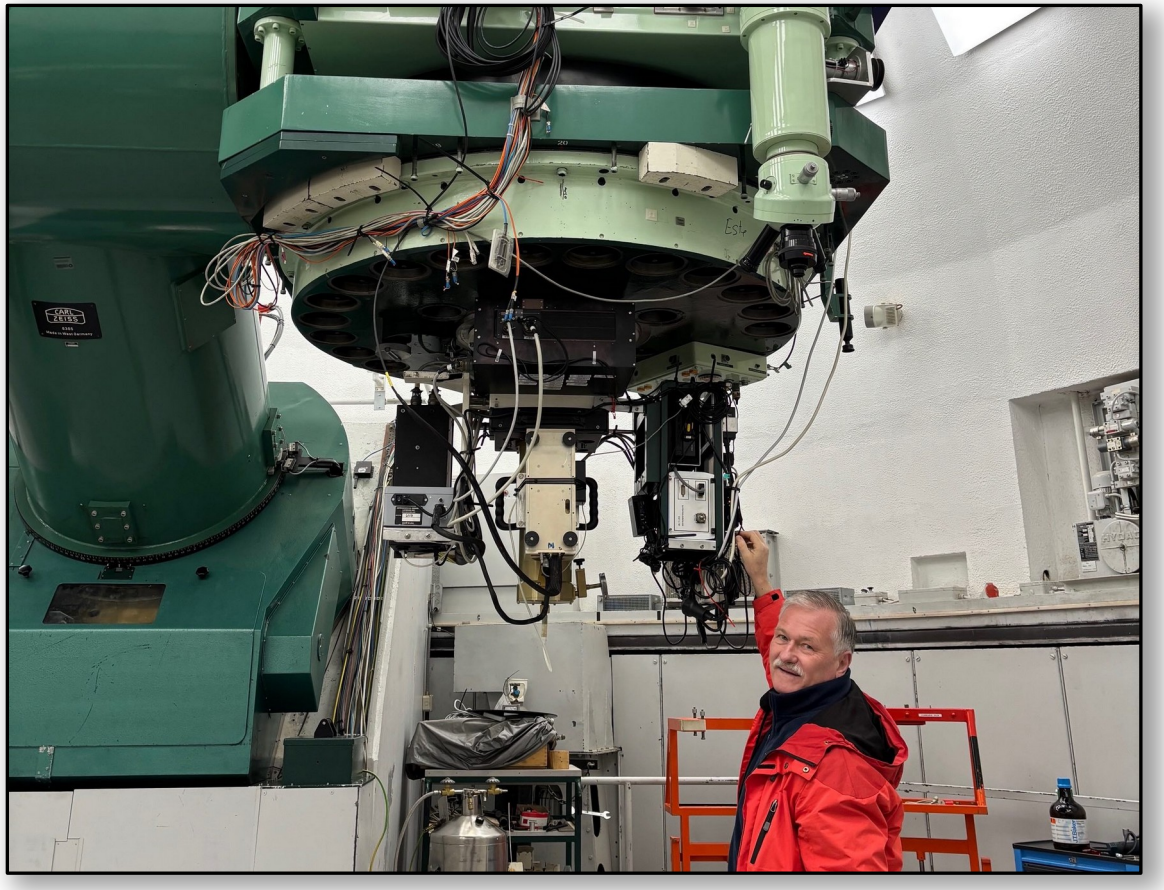
Fig 1: Left panel: snapshot data (instantaneous PSF convolved star plus shot noise) in the focal plane (rebinned to 100 × 100 pixels) of the 5.5 mag star Gl 777, acquired with the SHARK-VIS Forerunner instrument at the LBT in a 1 ms exposure; the interference pattern shaped by the atmospheric fluctuations ("speckles") is well visible all around the star. Middle panel: HCBI reconstruction of the PSF convolved star (without shot noise) for the corresponding frame, shown with the same logarithmic color map. Right panel: the reconstruction in the pupil plane of the optical path difference field for that frame of the Gl 777 sequence, which determines the reconstructed PSF shown in the middle panel (from Roth et al. 2023).

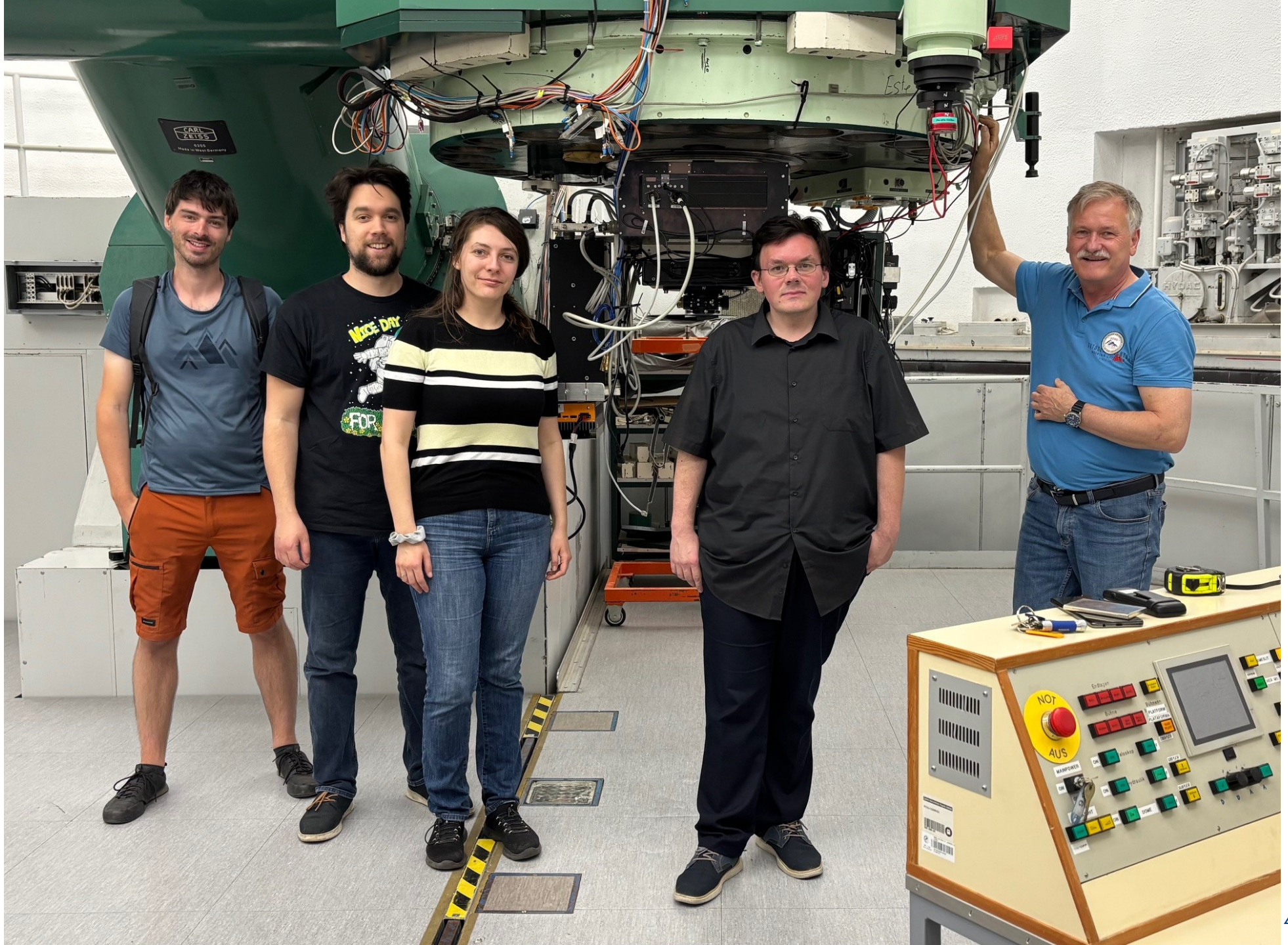
Recently, we introduced a new method, dubbed Hight Contrast Bayesian Imaging (HCBI, Roth et al. 2023) to improve exoplanets detection in high contrast imaging by exploiting the statistical properties of the rapid variation of the PSF acquired by the fast-cadence SHARK-VIS camera at LBT (Pedichini et al. 2024), thanks to an explicit forward data modeling that simulates the natural information flow from the signal to the detector. The algorithm is based on the mathematical methods of Information Field Theory (IFT, *Enßlin 2019*) and uses Bayesian inference to simultaneously reconstruct the true object and the PSF evolution from a kilohertz-rate frame sequence acquisition, where the speckle pattern can be considered freezed in each frame. In the practice, it infers the instantaneous wavefront at the telescope pupil which produced the observed speckles for each frame (Fig 1), leveraging on a set of prior information reflecting the physics of the object, the atmospheric perturbations, the telescope and detector response, and the photon and readout noise statistics.

In these short acquisitions the individual speckles are imaged in a photon starved regime, a situation where the photon count accuracy would be greatly improved if a photon counting device were used. In this context a low-noise qCMOS camera like the Hamamatsu ORCA-Quest would provide a noticeable advance with respect to the current Zyla sCMOS sensor on board SHARK-VIS, whose read out noise is larger than the single photon signal which does not allow exact photon counting and reduces the performance of the bayesian reconstruction. Such a photon counting camera can acqire frames at 1KHz rate in a 256x256 pixels format, which is the standard frame size in SHARK-VIS for close companions targets and, being only limited by photon noise, it's usage could reveal the physically faintest detectable exoplanets given the star magnitude, the telescope size, and the atmospheric conditions.

Calar Alto Observatory (southern Spain)

ORCA-TWIN @ 1.23m Telescope




CARL ZEISS
NOT
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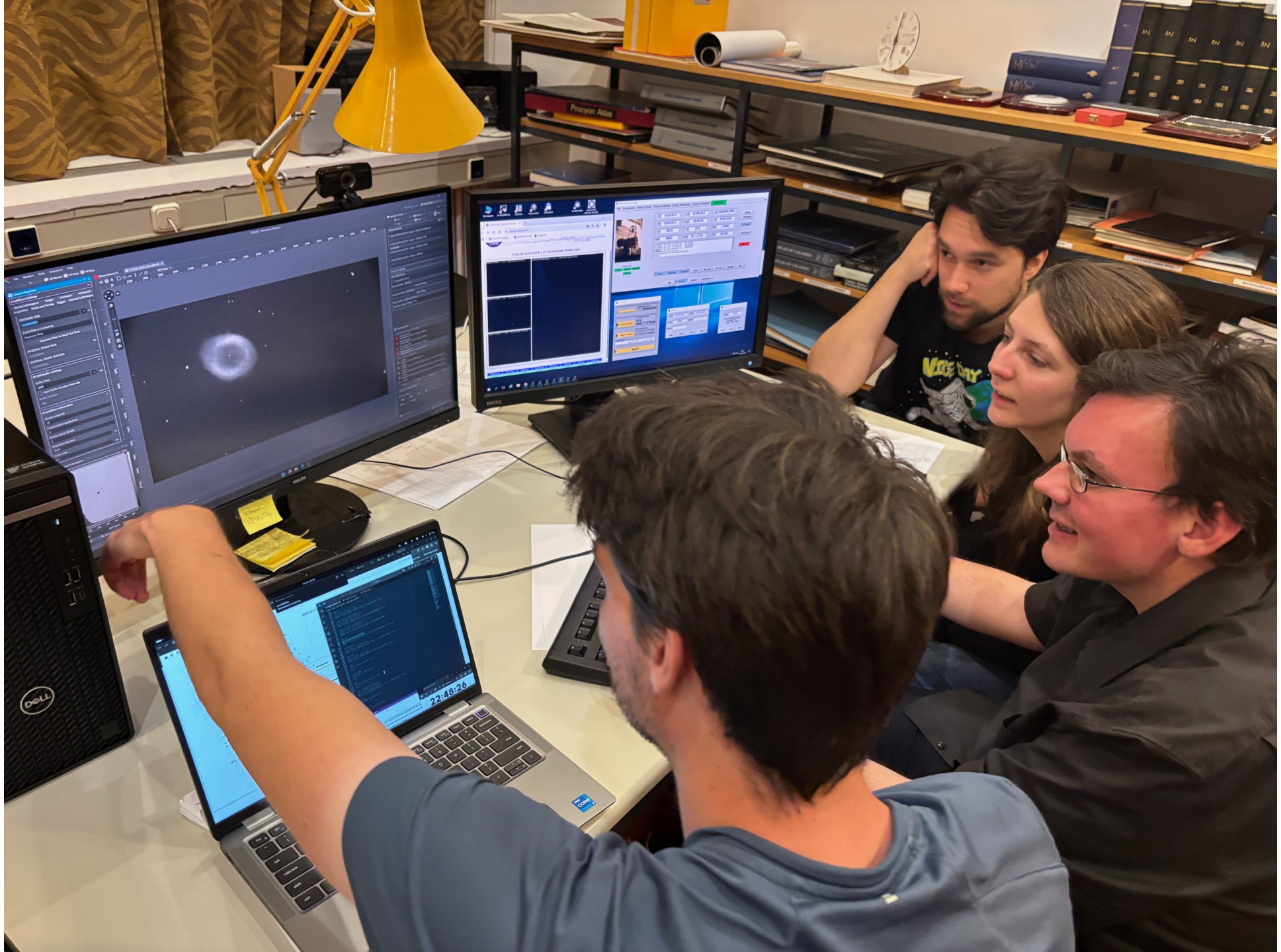
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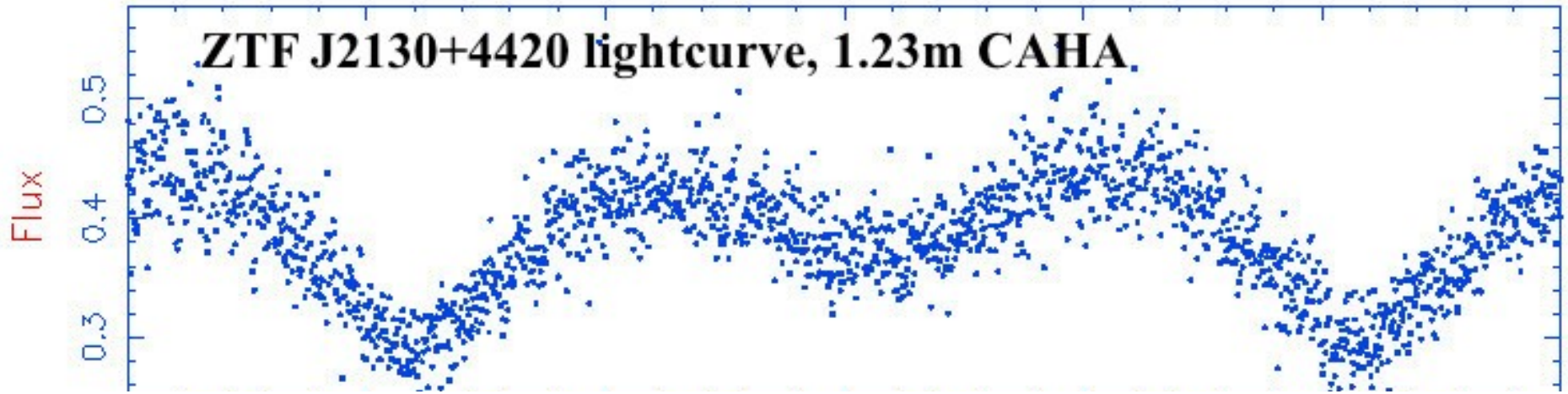
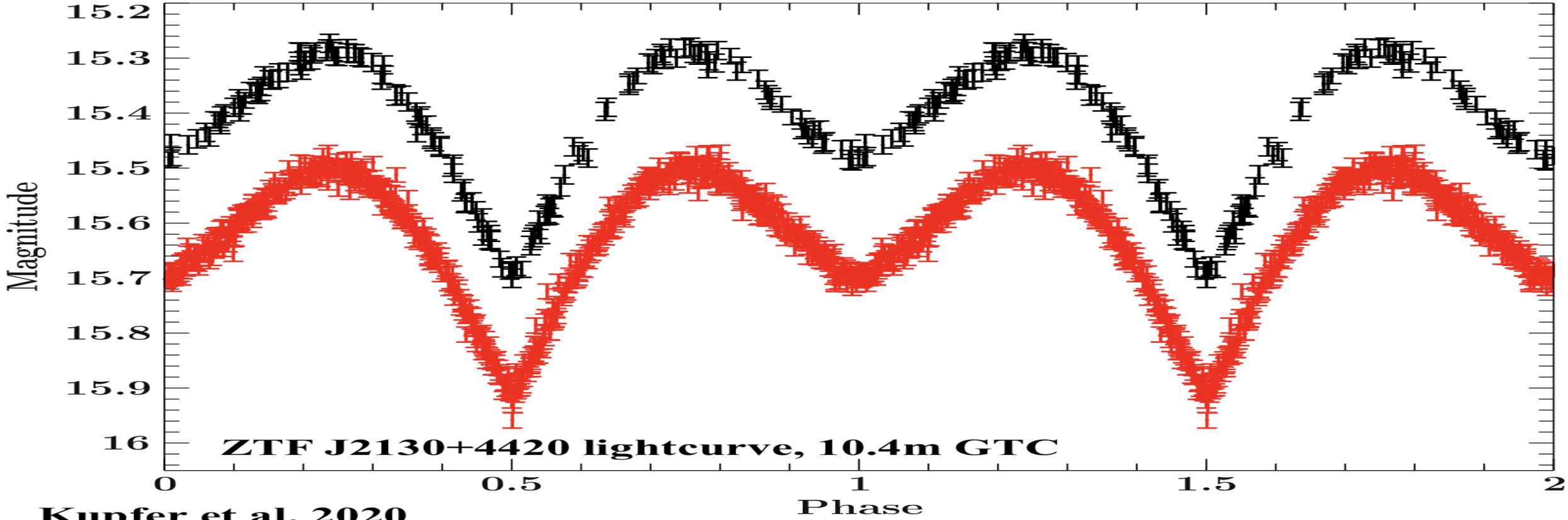


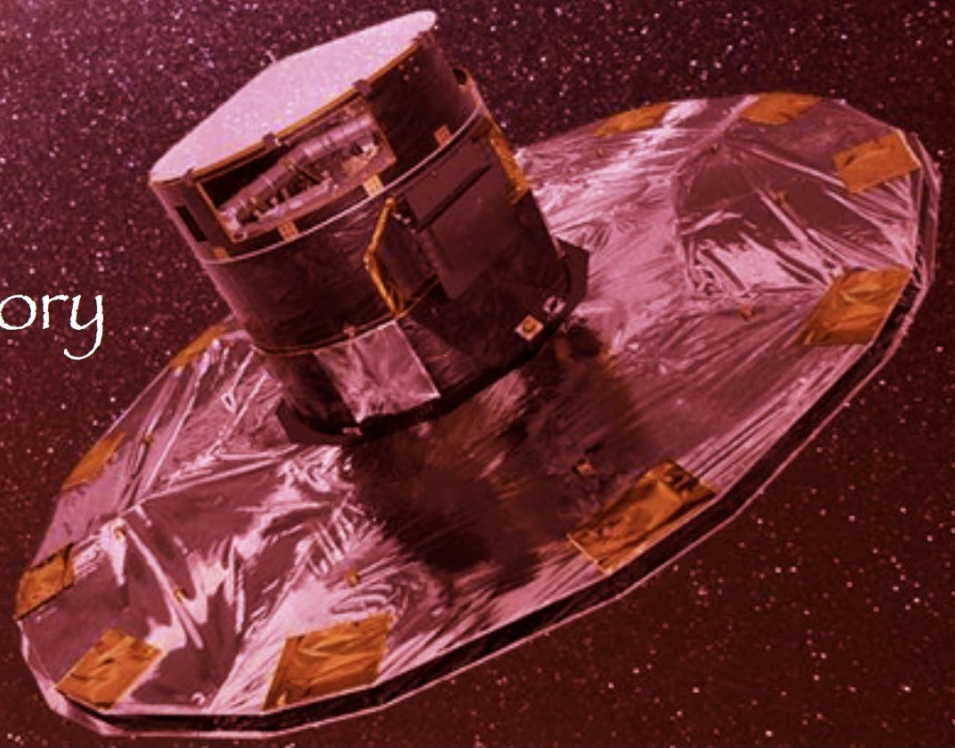


Kupfer et al. 2020

Figure 1. Phase-folded ZTF *g* (black) and *r* (red) discovery light curves.

The GaiaNIR mission and the hidden regions of our Galaxy

David Hobbs
Lund Observatory
Sweden



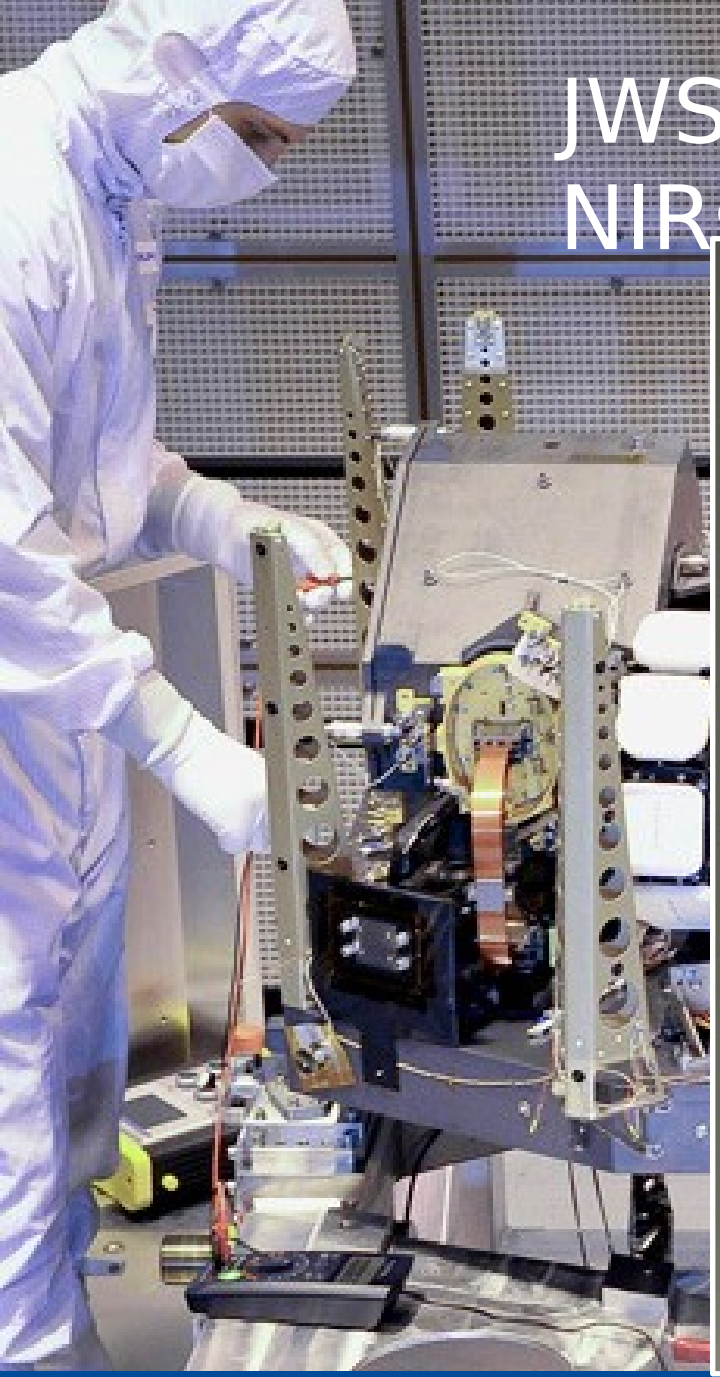
AIP

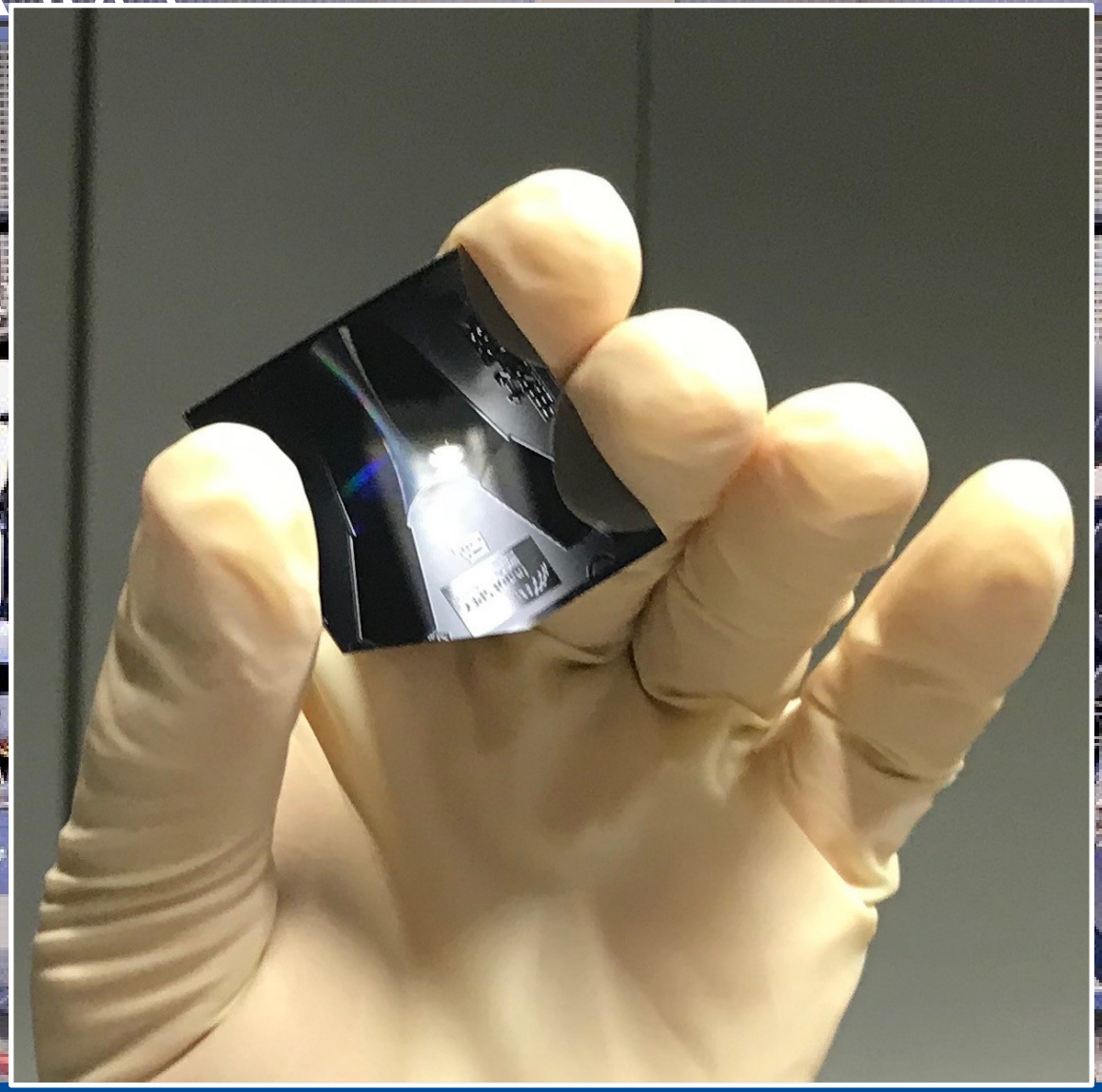
innoFSPEC
Innovative faseroptische Spektroskopie und Sensorik

Universität Potsdam

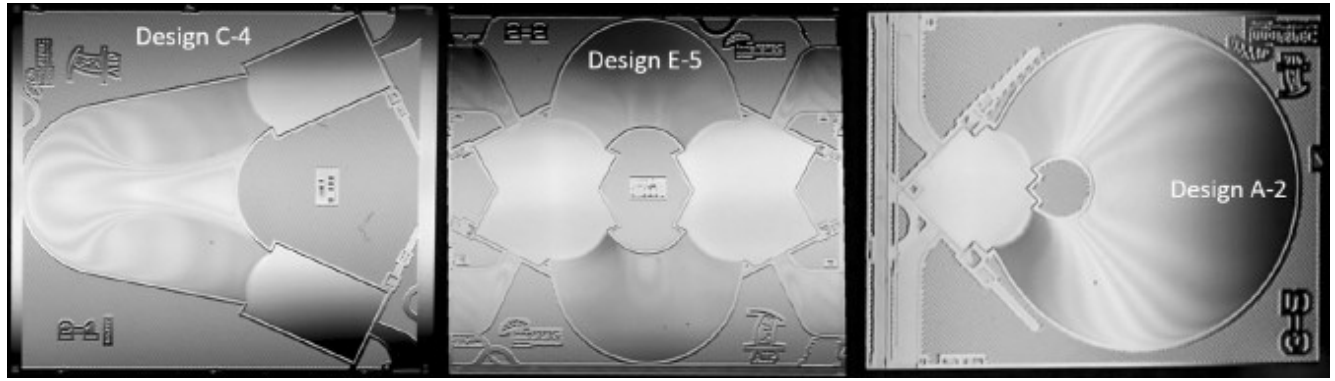
innoFSPEC Potsdam: innovative fiber-coupled spectroscopy and sensing

JWST NIRspec

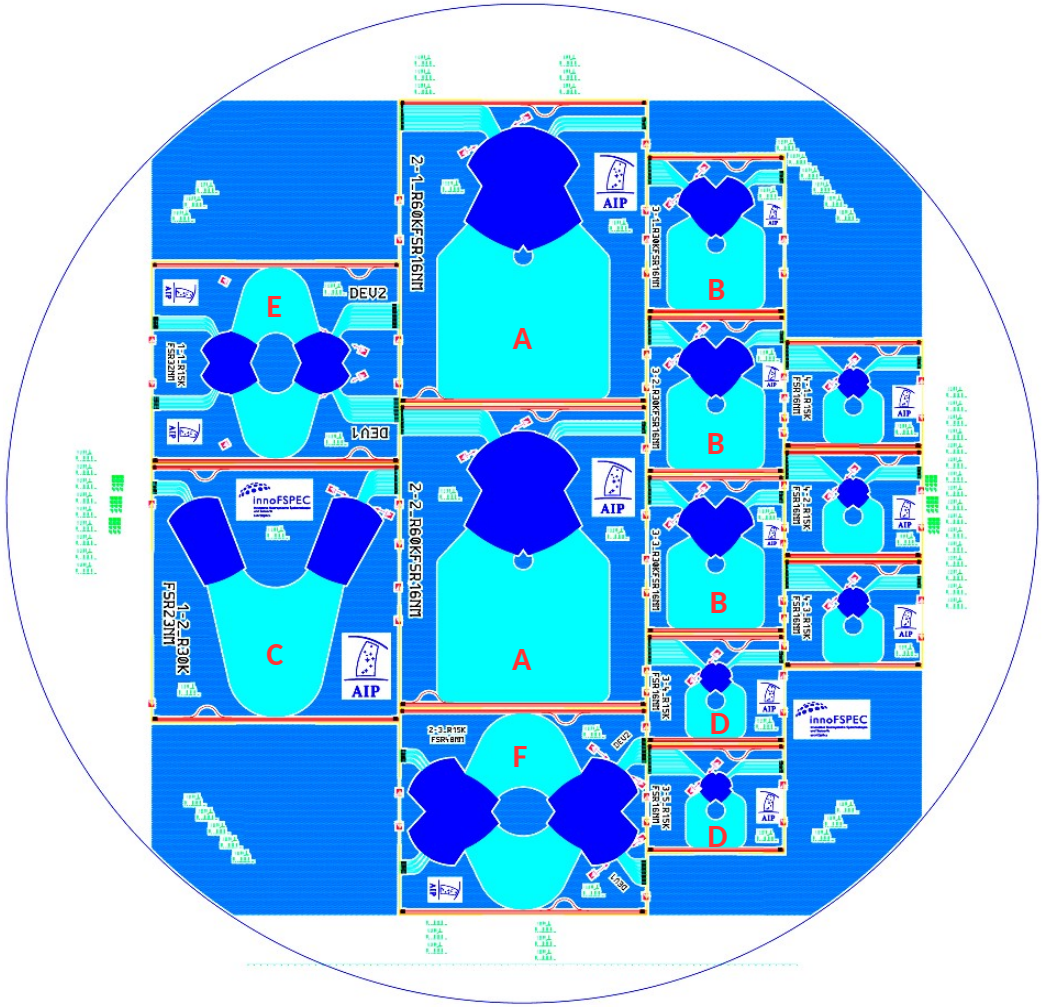




Spectrograph-on-a-chip: Generation II.



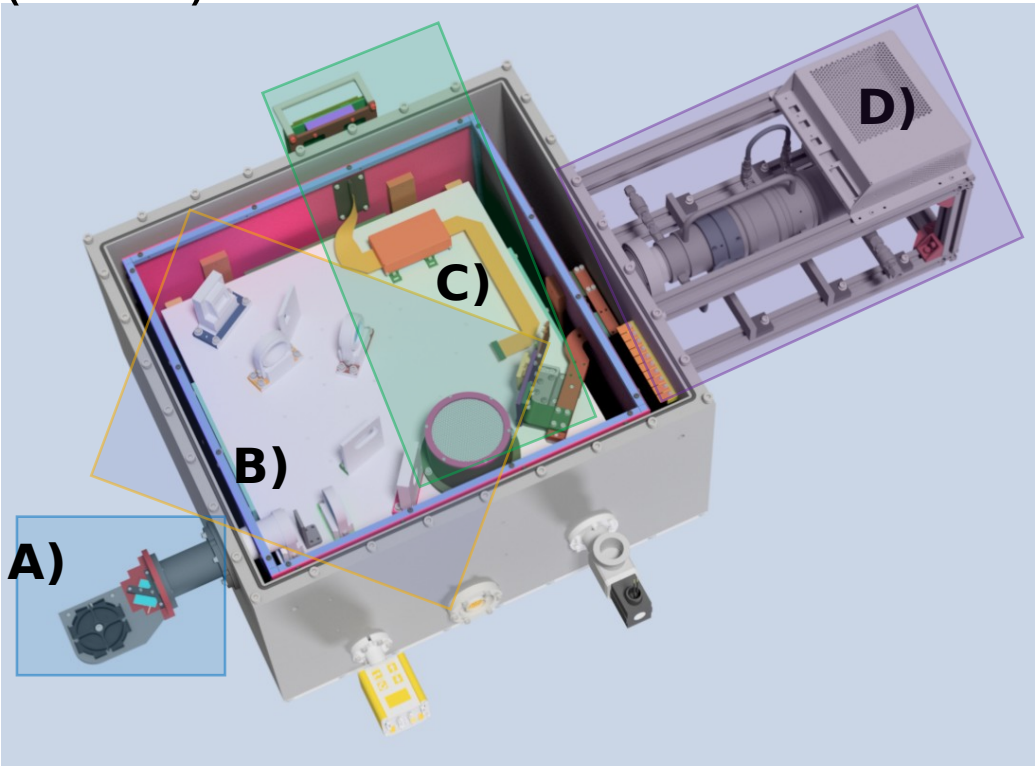
Design	A-1	A-2	B-3	B-5	C-4	D-3	E-5
FSR (nm)	11.9	11.9	16.1	16.1	22.6	32.2	47.4
IL (dB)	1.45	2	1.99	3	2.2	1.66	1.65
$\Delta\lambda$ (pm)	96	70	78	56	77.5	146	152
$PD\lambda$ (pm)	28	27	39	57	40	48	65
R simulated	17,400	24,600	23,100	34,800	23,300	11,500	11,800
R measured (TE)	16,100	22,000	20,000	27,600	20,000	10,600	10,200
R_{direct} (TE)	20,540	29,490	25,270	36,000	25,760	13,880	12,880
R_{direct} (unpolarized)	18,600	24,000	18,300	-	16,700	12,100	9,600
ΔR	0.08	0.06	0.06	0.14	0.156	0.075	0.084



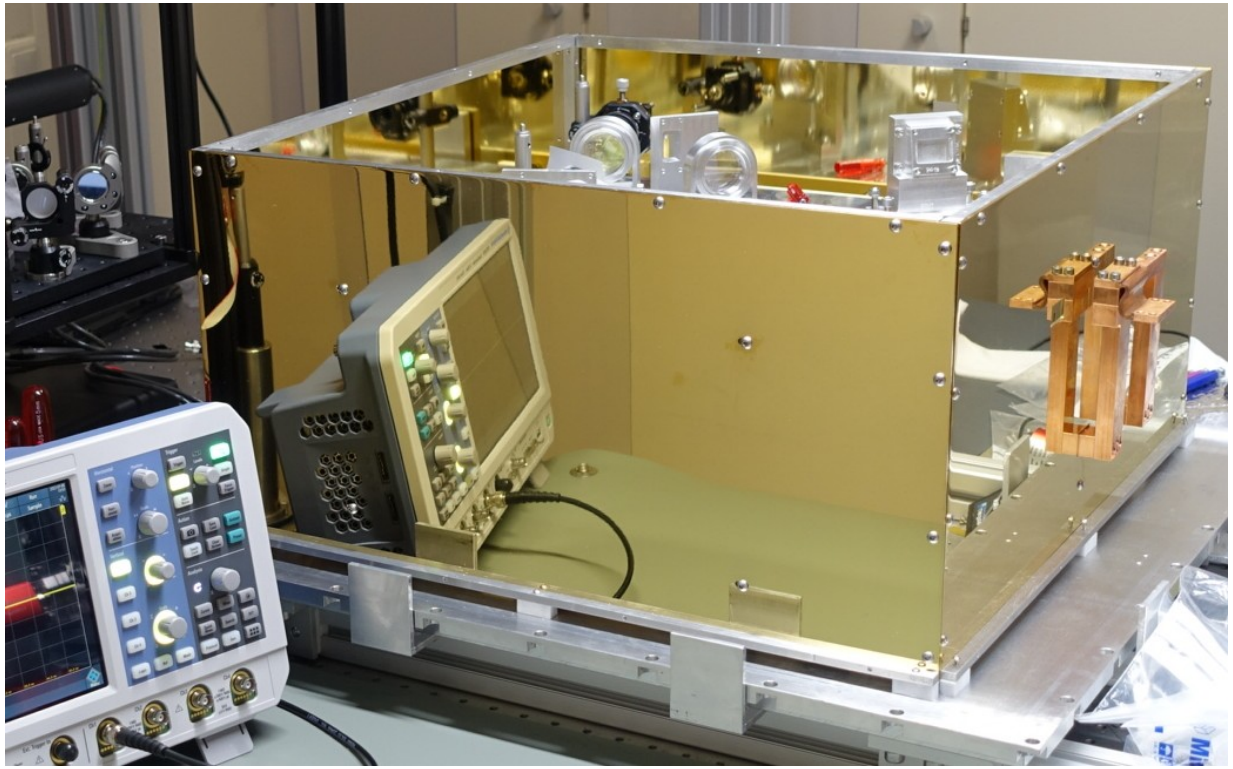
15 cm

AWG lithographic mask

Potsdam Arrayed Waveguide Spectrograph (PAWS)

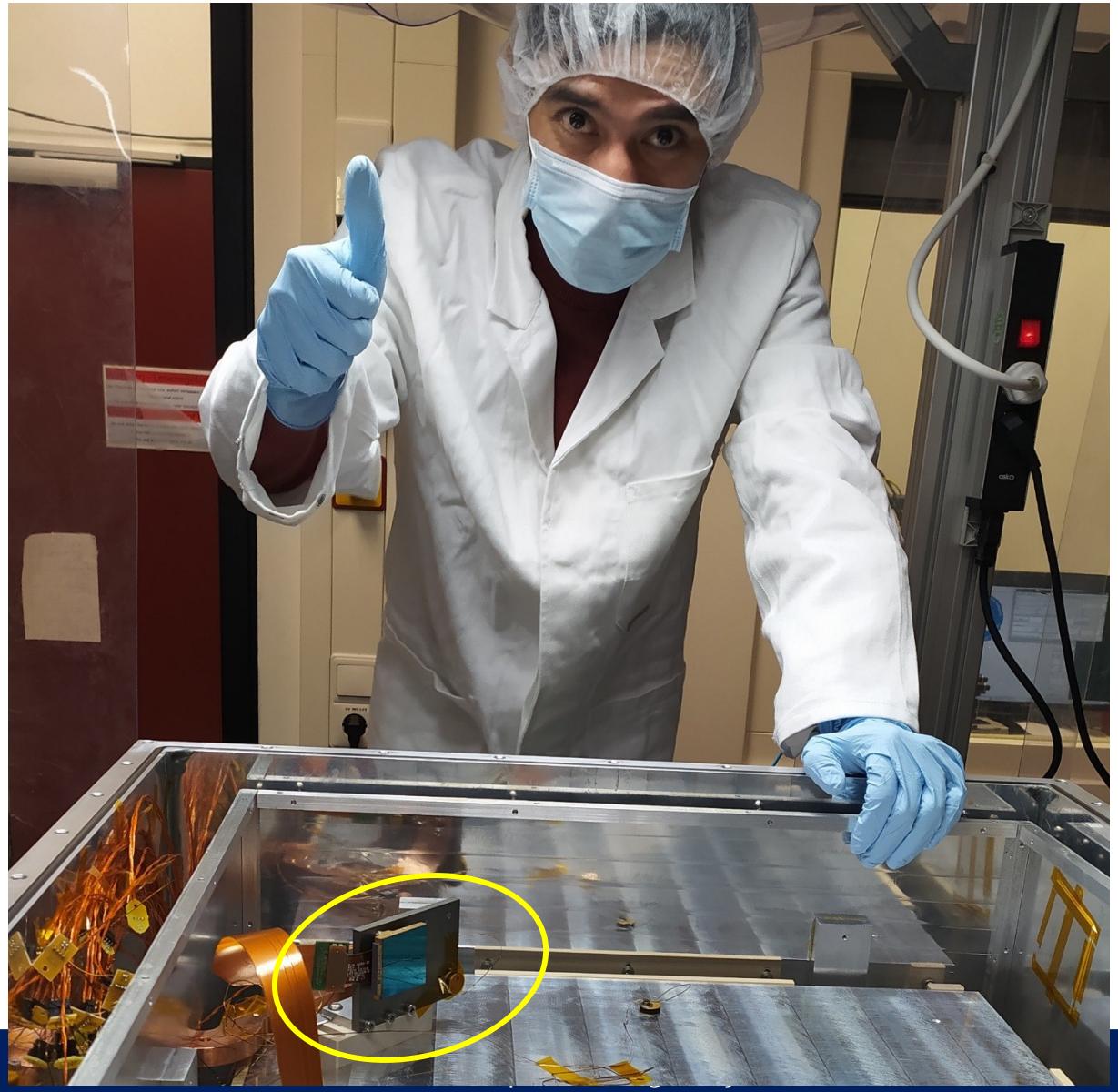


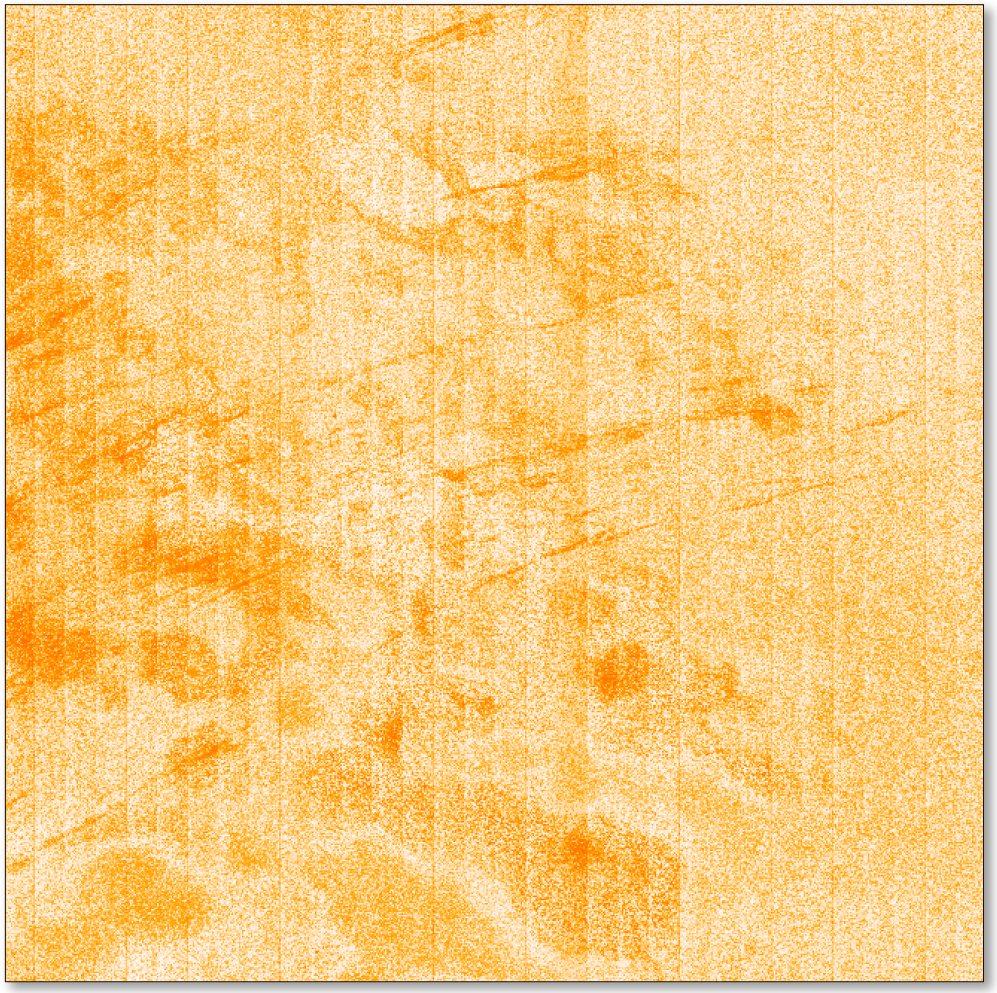
CAD View



PAWS assembled in the lab

First H2RG Light 15 Nov 2021





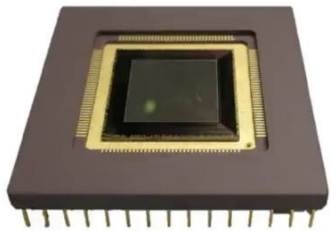
MVGaiaDN Detector Meeting

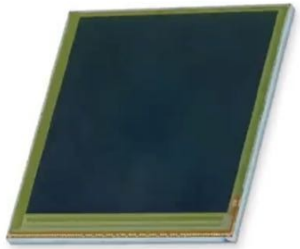
Meeting being held in Cambridge in July 15-16th to discuss technology for GaiaNIR

Technical challenges of space-based astronomy

Industrial partners like Leonardo UK will attend and all people interested are welcome

Update of LmAPDs for low background flux applications



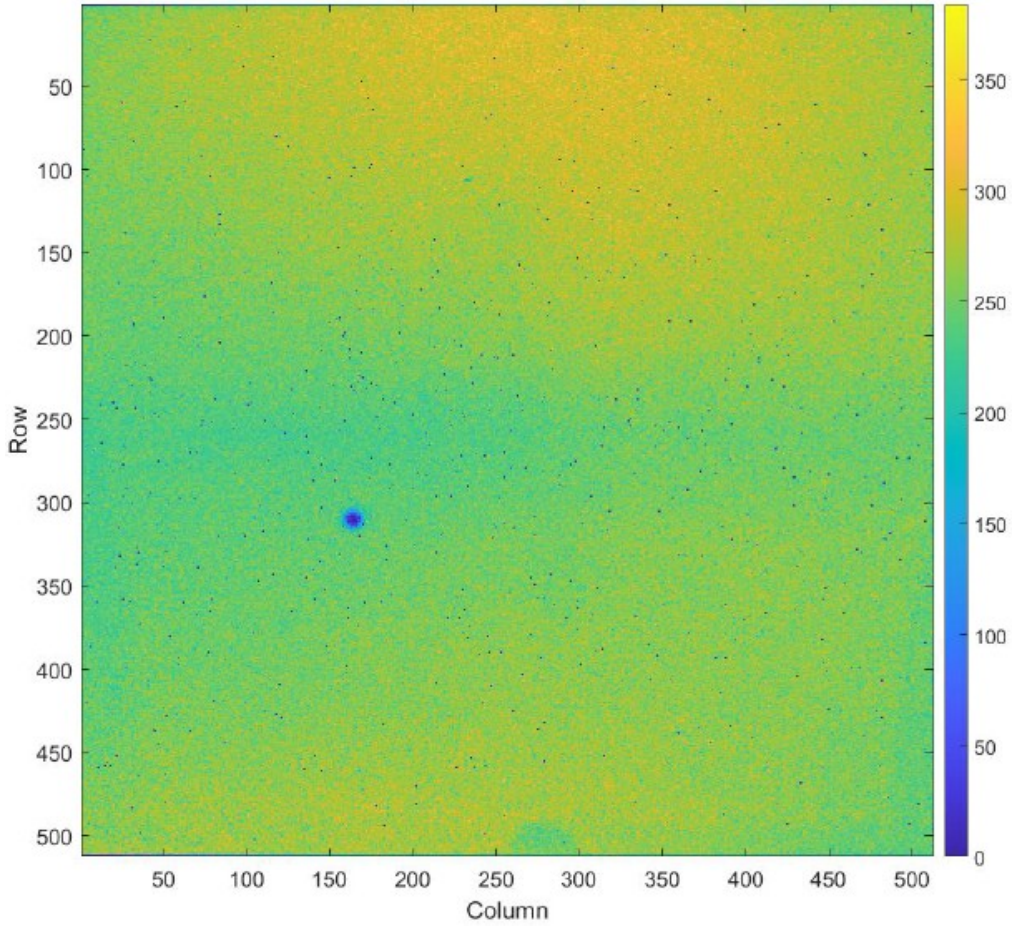


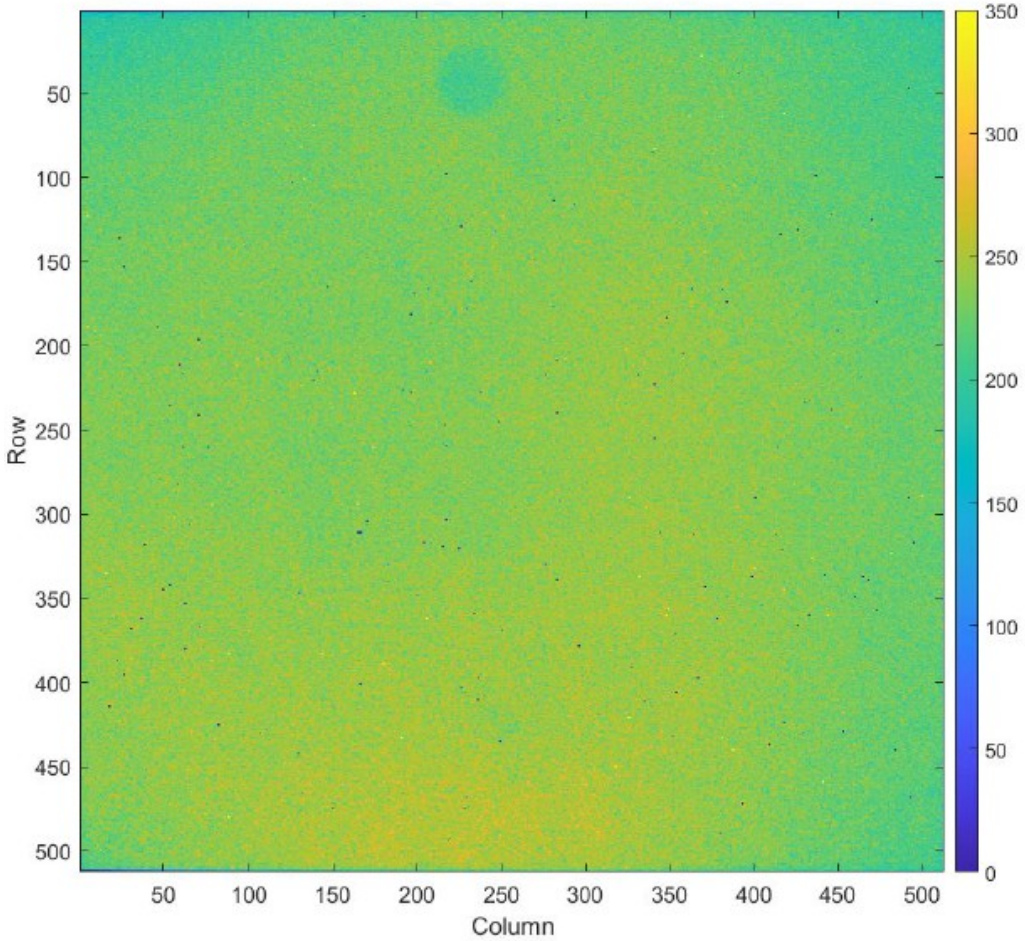
	Large Saphira	Ike-Pono	IBEX
Dimensions	512x512/24μm	1024x1024/15μm	2048x2048/15μm
Status	Detectors provided to consortium partners for evaluation and system development.	First science grade devices under assessment – see **Charles-Antoine Claveau** talk tomorrow for further details.	Prototype arrays manufactured
Collaborator	ESO, Max Planck and NC	ASA APRA ROSES, University of Hawai'i	ESA
Current Planned Uses	Wavefront sensing for extreme Adaptive Optics (AO) Over 2000 frames per second.	Extreme low dark current applications	Earth Observation

AI
P

Large Saphira contract with AIP

2 devices delivered

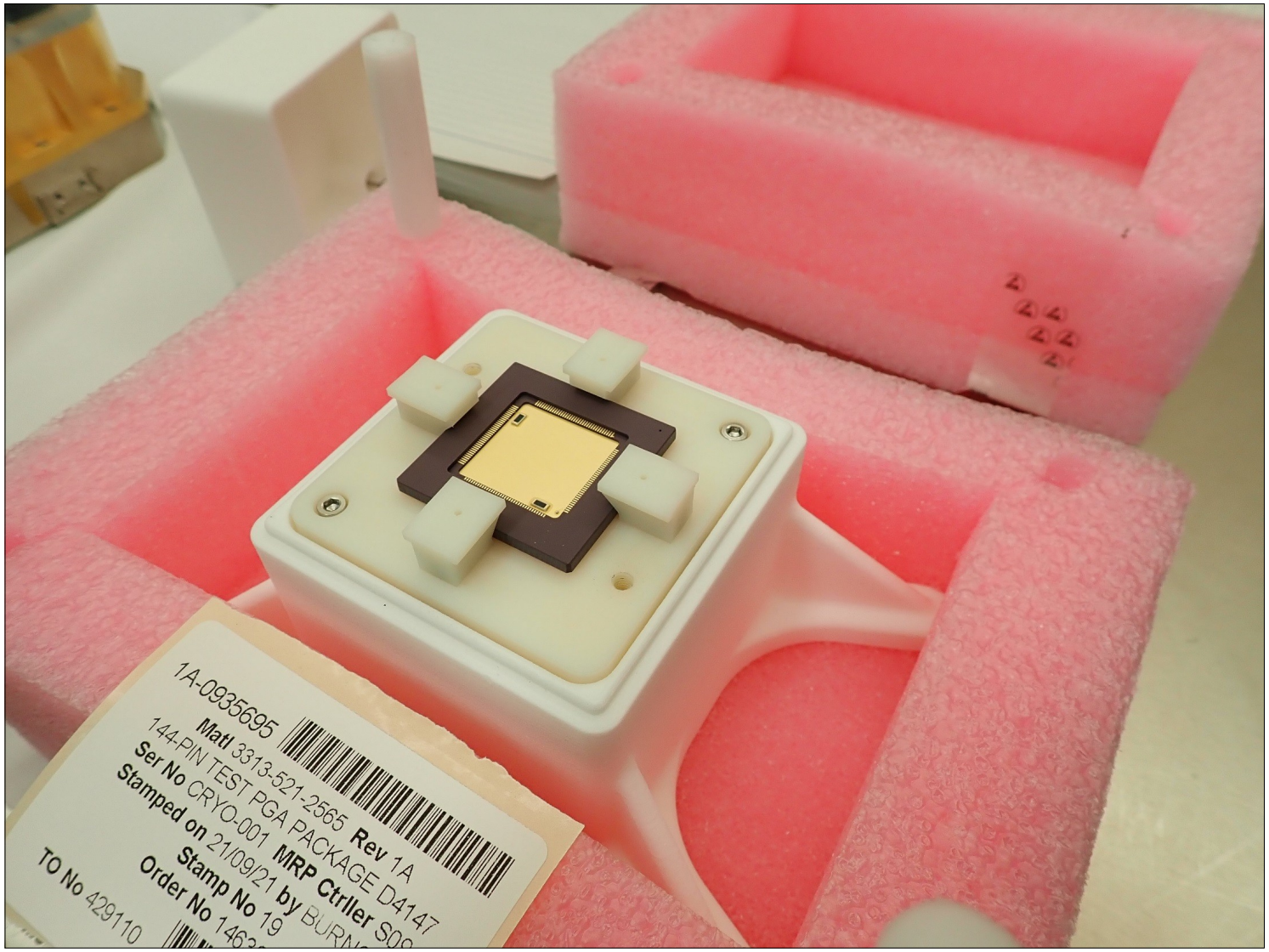




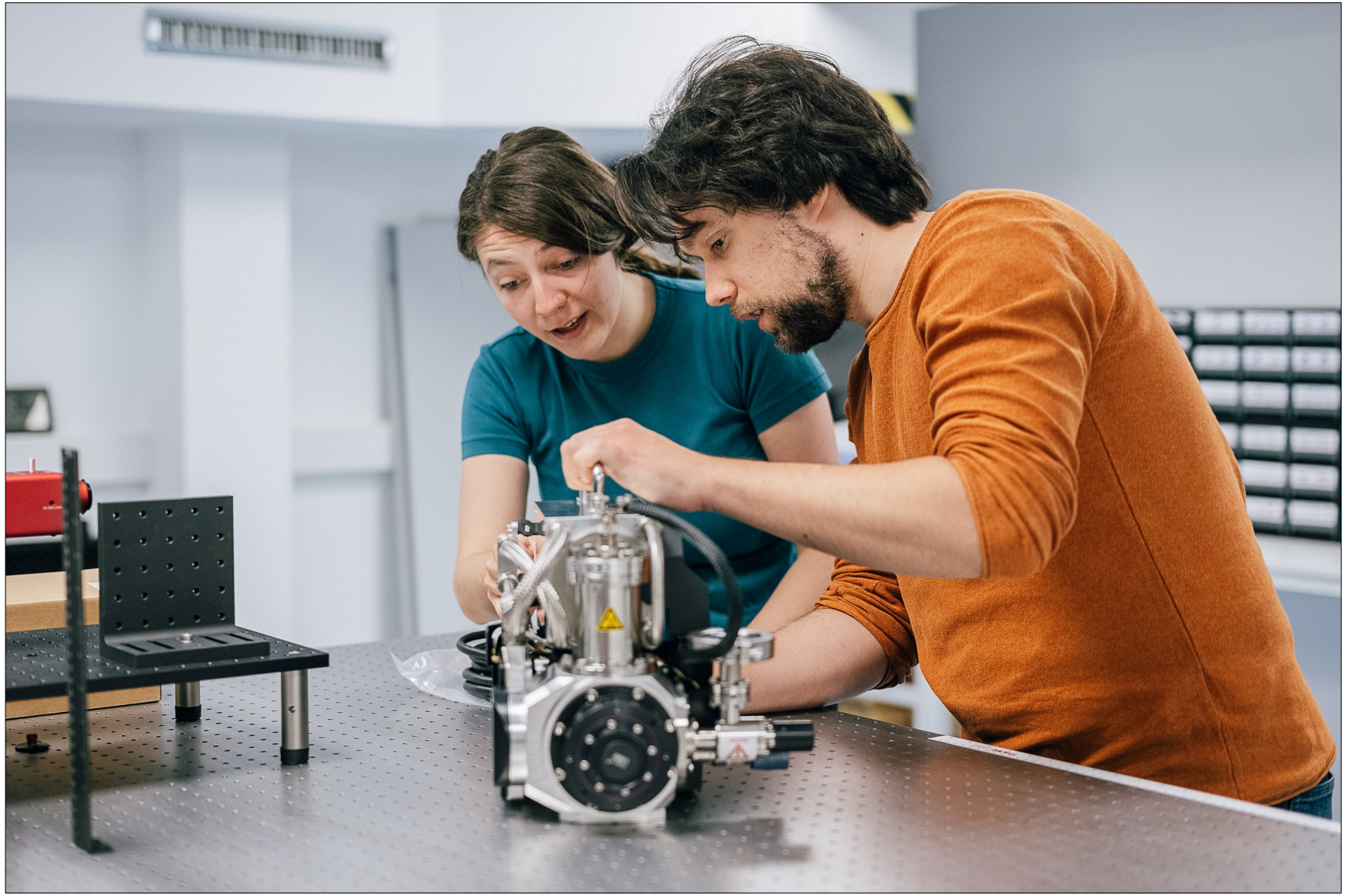
Large Saphira contract with AIP

Test PGA

Dr. Manoj Varma (AIP)



C-Red-One camera available at DZA Detector Lab



Stella Vjesnica (DZA)

Pasko Roje (DZA)

C-Red-One camera available at DZA Detector Lab

Received: 6 September 2023 | Accepted: 6 September 2023

DOI: 10.1002/asna.20230124

Astronomische Nachrichten

PROCEEDING

Characterization of a C-RED One camera for astrophotonical applications

Stella Vješnica[1] | Eloy Hernandez[1] | Kalaga Madhav[1] | Martin M. Roth[1,2]

[1]innoFSPEC–Technical Section/Detector Systems, Leibniz-Institut für Astrophysik Potsdam (AIP), Germany

[2]Institut für Physik und Astronomie, Universität Potsdam, Germany

Correspondence
Stella Vješnica, innoFSPEC–Technical Section/Detector Systems, Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16, Potsdam 14482, Germany.
Email: svjesnica@aip.de

Funding information
Bundesministerium für Bildung und Forschung, Grant/Award Numbers: 03Z22A51 Meta-Zik AstrOOPtics, 03Z22AB1A NIRDETECT, 03Z22AI1 Strategic Investment, 03Z22AN11 Astrophotonics

Abstract
To better understand the impact of the avalanche gain applied in the detector technology and apply this technology in our in-house astrophotonic projects, we have characterized a C-RED One camera and produced a stable and reliable method for calculating the system gain at any desired avalanche gain setting. We observed that depending on how the system gain is obtained, multiplying the system gain times the avalanche gain may not accurately produce a conversion factor from electrons to ADUs. As the acquisition of a photon transfer curve (PTC) was possible at different avalanche gain levels, several PTCs at low avalanche gain levels were acquired. Consequently, a linear fit was produced from the acquired system gain as a function of the avalanche gain setting. Through the linear fit, the effective system gain was calculated at any desired avalanche level. The effective system gain makes possible to accurately calculate the initial system gain without the ambiguity introduced by the nonlinearity of the system. Besides, the impact of the avalanche gain on the dynamic range was also analyzed and showed a stable behavior through the measured avalanche range.

KEYWORDS
C-RED One, SAPHIRA, detector, avalanche photodiode, sub-e noise

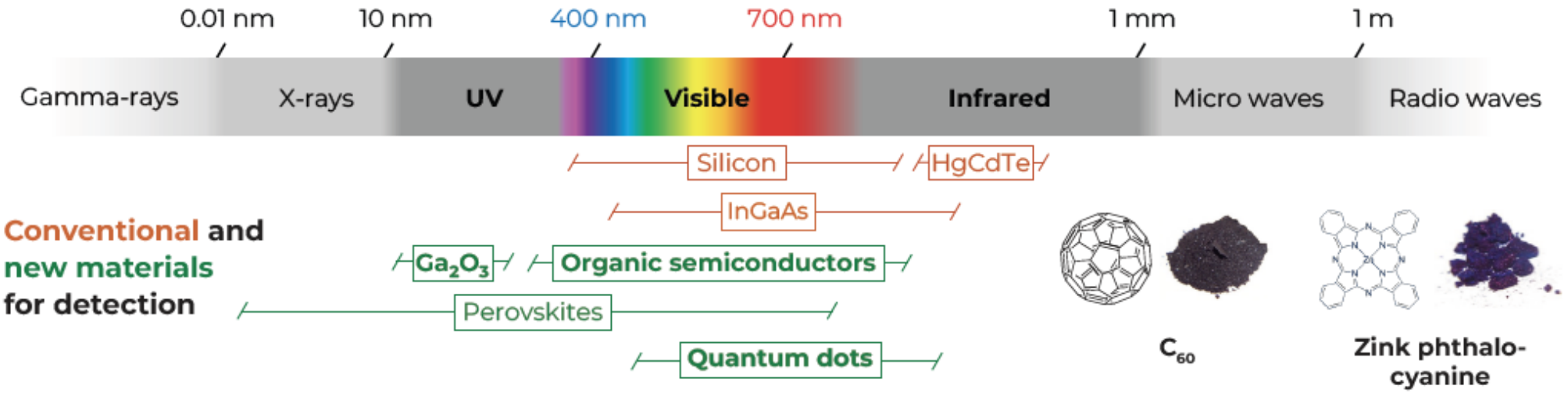
Stella Vjesnica (DZA)

ZENTRUM FÜR TECHNOLOGIEENTWICKLUNG // SCHWERPUNKT DETEKTORFORSCHUNG

Novel Detector Technologies and their Application Potential

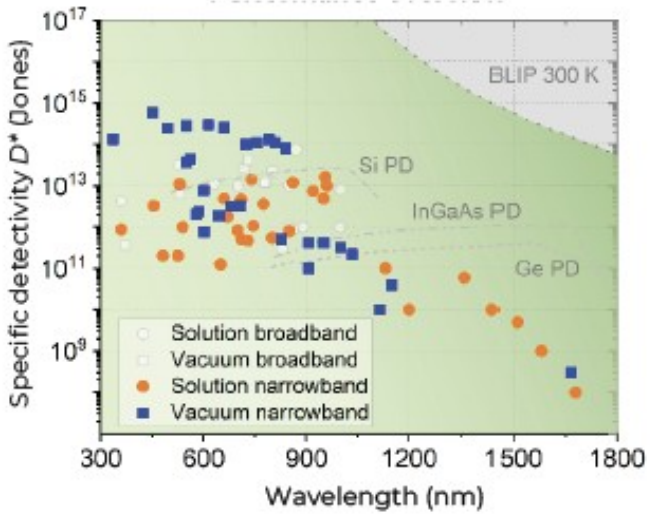
Johannes Benduhn
DZA/TU Dresden

H. THIERSCH, L.C. WINKLER, F. KRETSCHMER, J. BENDUHN



$$D^* \propto \frac{\text{External quantum efficiency}}{\text{Noise current}}$$

Performance overview



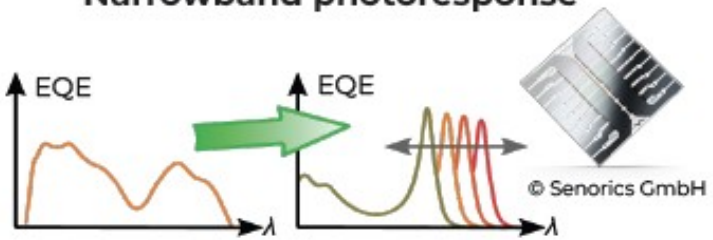
Ref.: Wang, Benduhn *et al.* Materials Horizons 9, 220 (2022) + updates

Flexibility

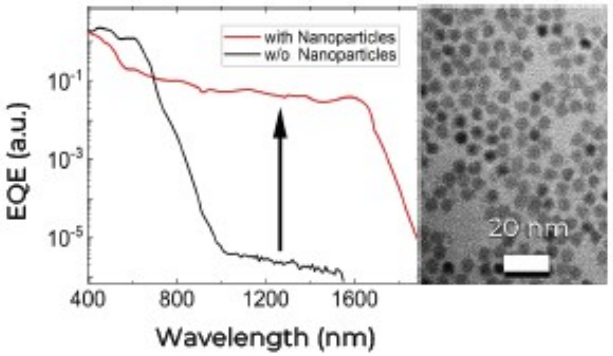
New materials for detection

Semitransparency

Narrowband photoresponse



Quantum dots for NIR



With funding from the:
Federal Ministry of Research, Technology and Space

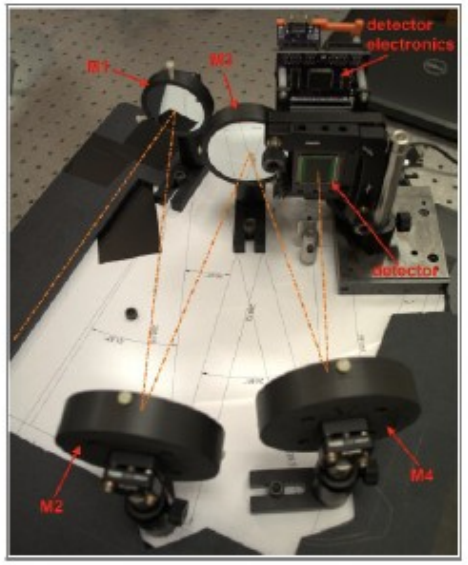
In cooperation with: AIP, Fraunhofer IPMS, Technische Universität Dresden, iapp

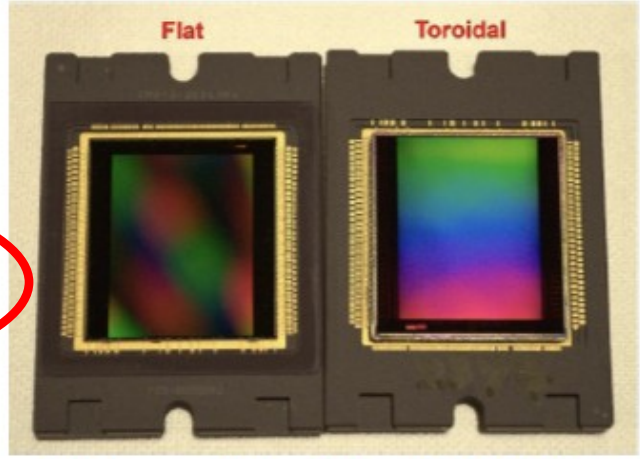
DZA Deutsches Zentrum Astrophysik

Curved detectors

Increased sensitivity: Better match of detector to focal plane geometry

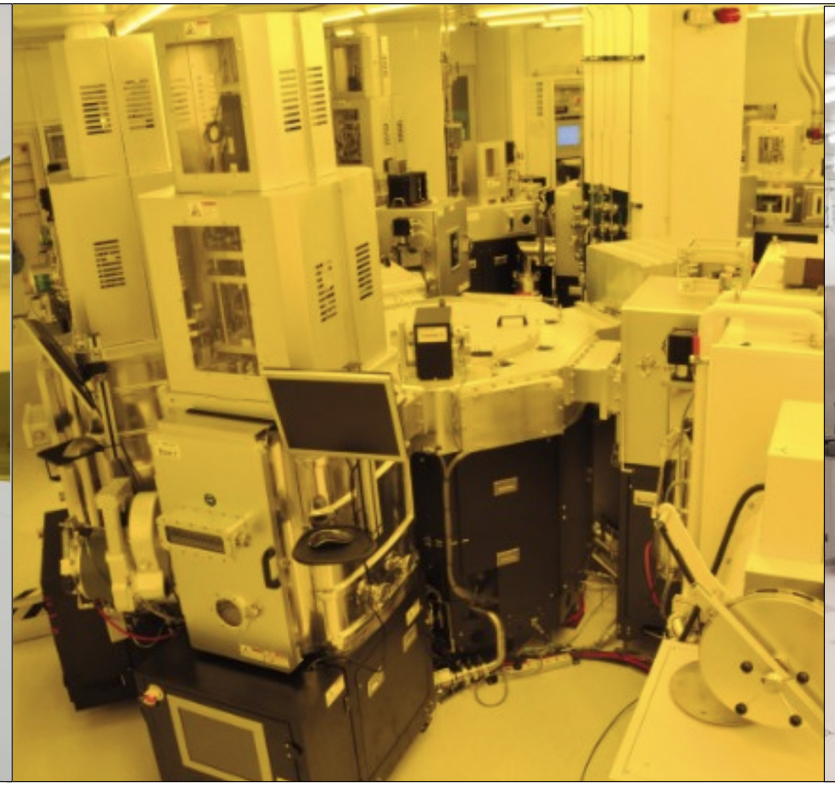
- Telescope field curvature compensated by curving the detector rather than flattening the field with additional optical surfaces
  - Increased instrument throughput, reduced mass, cost….
- ESO is developing a highly curved CMOS detector
  - 4K, 6K to 10K sensor, minimum 10-15 µm pixel
  - Dark noise ~1 e- / 30min / pixel
  - Ratio (radius of curvature) / (diameter of the sensor) > 4
  - Collaboration with IPMS Fraunhofer Dresden and Deutsches Zentrum für Astrophysik, on this topic in preparation
- Proof of concept at a toroidally curved detector by Muslimov et al., 2025





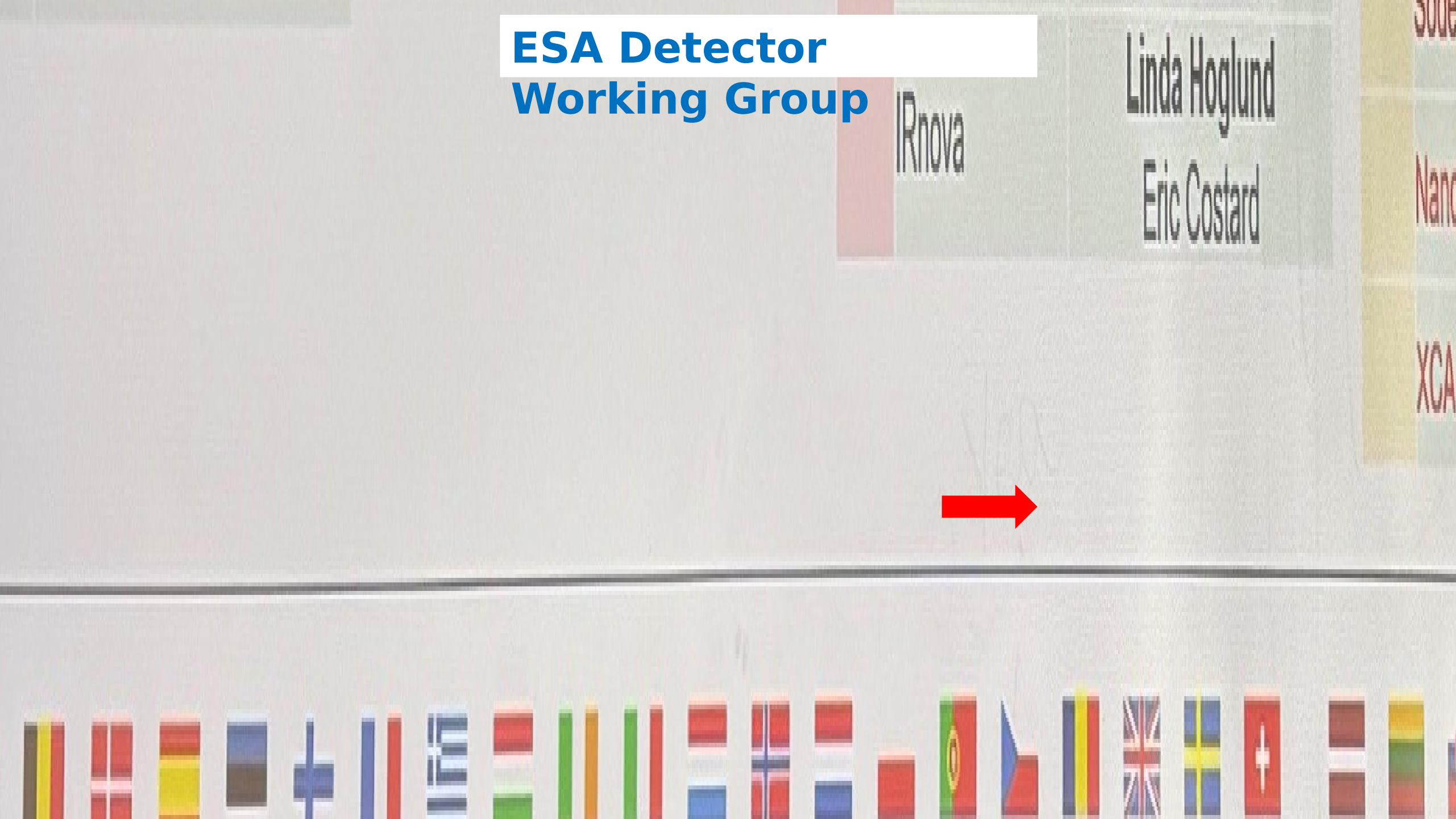
Muslimov et al, arXiv:2503.09300v1

300 mm Wafer CMOS Facility in Dresden



Fraunhofer
IPMS

ESA Detector Working Group



SCIENTIFIC DETECTOR WORKSHOP

6th - 10th October 2025
Canberra, Australia

TELEDYNE TECHNOLOGIES Everywhereyoulook™ LEONARDO CANBERRA CONVENTION BUREAU SEMICONDUCTOR TECHNOLOGY ASSOCIATES INC IAC 25 SYD DZA

DZA interests in GaiaNIR

- Science (with TUD and AIP)
- Conceptual design studies of detector subsystem
- On-sky TDI experiments with eAPD
- Industrial scale detector development
- Long-term: detector system integration & test

WST – the next big thing @ ESO?

arXiv > astro-ph > arXiv:2403.05398

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Astrophysics > Instrumentation and Methods for Astrophysics

[Submitted on 8 Mar 2024 (v1), last revised 12 Apr 2024 (this version, v2)]

The Wide-field Spectroscopic Telescope (WST) Science White Paper

Vincenzo Mainieri, Richard I. Anderson, Jarle Brinchmann, Andrea Cimatti, Richard S. Ellis, Vanessa Hill, Jean-Paul Kneib, Anna F. McLeod, Cyrielle Opitom, Martin M. Roth, Paula Sanchez-Saez, Rodolfo Smiljanic, Eline Tolstoy, Roland Bacon, Sofia Randich, Angela Adamo, Francesca Annibali, Patricia Arevalo, Marc Audard, Stefania Barsanti, Giuseppina Battaglia, Amelia M. Bayo Aran, Francesco Belfiore, Michele Bellazzini, Emilio Bellini, Maria Teresa Beltran, Leda Berni, Simone Bianchi, Katia Biazzo, Sofia Bisero, Susanna Bisogni, Joss Bland-Hawthorn, Stephane Blondin, Julia Bodensteiner, Henri M.J. Boffin, Rosaria Bonito, Giuseppe Bono, Nicolas F. Bouche, Dominic Bowman, Vittorio F. Braga, Angela Bragaglia, Marica Branchesi, Anna Brucalassi, Julia J. Bryant, Ian Bryson, Innocenza Busa, Stefano Camera, Carmelita Carbone, Giada Casali, Mark Casali, Viviana Casasola, Norberto Castro, Marcio Catelan, Lorenzo Cavallo, Cristina Chiappini, Maria-Rosa Cioni, Matthew Colless, Laura Colzi, Sofia Contarini, Warrick Couch, Filippo D'Ammando, William d'Assignies D., Valentina D'Orazi, Ronaldo da Silva, Maria Giovanna Dainotti, Francesco Damiani, Camilla Danielski, Annalisa De Cia, Roelof S. de Jong, Suhail Dhawan, Philippe Dierickx, Simon P. Driver, Ulyana Dupletsa, Stephanie Escoffier, Ana Escorza, Michele Fabrizio, Giuliana Fiorentino, Adriano Fontana, Francesco Fontani, Daniel Forero Sanchez, Patrick Franois, Francisco Jose Galindo-Guil, Anna Rita Gallazzi, Daniele Galli, Miriam Garcia, Jorge Garcia-Rojas, Bianca Garilli, Robert Grand, Mario Giuseppe Guarcello, Nandini Hazra, Amina Helmi, Artemio Herrero, Daniela Iglesias, Dragana Ilic, Vid Irsic, Valentin D. Ivanov, Luca Izzo, Pascale Jablonka, Benjamin Joachimi, Darshan Kakkad et al. (117 additional authors not shown)

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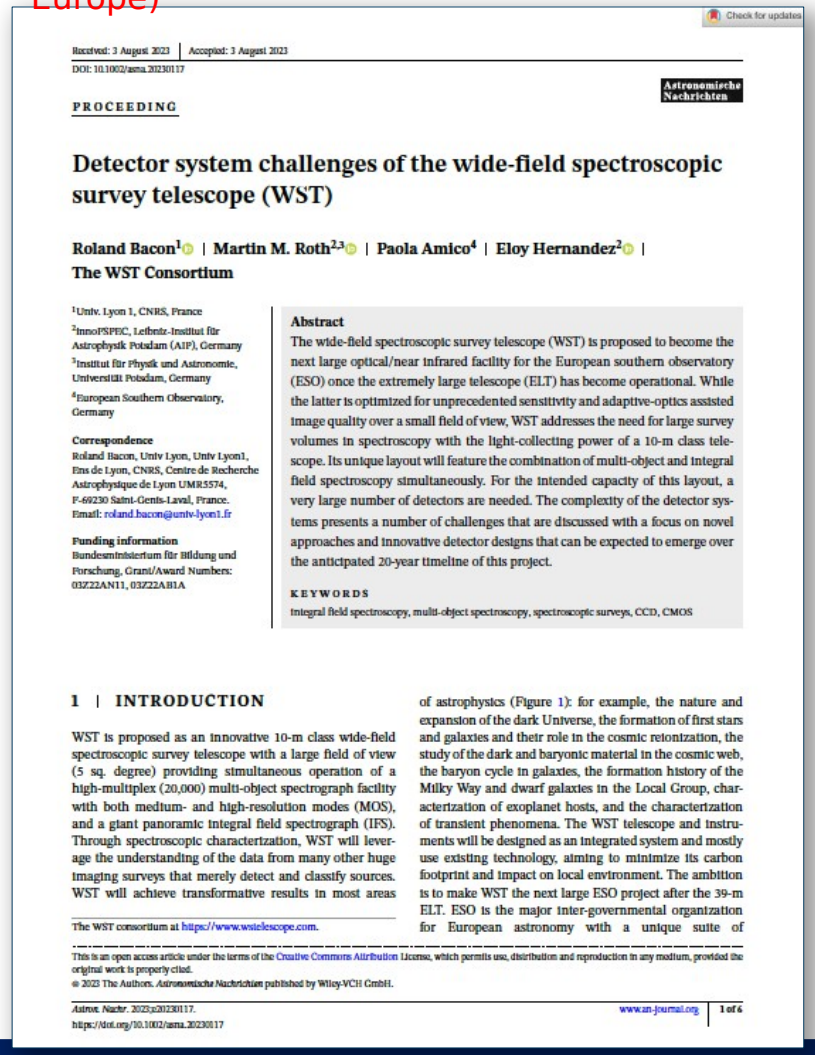
WST – the next big thing @ ESO?

Conception Design Study (Horizon Europe)



Received: 3 August 2023 | Accepted: 3 August 2023
DOI: 10.1002/asna.20230117

Astronomische Nachrichten

PROCEEDING

Detector system challenges of the wide-field spectroscopic survey telescope (WST)

Roland Bacon[1] | Martin M. Roth[2,3] | Paola Amico[4] | Eloy Hernandez[2] | The WST Consortium

[1]Univ. Lyon 1, CNRS, France
[2]InnoPSPEC, Leibniz-Institut für Astrophysik Potsdam (AIP), Germany
[3]Institut für Physik und Astronomie, Universität Potsdam, Germany
[4]European Southern Observatory, Germany

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Funding information
Bundesministerium für Bildung und Forschung, Grant/Award Numbers: 03Z22AN11, 03Z22AB1A

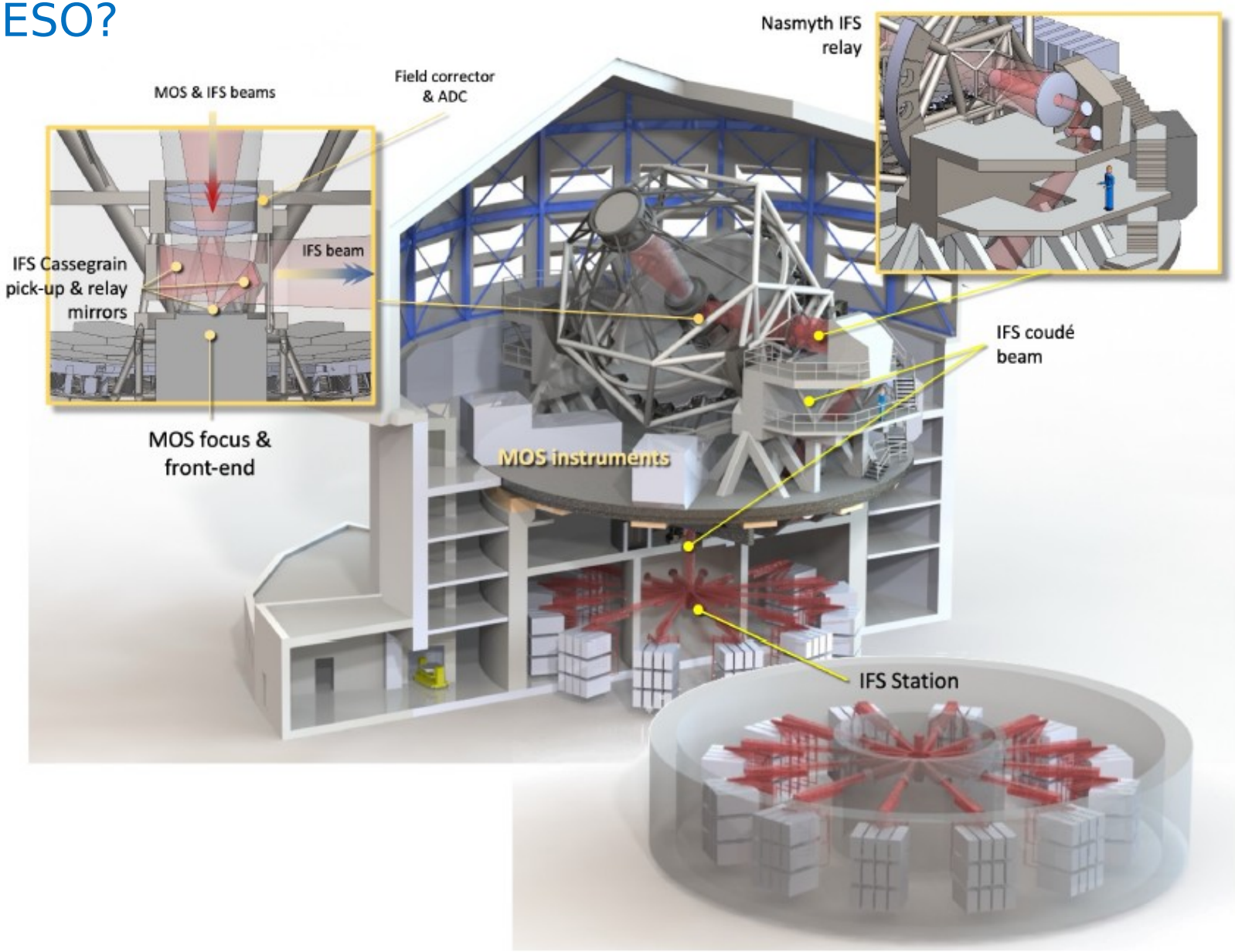
Abstract
The wide-field spectroscopic survey telescope (WST) is proposed to become the next large optical/near infrared facility for the European southern observatory (ESO) once the extremely large telescope (ELT) has become operational. While the latter is optimized for unprecedented sensitivity and adaptive-optics assisted image quality over a small field of view, WST addresses the need for large survey volumes in spectroscopy with the light-collecting power of a 10-m class telescope. Its unique layout will feature the combination of multi-object and integral field spectroscopy simultaneously. For the intended capacity of this layout, a very large number of detectors are needed. The complexity of the detector systems presents a number of challenges that are discussed with a focus on novel approaches and innovative detector designs that can be expected to emerge over the anticipated 20-year timeline of this project.

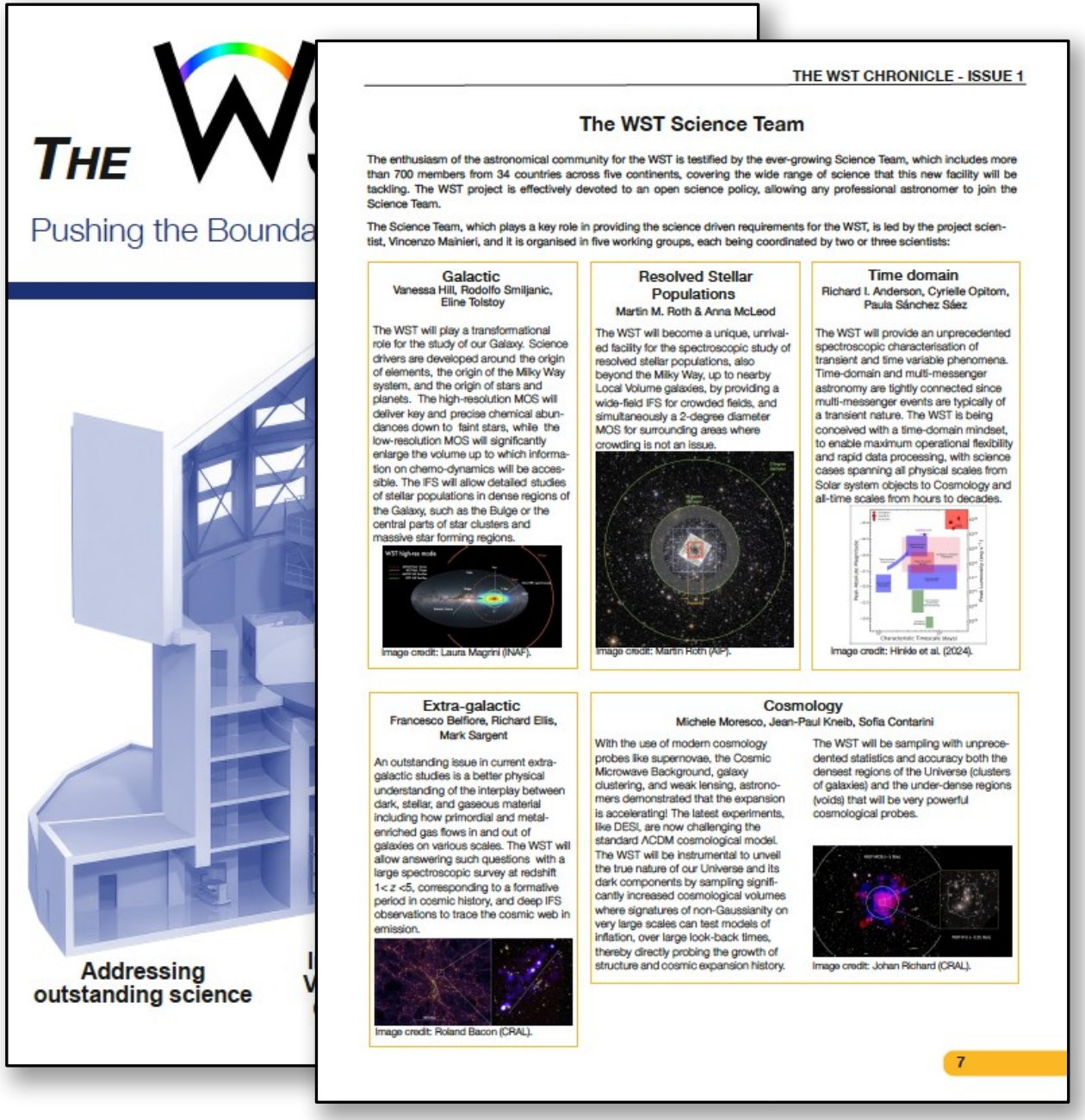
KEYWORDS
integral field spectroscopy, multi-object spectroscopy, spectroscopic surveys, CCD, CMOS

1 | INTRODUCTION

WST is proposed as an innovative 10-m class wide-field spectroscopic survey telescope with a large field of view (5 sq. degree) providing simultaneous operation of a high-multiplex (20,000) multi-object spectrograph facility with both medium- and high-resolution modes (MOS), and a giant panoramic integral field spectrograph (IFS). Through spectroscopic characterization, WST will leverage the understanding of the data from many other huge imaging surveys that merely detect and classify sources. WST will achieve transformative results in most areas of astrophysics (Figure 1): for example, the nature and expansion of the dark Universe, the formation of first stars and galaxies and their role in the cosmic reionization, the study of the dark and baryonic material in the cosmic web, the baryon cycle in galaxies, the formation history of the Milky Way and dwarf galaxies in the Local Group, characterization of exoplanet hosts, and the characterization of transient phenomena. The WST telescope and instruments will be designed as an integrated system and mostly use existing technology, aiming to minimize its carbon footprint and impact on local environment. The ambition is to make WST the next large ESO project after the 39-m ELT. ESO is the major inter-governmental organization for European astronomy with a unique suite of

The WST consortium at https://www.wstelescope.com.





THE WST CHRONICLE - ISSUE 1

The WST Science Team

The enthusiasm of the astronomical community for the WST is testified by the ever-growing Science Team, which includes more than 700 members from 34 countries across five continents, covering the wide range of science that this new facility will be tackling. The WST project is effectively devoted to an open science policy, allowing any professional astronomer to join the Science Team.

The Science Team, which plays a key role in providing the science driven requirements for the WST, is led by the project scientist, Vincenzo Mainieri, and it is organised in five working groups, each being coordinated by two or three scientists:

Galactic
Vanessa Hill, Rodolfo Smiljanic, Eline Tolstoy

The WST will play a transformational role for the study of our Galaxy. Science drivers are developed around the origin of elements, the origin of the Milky Way system, and the origin of stars and planets. The high-resolution MOS will deliver key and precise chemical abundances down to faint stars, while the low-resolution MOS will significantly enlarge the volume up to which information on chemo-dynamics will be accessible. The IFS will allow detailed studies of stellar populations in dense regions of the Galaxy, such as the Bulge or the central parts of star clusters and massive star forming regions.

Image credit: Laura Magrini (INAF).

Resolved Stellar Populations
Martin M. Roth & Anna McLeod

The WST will become a unique, unrivaled facility for the spectroscopic study of resolved stellar populations, also beyond the Milky Way, up to nearby Local Volume galaxies, by providing a wide-field IFS for crowded fields, and simultaneously a 2-degree diameter MOS for surrounding areas where crowding is not an issue.

Image credit: Martin Roth (AIP).

Time domain
Richard I. Anderson, Cyrielle Opitom, Paula Sánchez Sáez

The WST will provide an unprecedented spectroscopic characterisation of transient and time variable phenomena. Time-domain and multi-messenger astronomy are tightly connected since multi-messenger events are typically of a transient nature. The WST is being conceived with a time-domain mindset, to enable maximum operational flexibility and rapid data processing, with science cases spanning all physical scales from Solar system objects to Cosmology and all-time scales from hours to decades.

Image credit: Hinkle et al. (2024).

Extra-galactic
Francesco Belfiore, Richard Ellis, Mark Sargent

An outstanding issue in current extra-galactic studies is a better physical understanding of the interplay between dark, stellar, and gaseous material including how primordial and metal-enriched gas flows in and out of galaxies on various scales. The WST will allow answering such questions with a large spectroscopic survey at redshift $1 < z < 5$, corresponding to a formative period in cosmic history, and deep IFS observations to trace the cosmic web in emission.

Image credit: Roland Bacon (CRAL).

Cosmology
Michele Moresco, Jean-Paul Kneib, Sofia Contarini

With the use of modern cosmology probes like supernovae, the Cosmic Microwave Background, galaxy clustering, and weak lensing, astronomers demonstrated that the expansion is accelerating! The latest experiments, like DESI, are now challenging the standard ΛCDM cosmological model. The WST will be instrumental to unveil the true nature of our Universe and its dark components by sampling significantly increased cosmological volumes where signatures of non-Gaussianity on very large scales can test models of inflation, over large look-back times, thereby directly probing the growth of structure and cosmic expansion history.

The WST will be sampling with unprecedented statistics and accuracy both the densest regions of the Universe (clusters of galaxies) and the under-dense regions (voids) that will be very powerful cosmological probes.

Image credit: Johan Richard (CRAL).

7

Resolved Stellar Populations

Martin M. Roth & Anna McLeod

The WST will become a unique, unrivaled facility for the spectroscopic study of resolved stellar populations, also beyond the Milky Way, up to nearby Local Volume galaxies, by providing a wide-field IFS for crowded fields, and simultaneously a 2-degree diameter MOS for surrounding areas where crowding is not an issue.

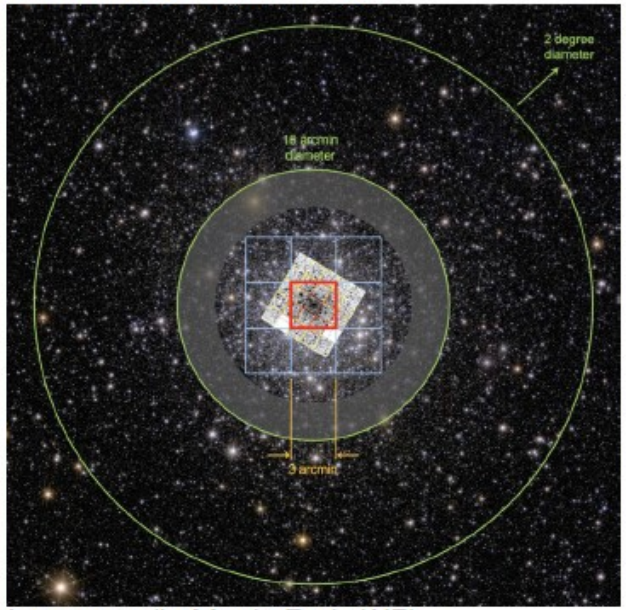
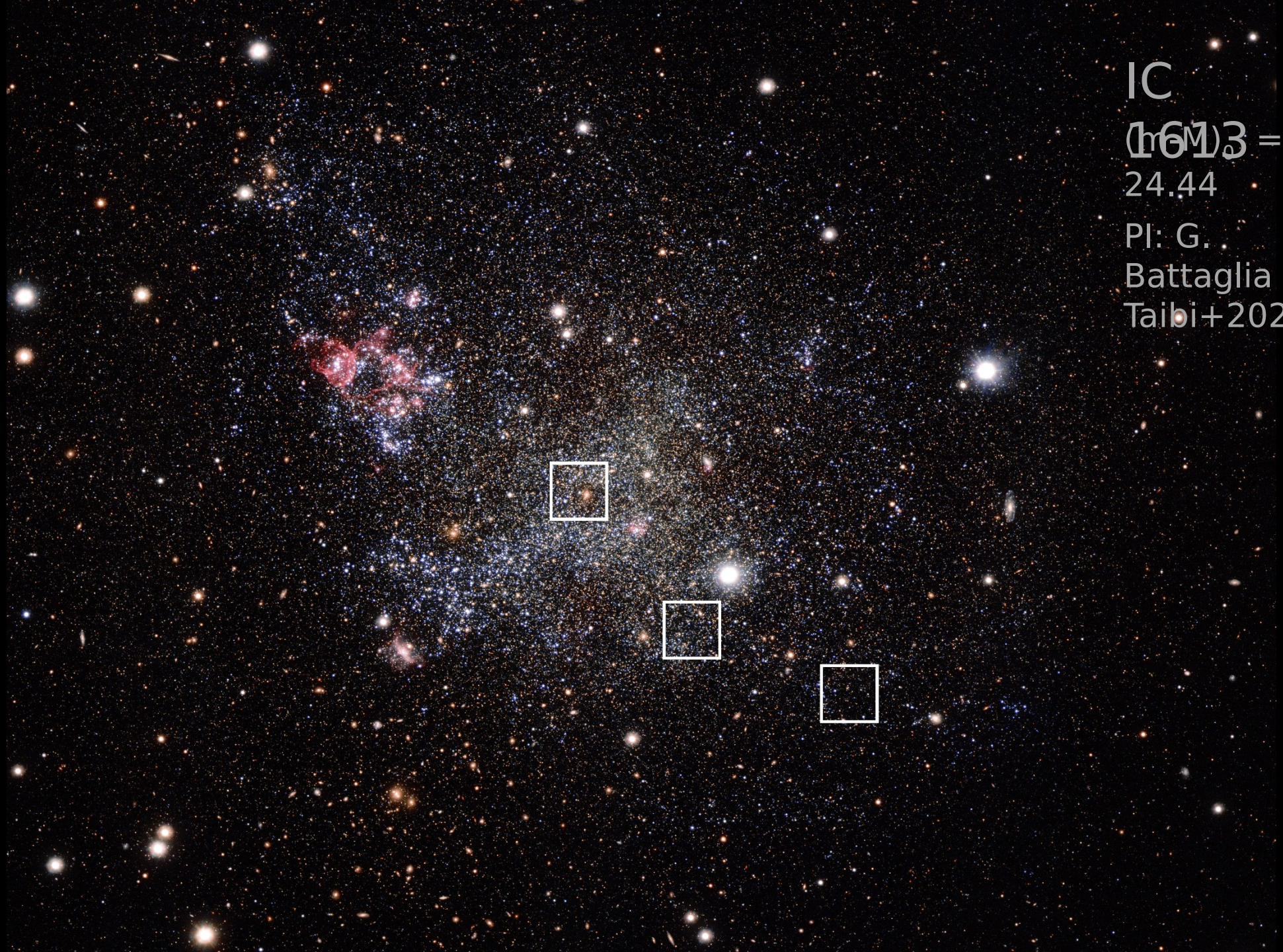


Image credit: Martin Roth (AIP).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PI: G. Battaglia
Taibi+2024

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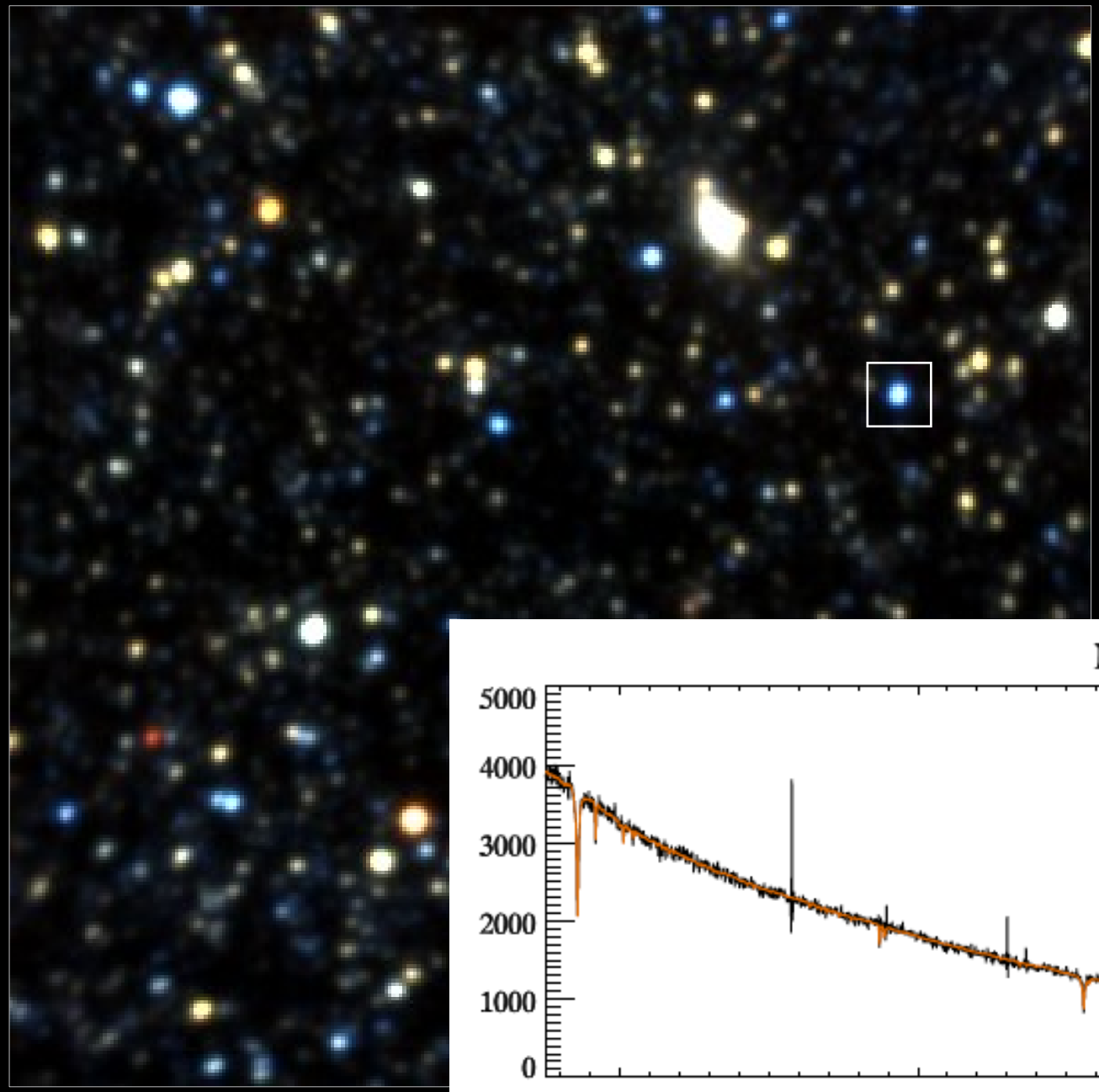

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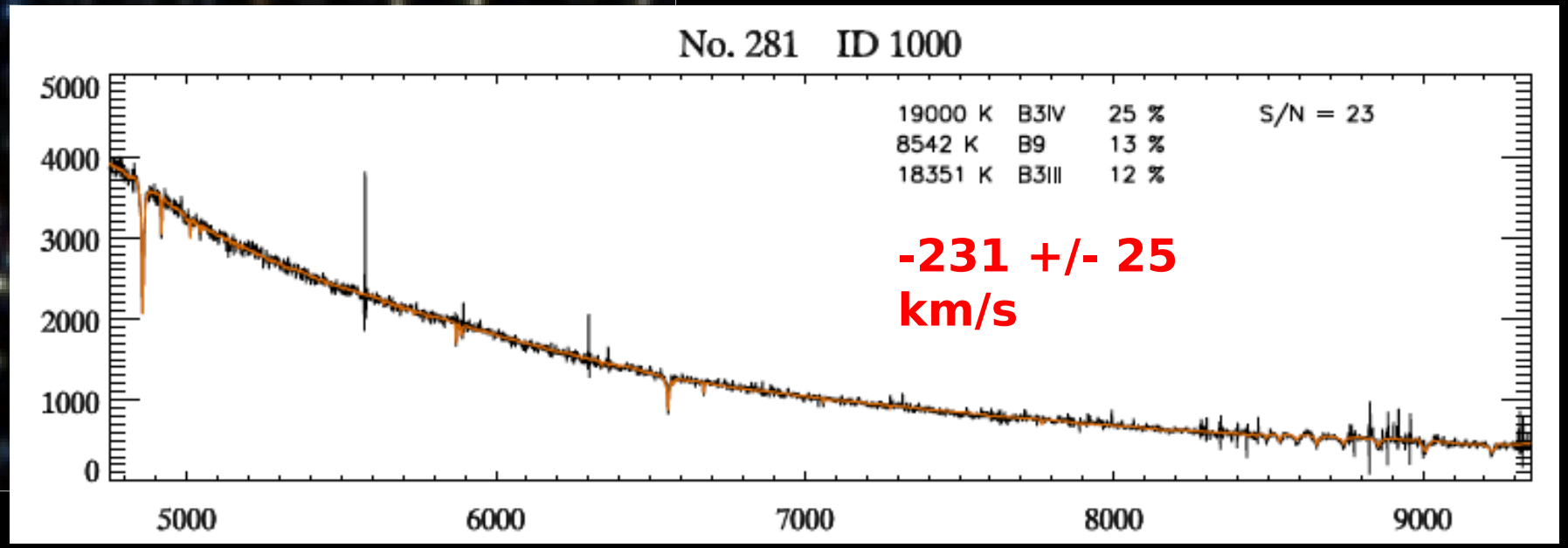

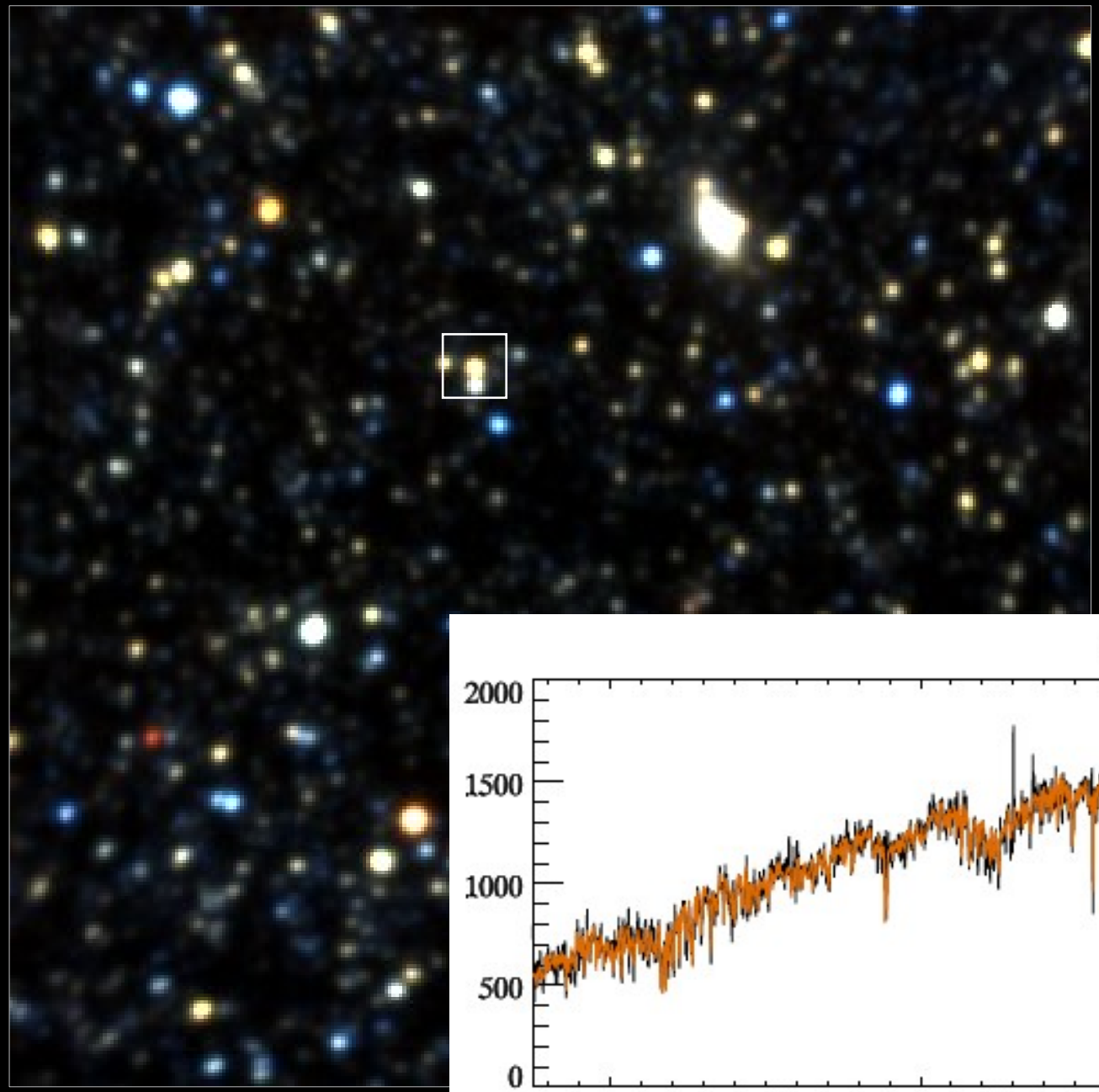

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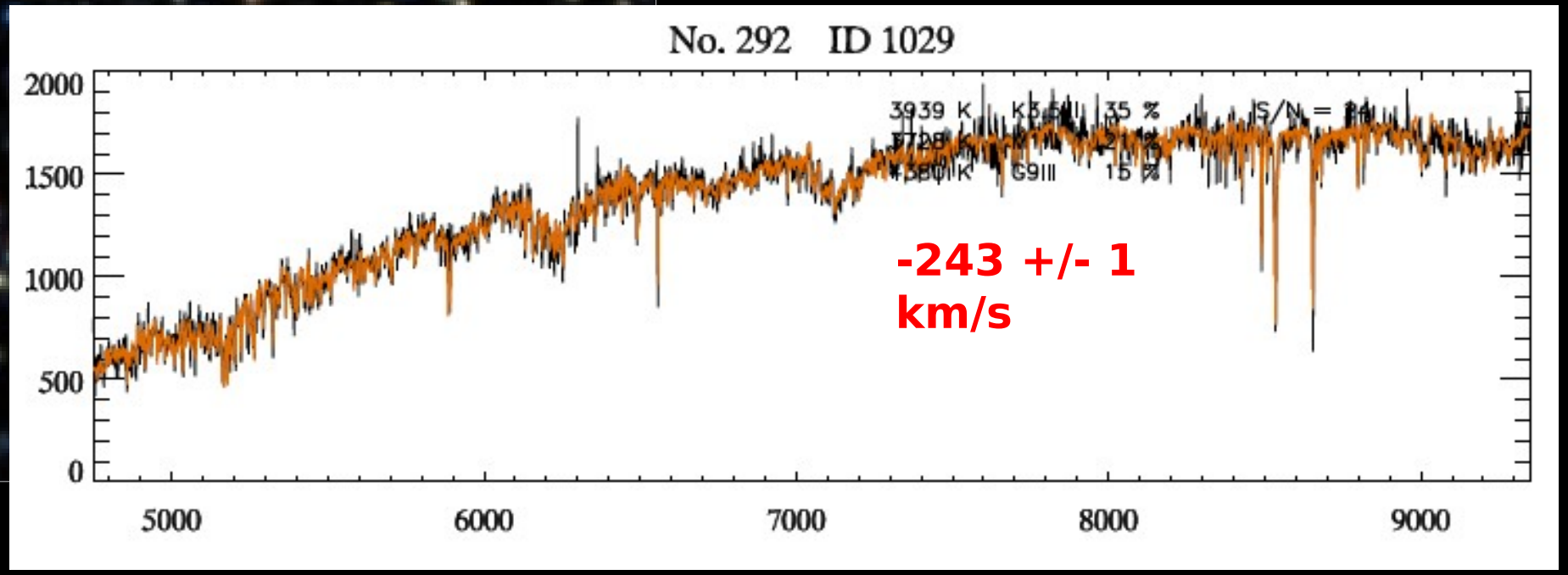

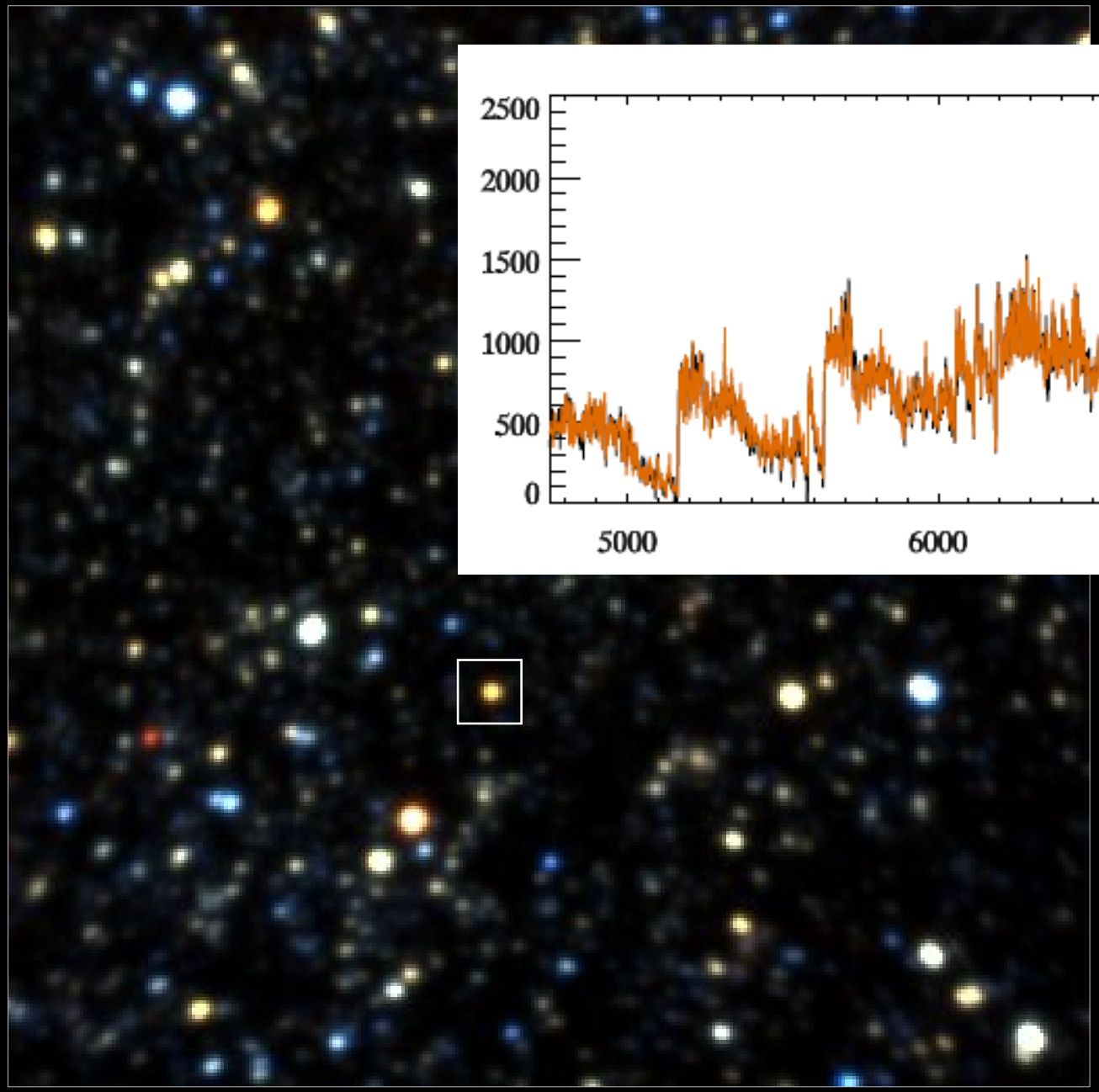

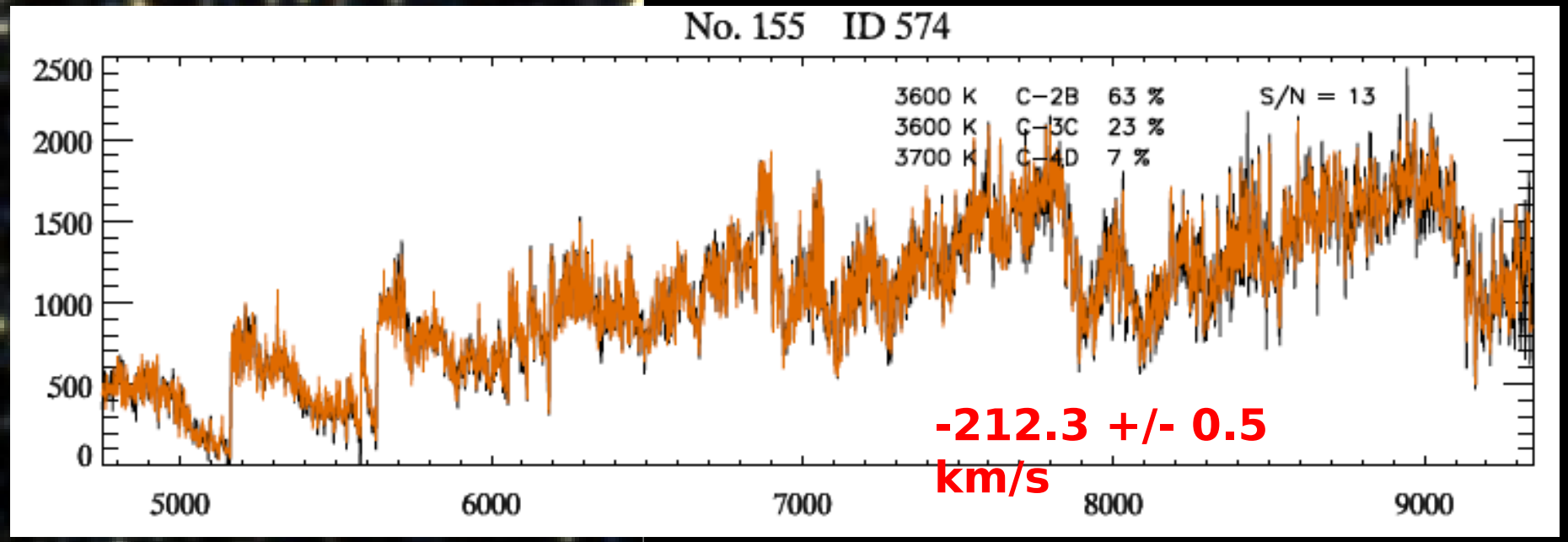
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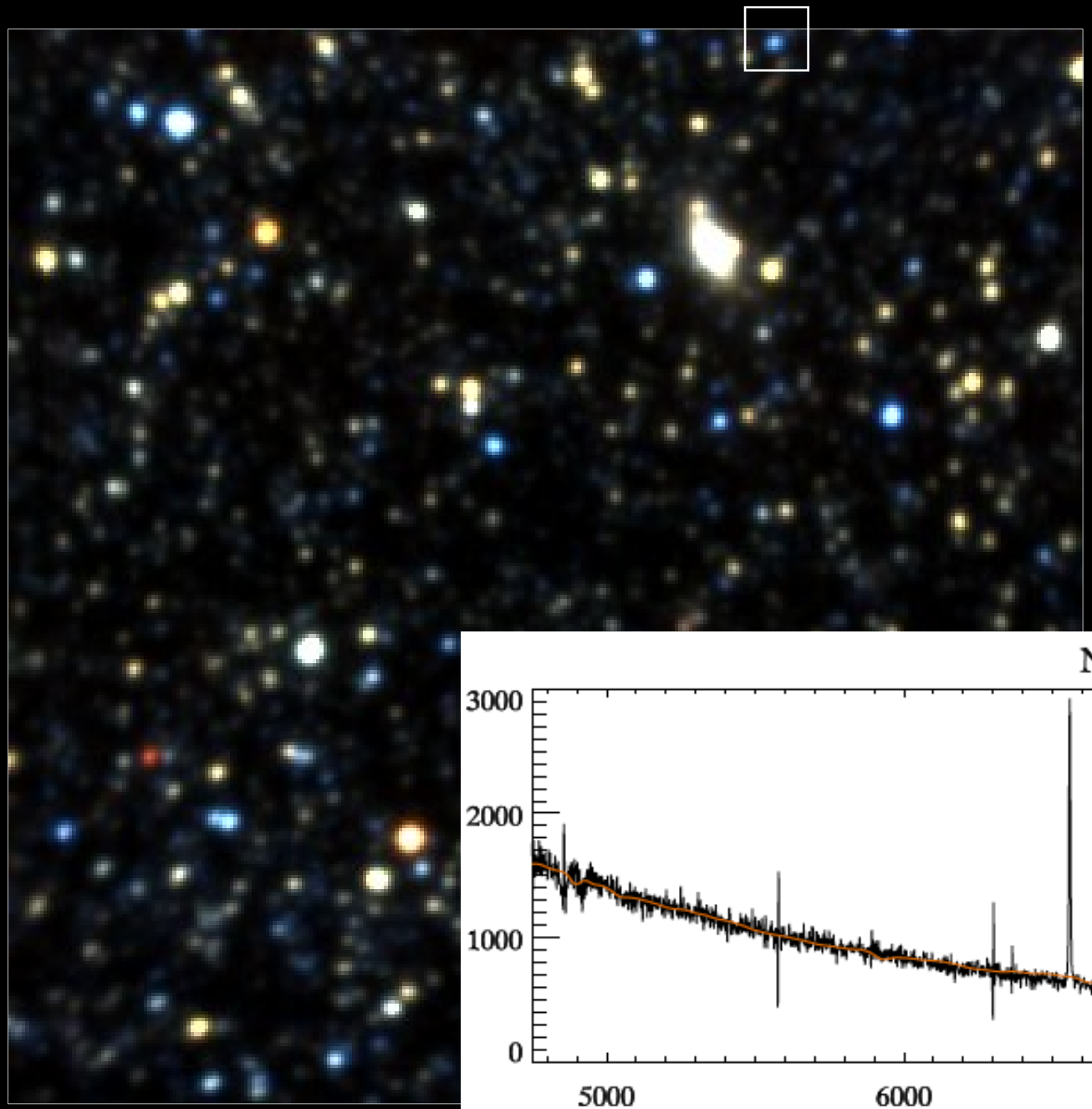
Carbon star



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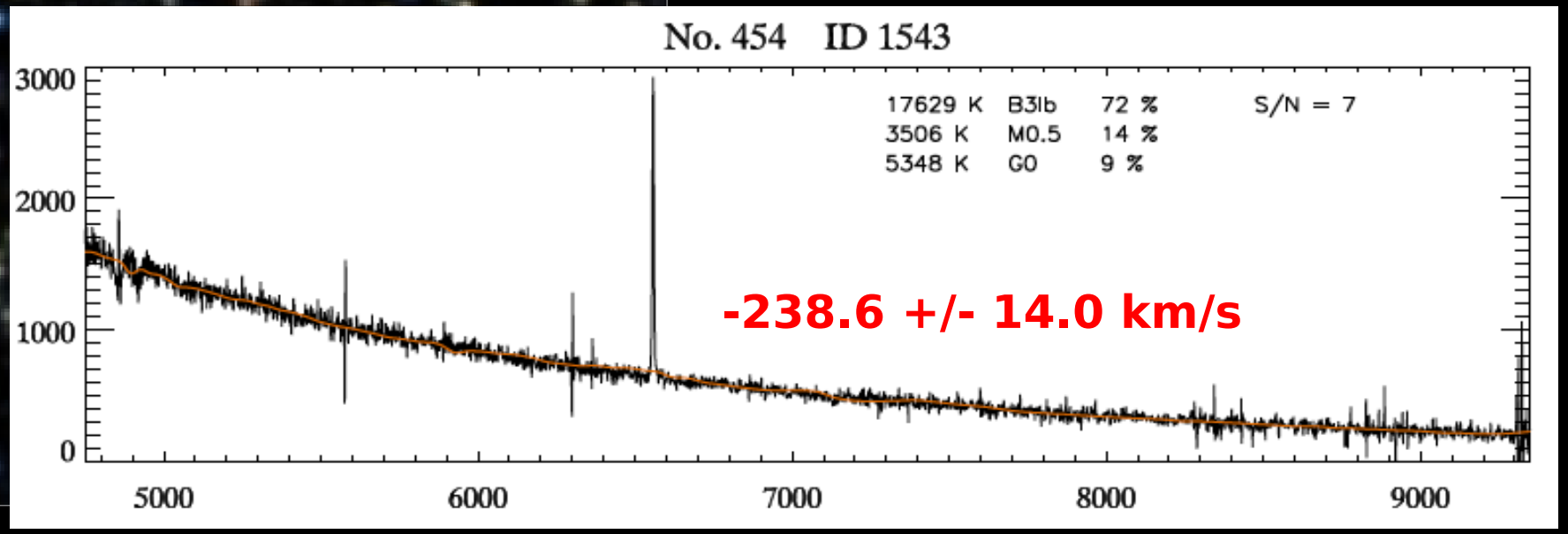
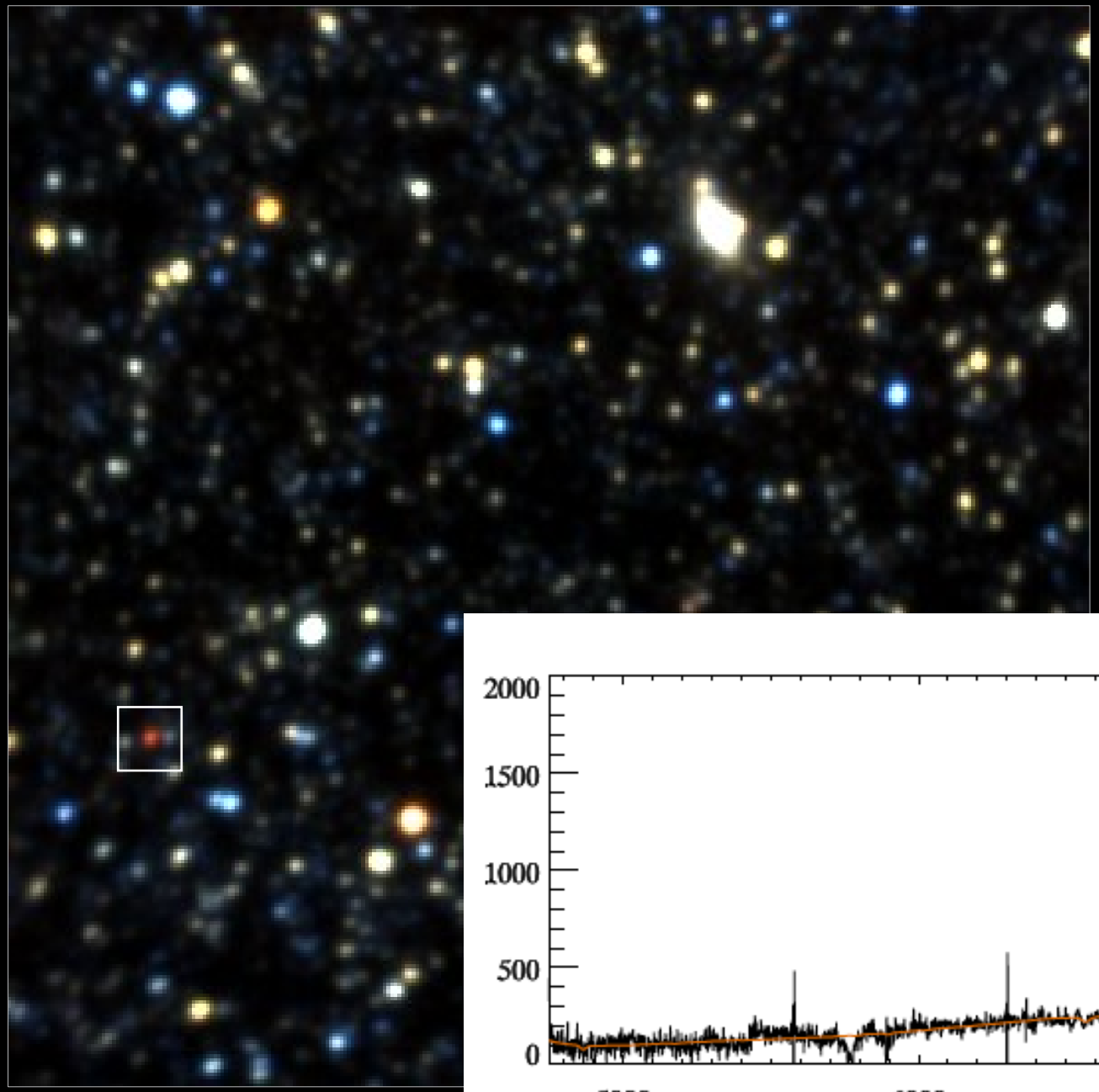
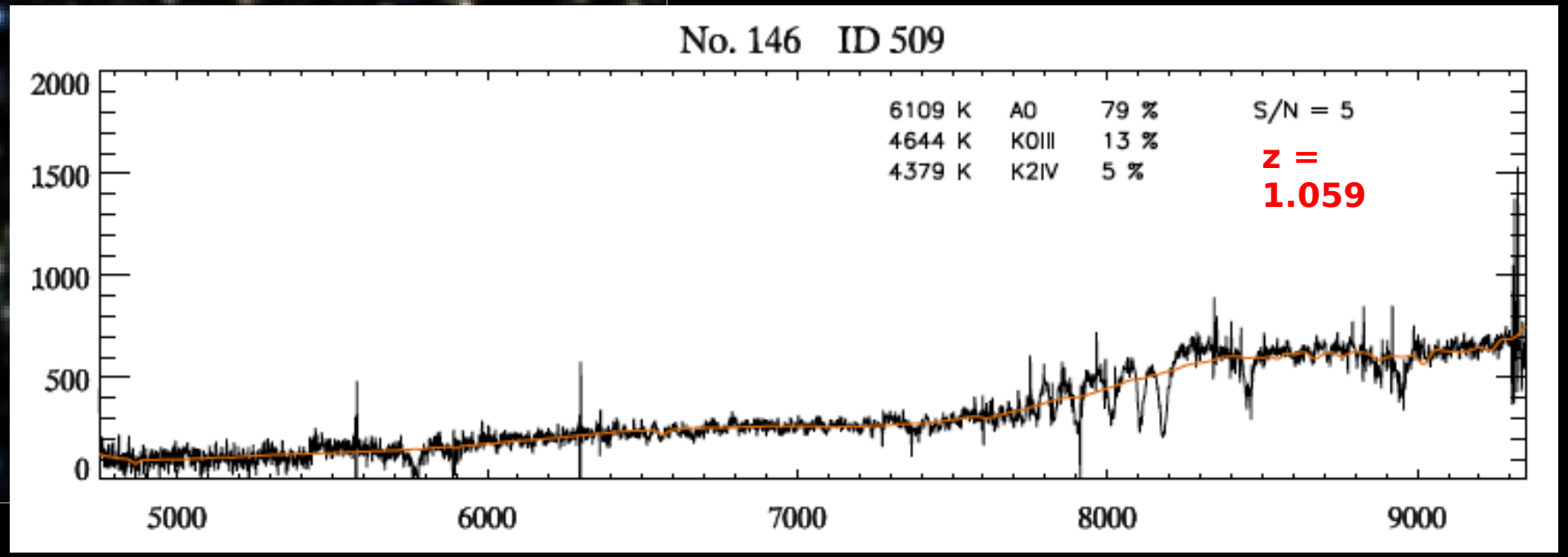


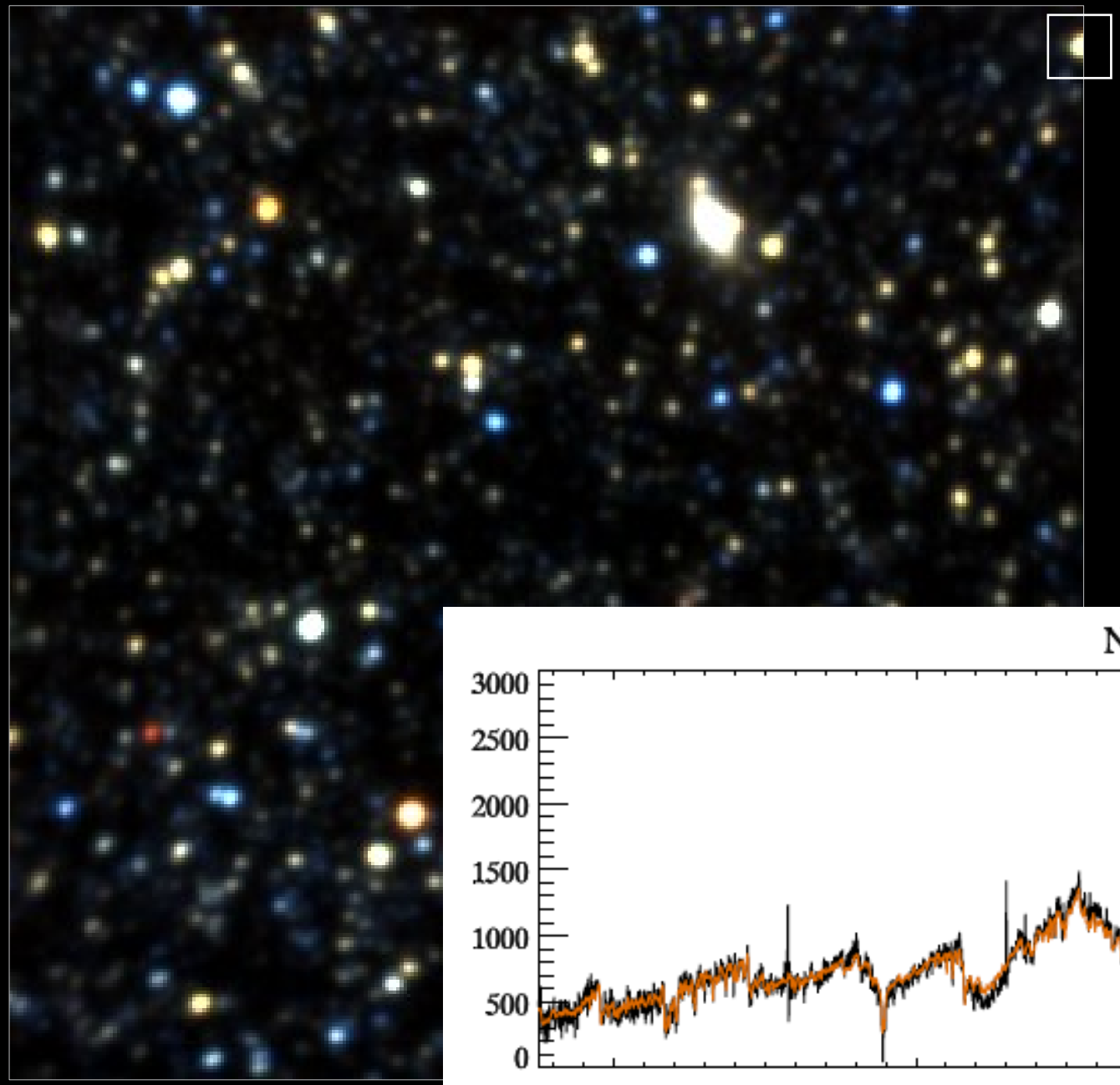


IC 1613

24

Background galaxy





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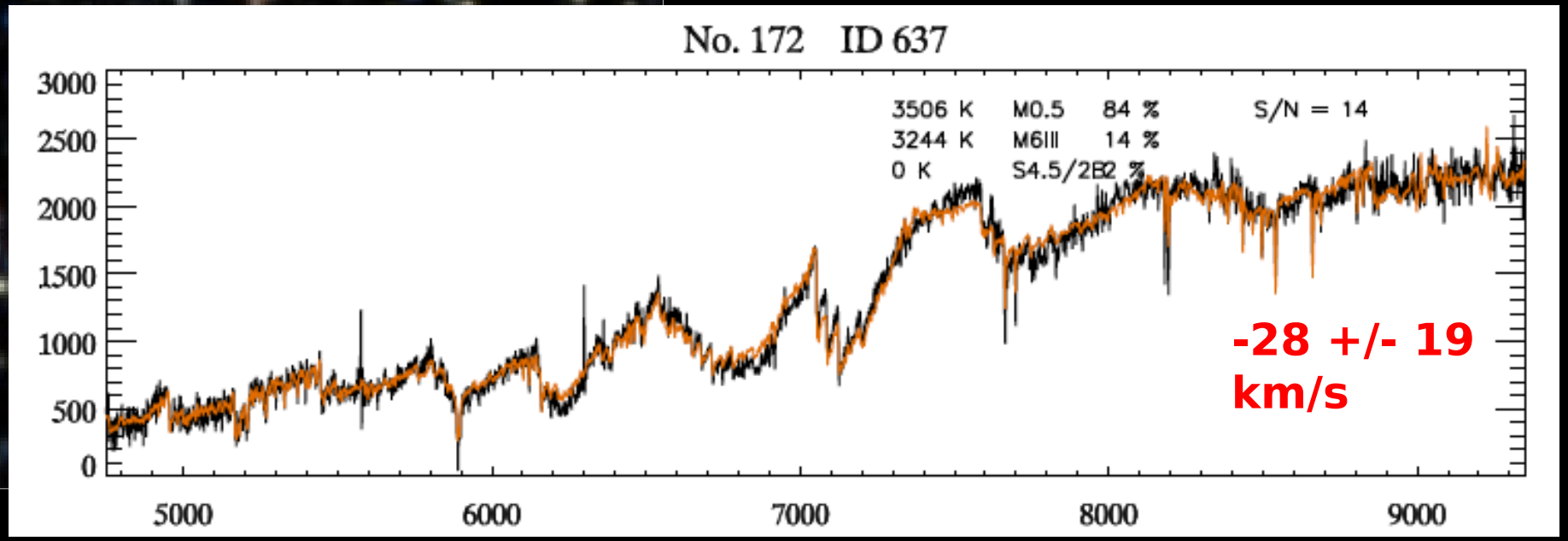
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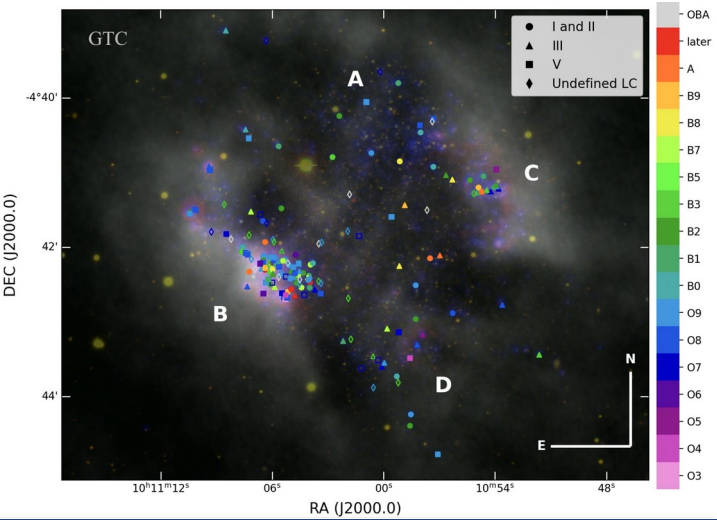
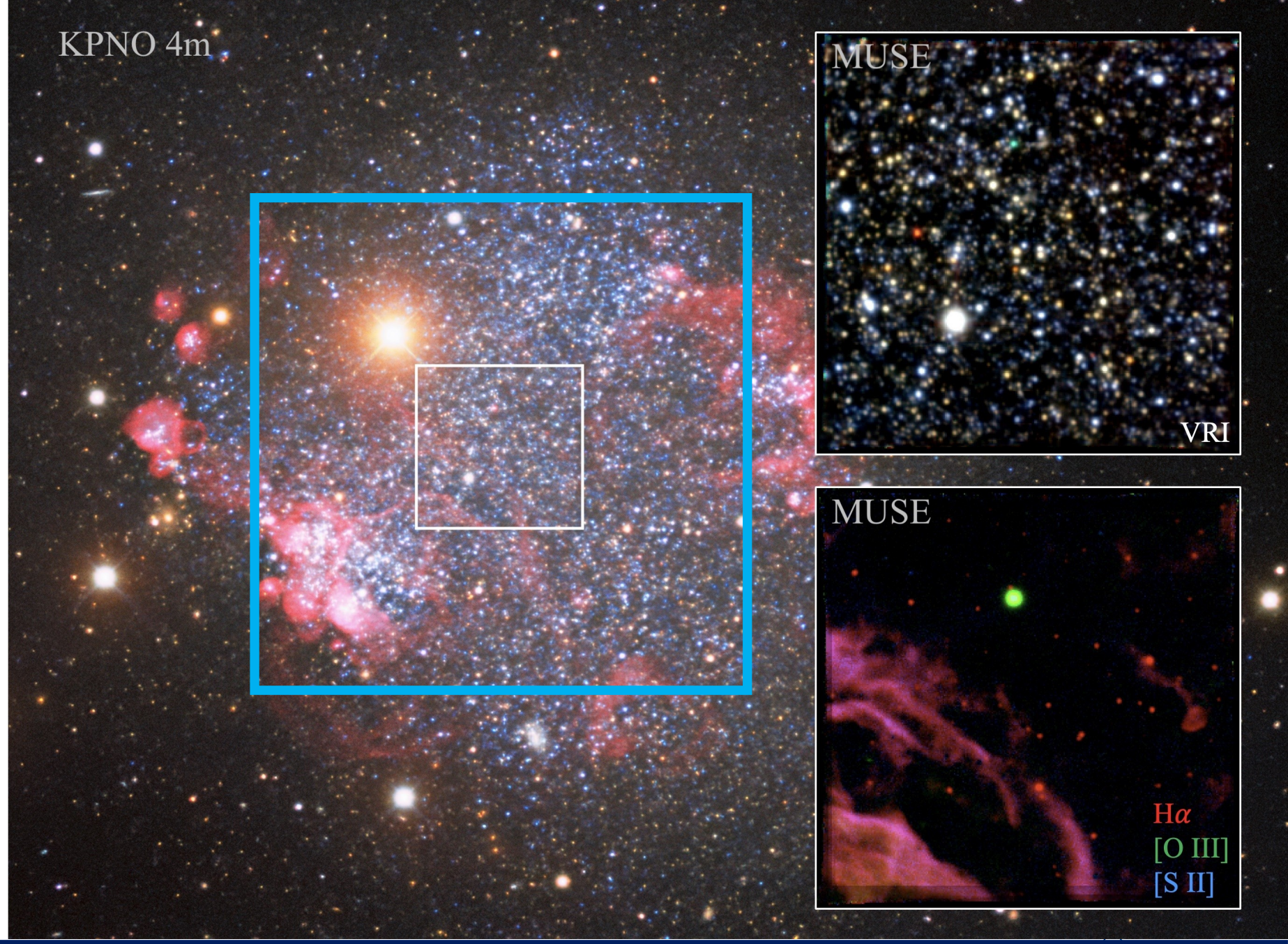
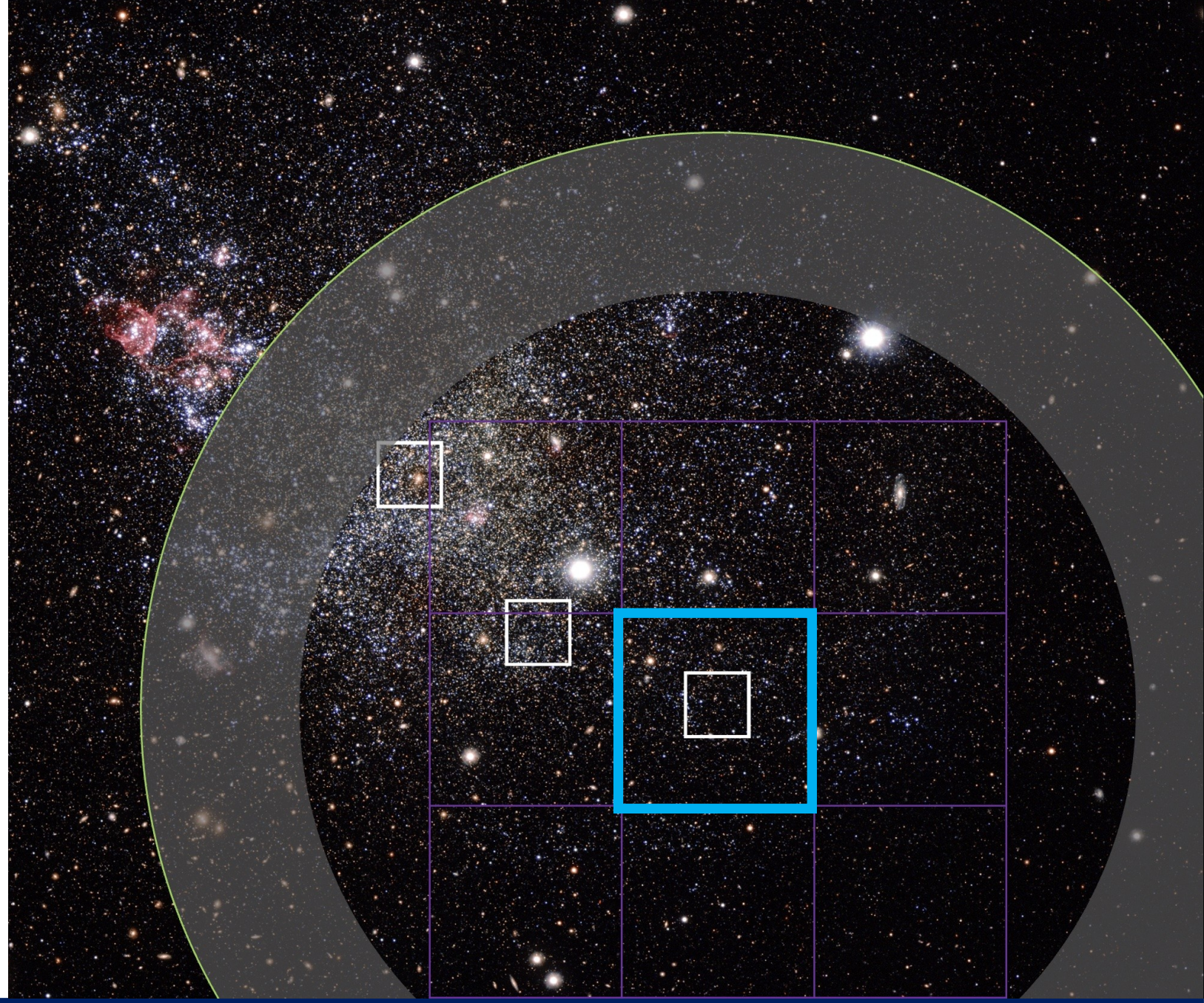
WST RESPOP Science Case: Massive Stars

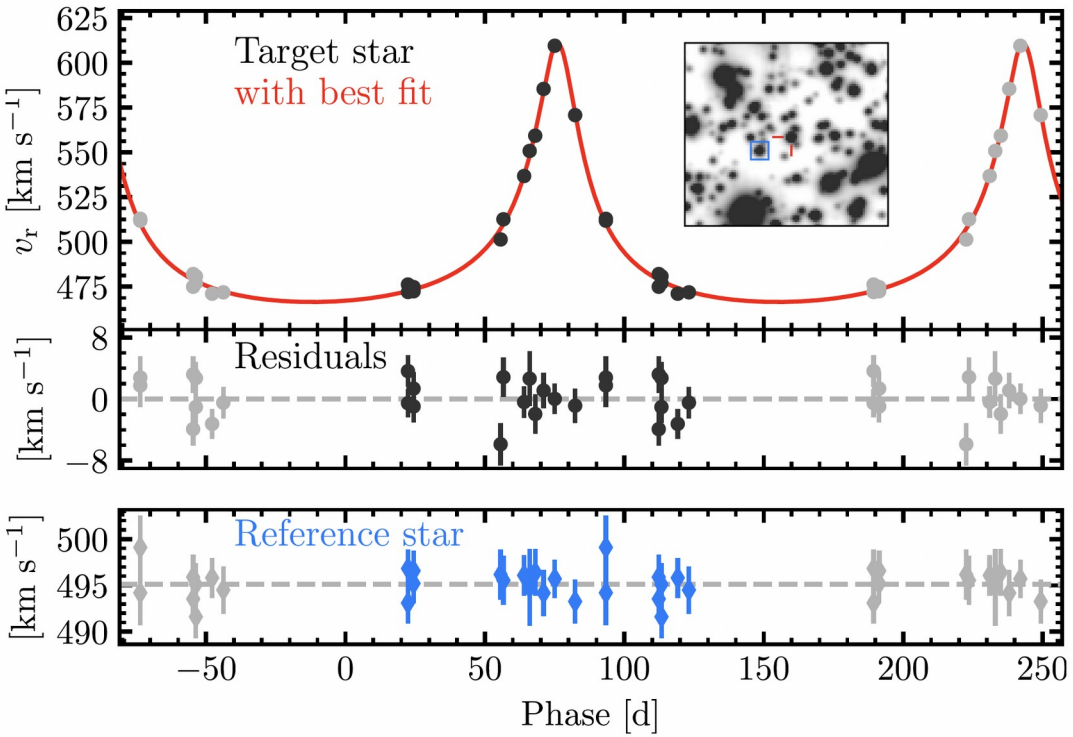


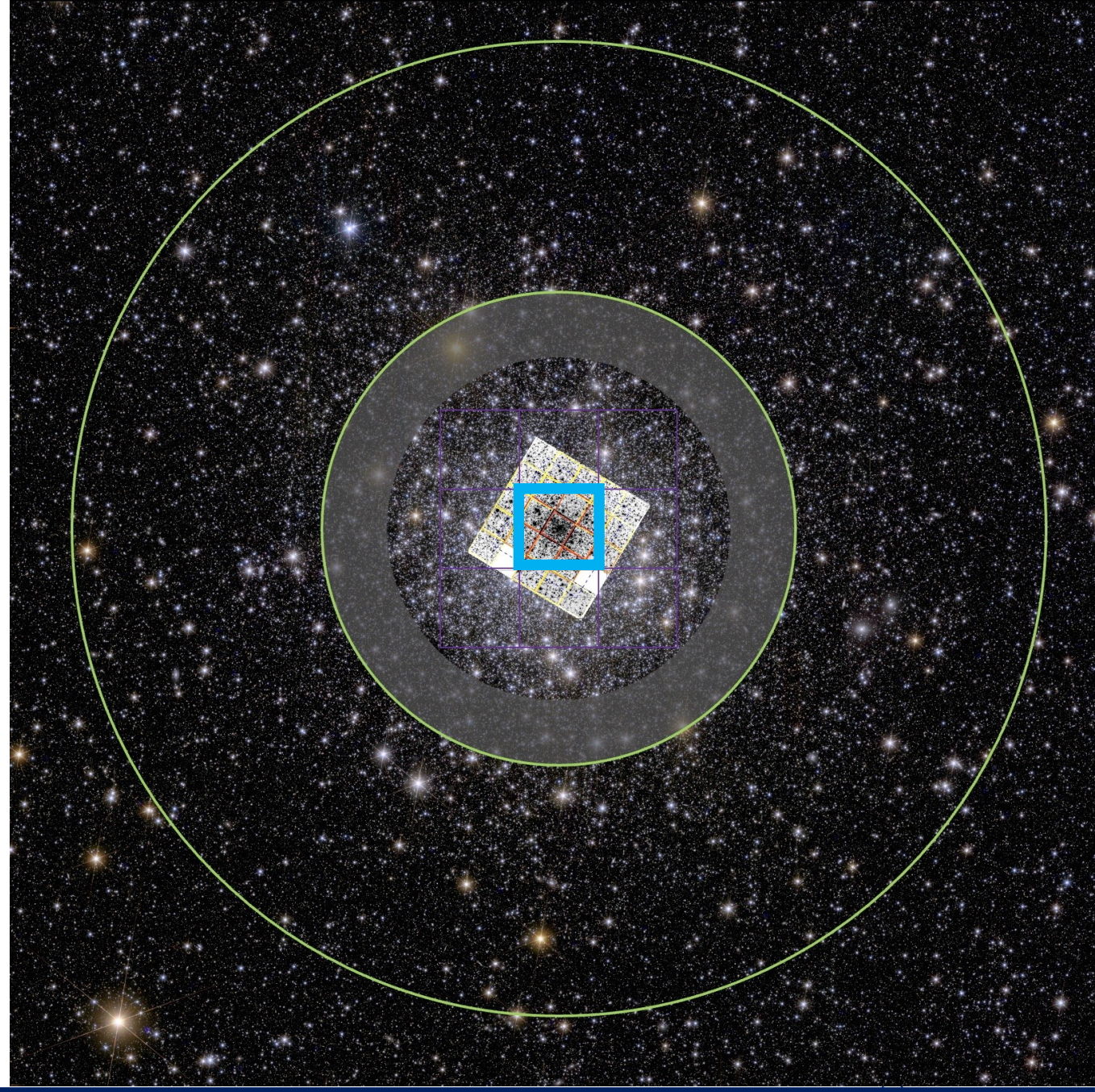


WST RESPOP Science Case: Local Group Dwarf Galaxies



WST RESPOP Science Case:
Binaries in Globular Clusters





WST RESPOP Science Case: Local Volume Galaxies