

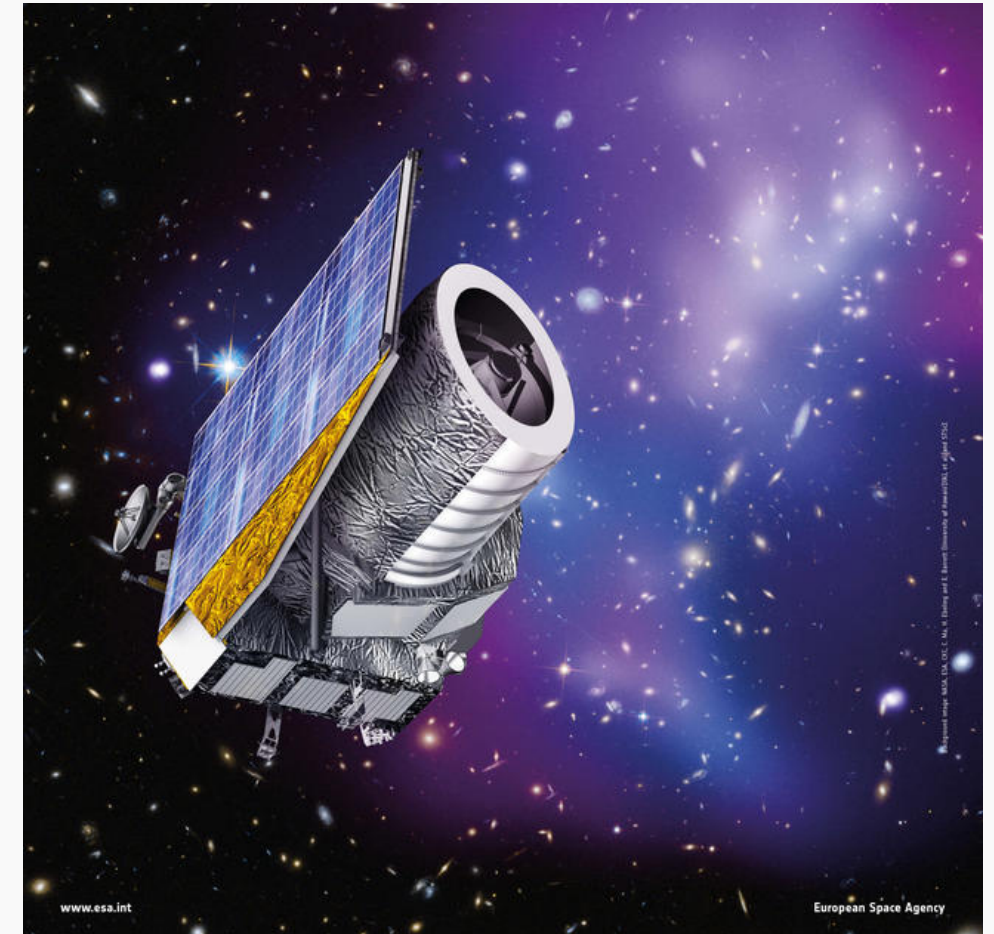
Euclid衛星計画

大栗 真宗

(東京大学 RESCEU/物理/カブリIPMU)

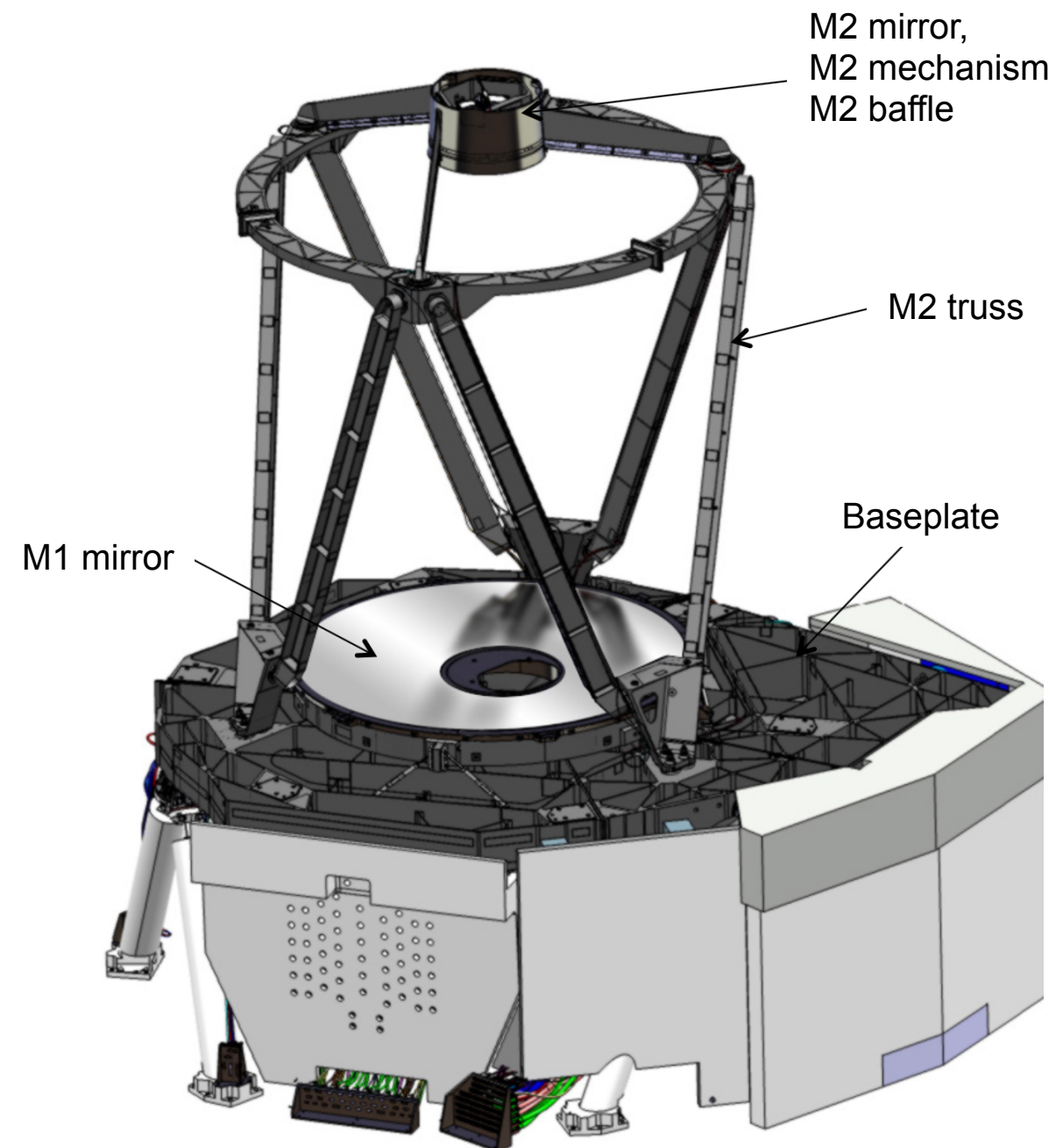
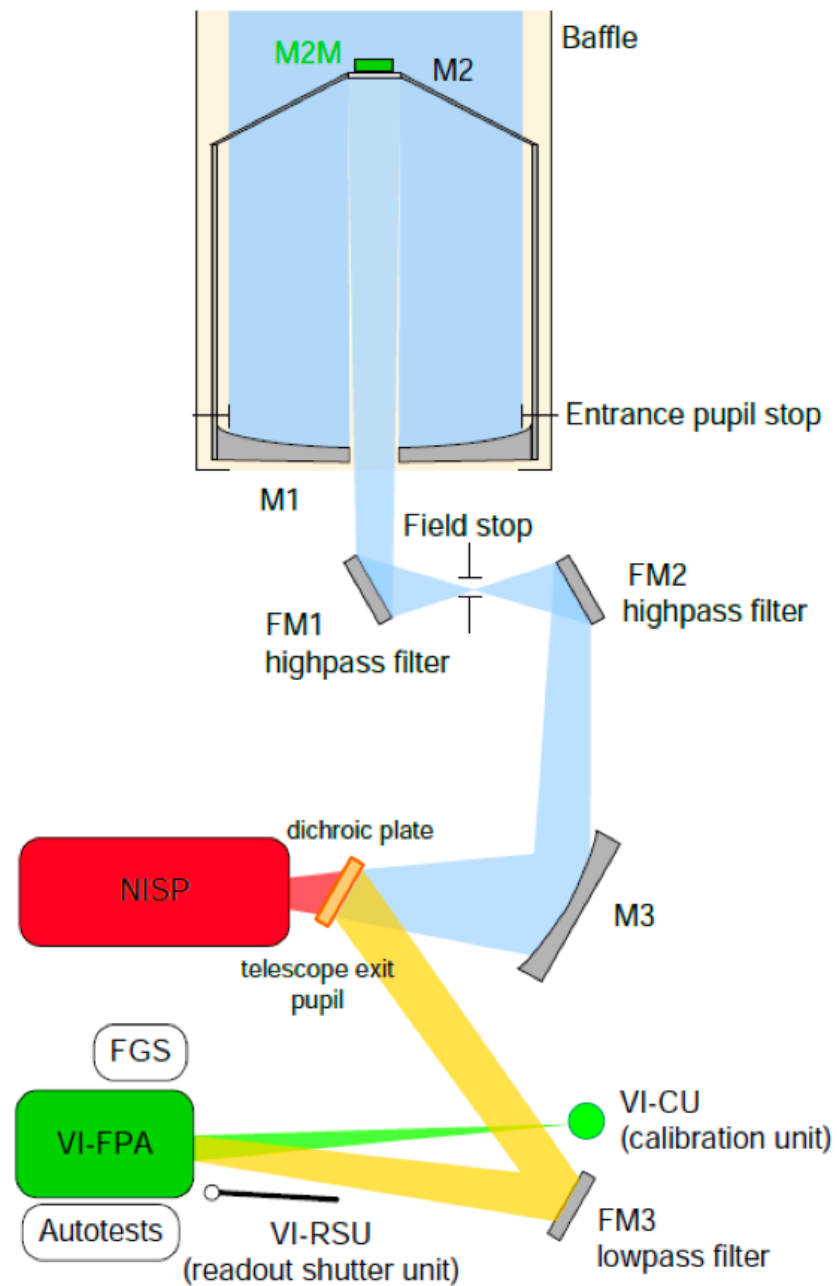
Euclid衛星計画

- 欧州宇宙機関 (ESA) のMクラスサーベイ観測衛星 (>6億ユーロ)
- $\sim 15000 \text{deg}^2$ の可視撮像, 近赤外撮像, グリズム分光
- 2022年打ち上げ予定



1.2m telescope
FOV 0.54 deg^2

望遠鏡



検出器

VIS (可視撮像)

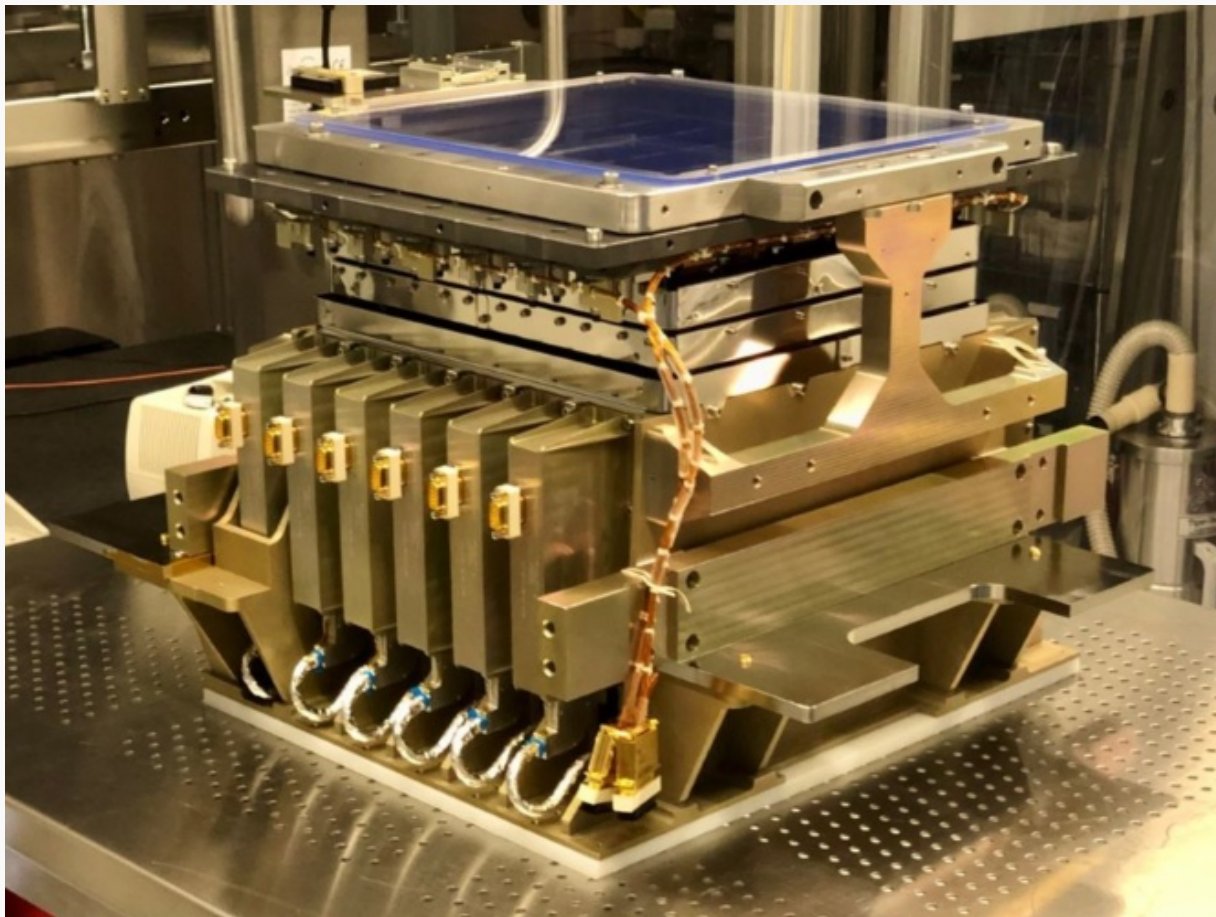
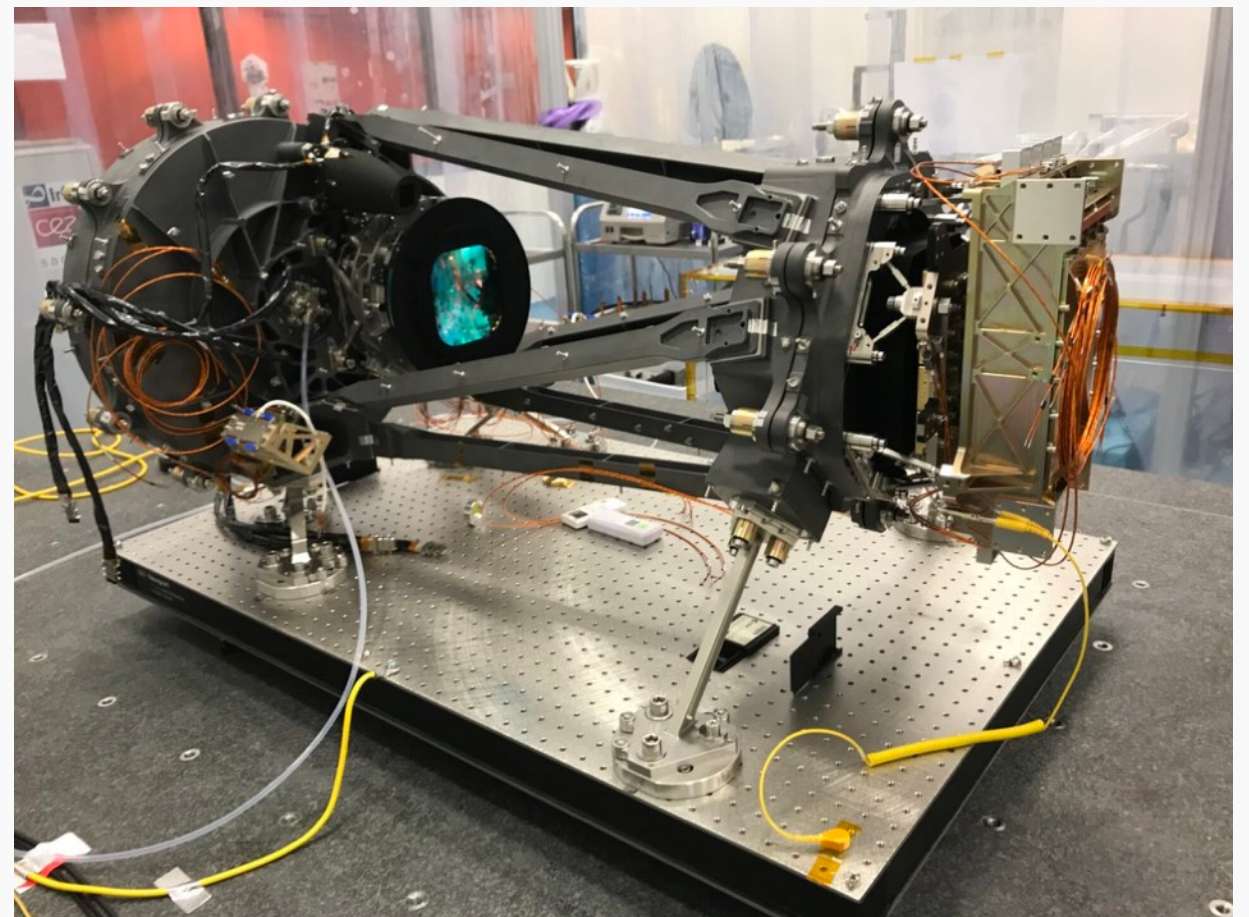


Image credit: CEA

NISP (近赤外撮像+分光)



https://www.esa.int/ESA_Multimedia/Images/2020/07/Euclid_s_NISP_instrument

検出器

VIS (可視撮像)

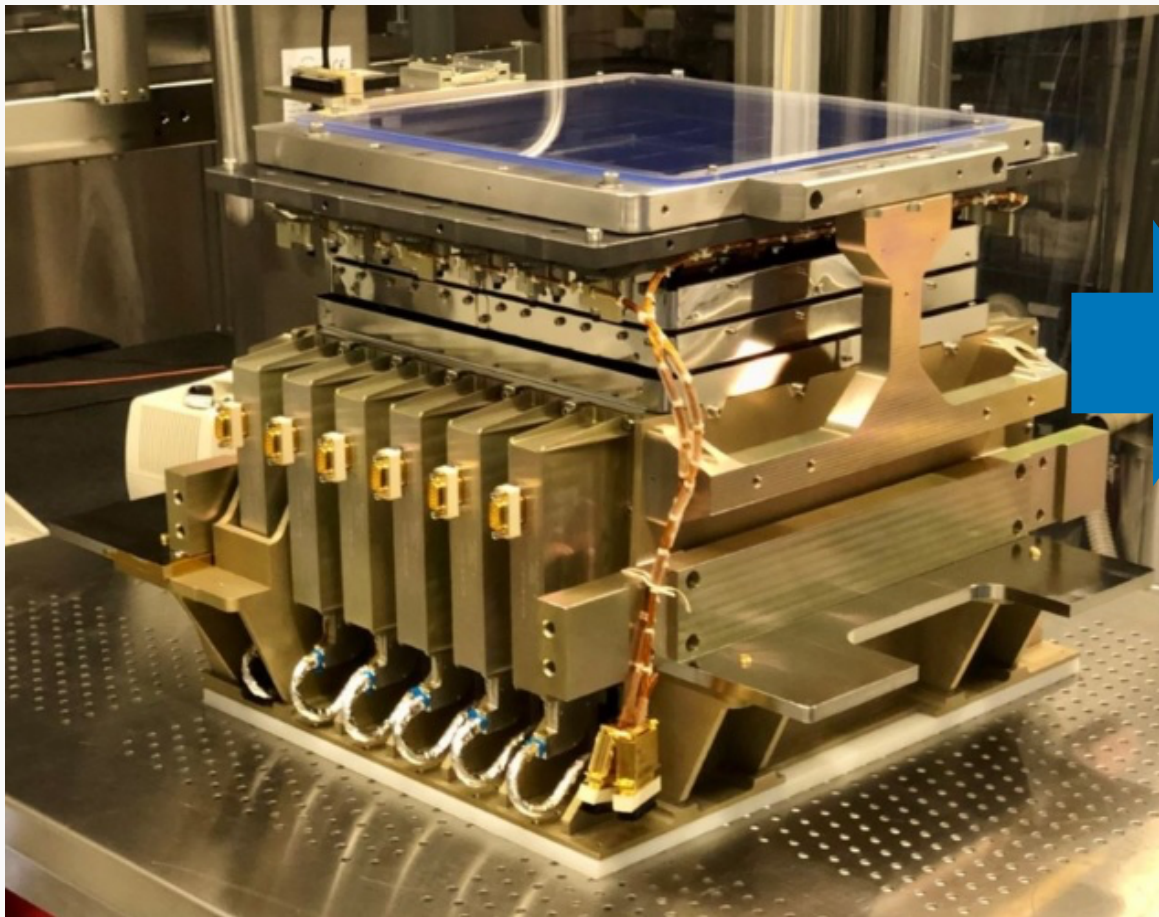
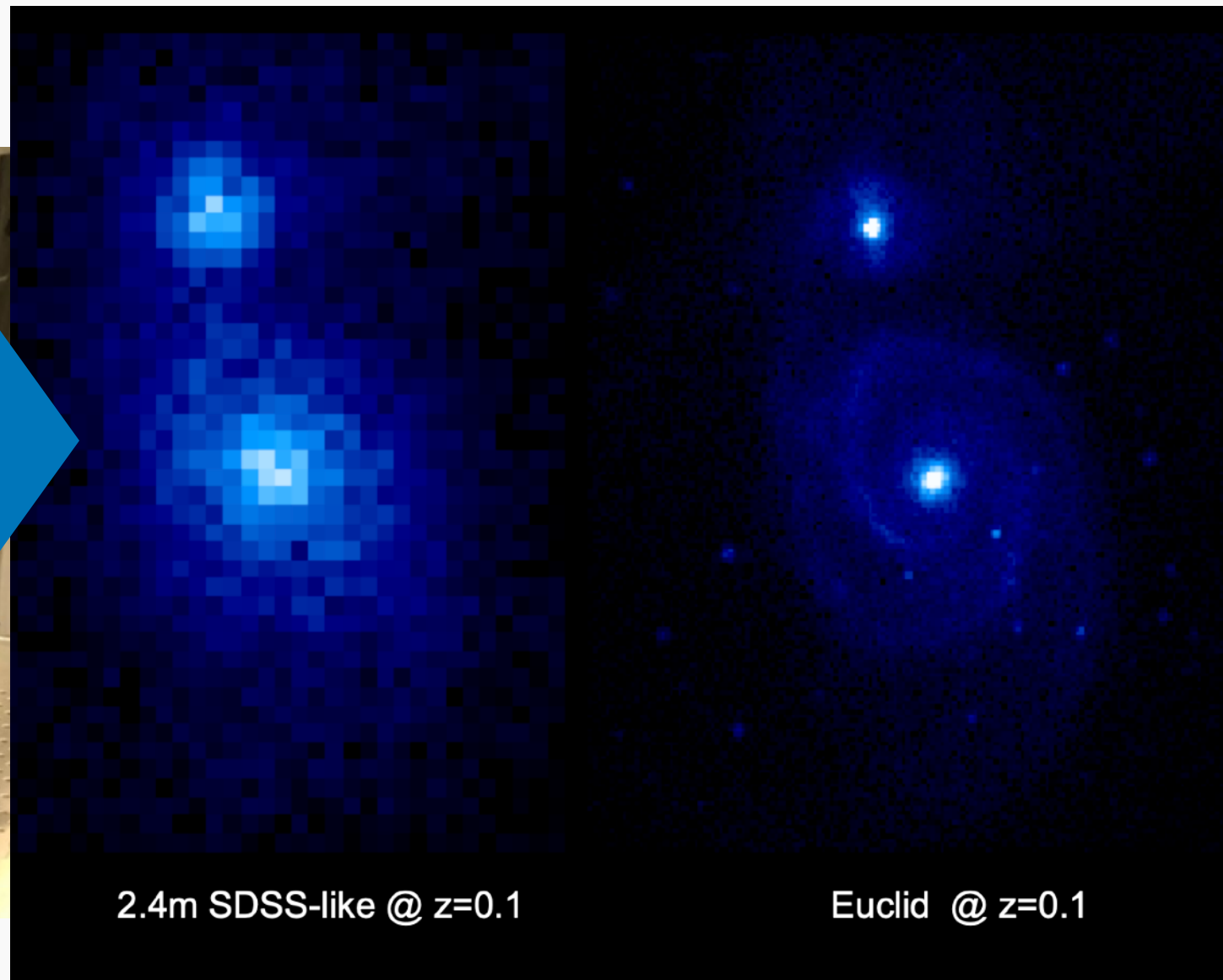


Image credit: CEA

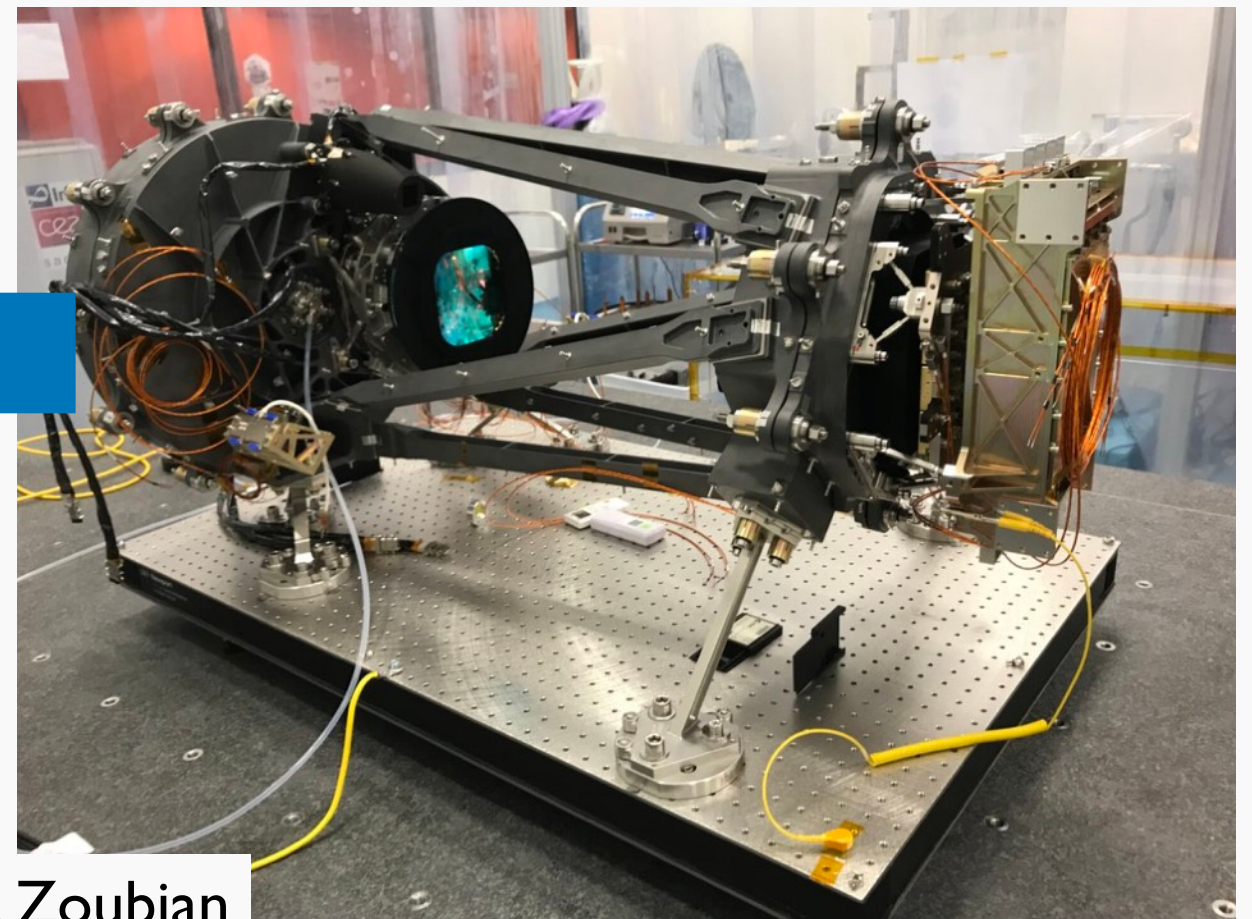
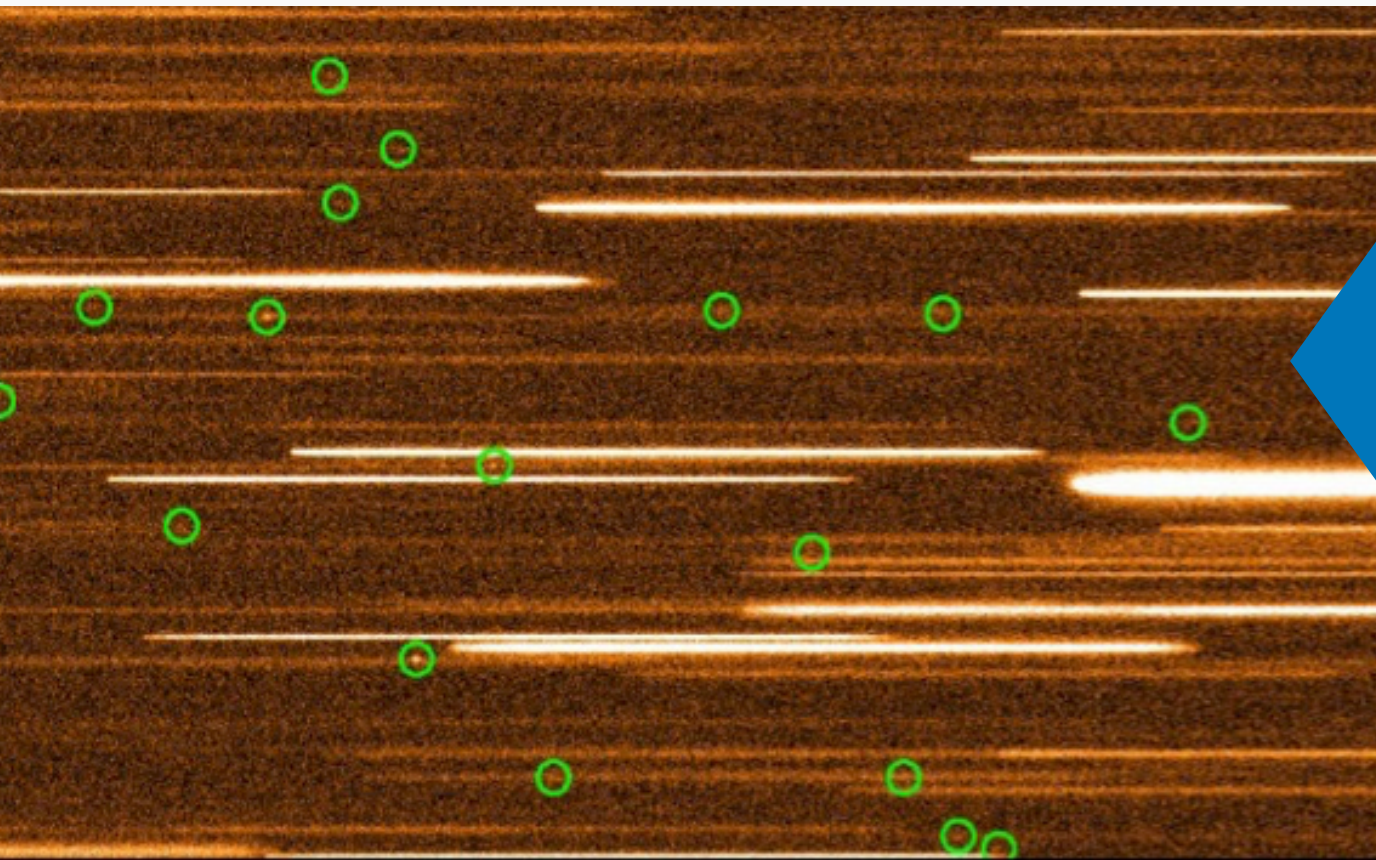


from J. Brinchmann

高解像度画像 → 重力レンズ

検出器

NISP (近赤外撮像+分光)



from P. Franzetti, B. Garilli, A. Ealet, N. Fourmanoit & J. Zoubian

https://www.esa.int/ESA_Multimedia/Images/2020/07/Euclid_s_NISP_instrument

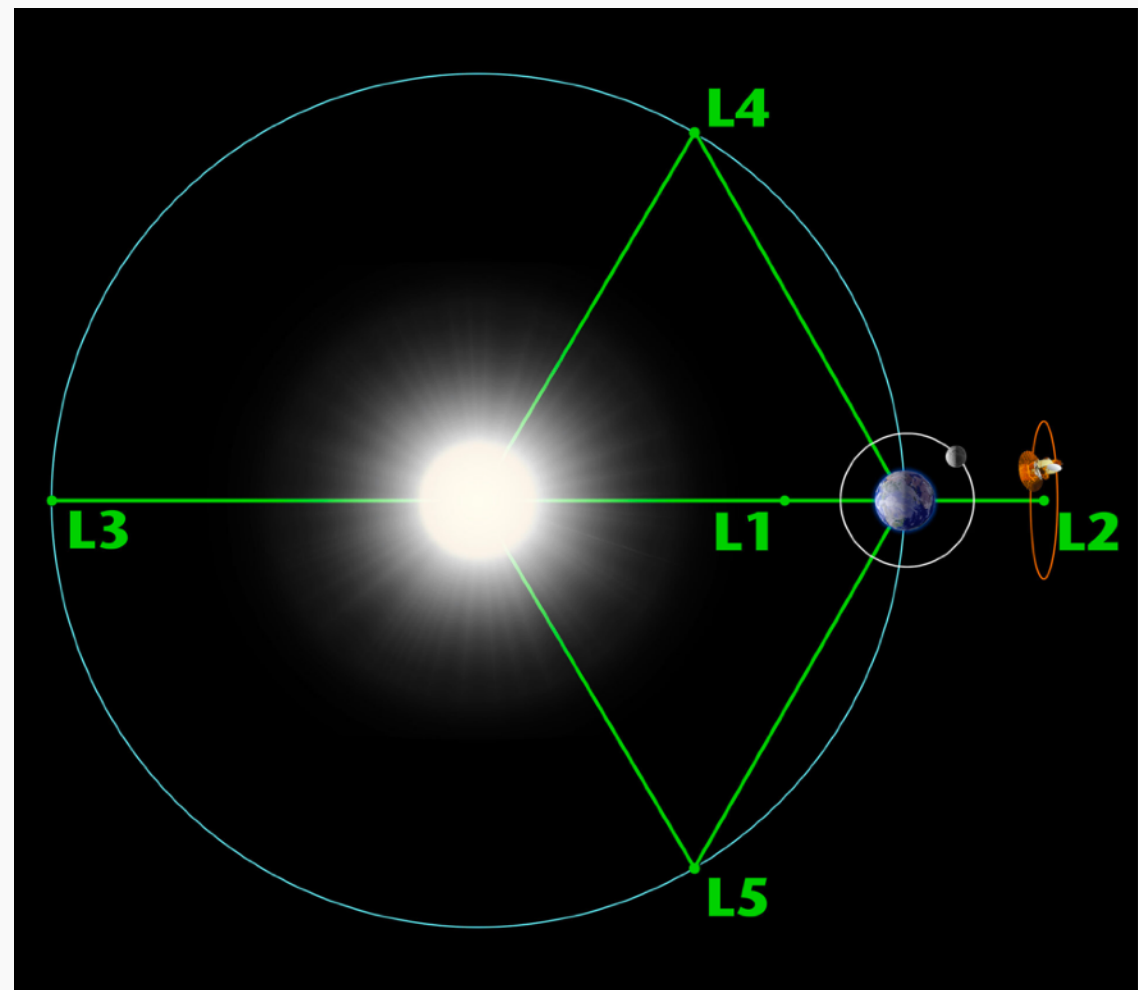
slitless分光 → 銀河クラスタリング
(撮像 → 測光的赤方偏移)

打ち上げ

- Soyuz ST-B Fregat-MT で打ち上げ (フランス領ギアナ)
- L2周りからサーベイ観測

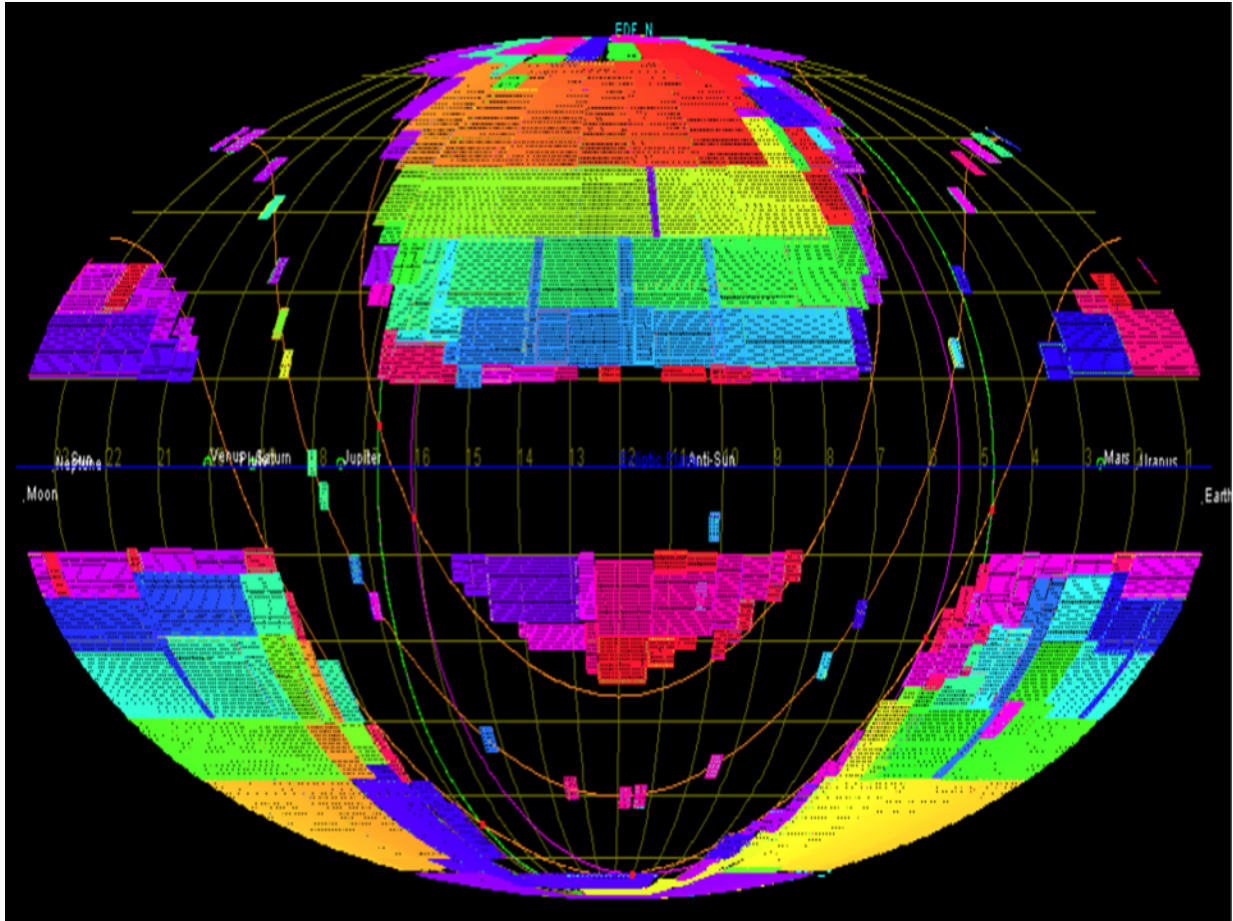


https://space.skyrocket.de/doc_lau_det/soyuz-stb_fregat-mt.htm



https://www.esa.int/ESA_Multimedia/Images/2017/11/Lagrange_points

サーベイ観測



Wideサーベイ領域
(黄道座標)

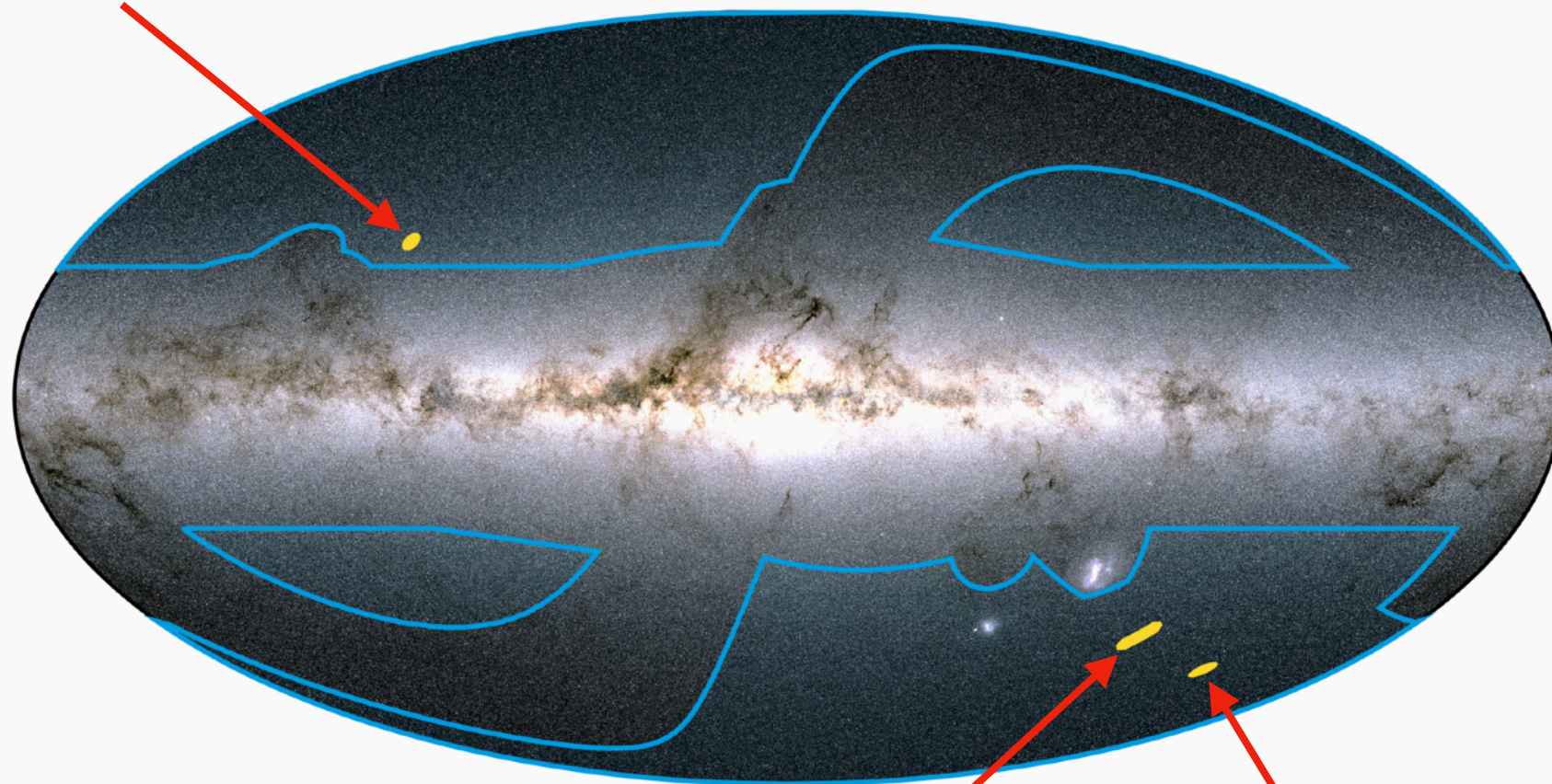
サーベイ
パラメータ

SURVEYS					
	Area (deg ²)	Description			
Wide Survey	15,000 deg²	Step and stare with 4 dither pointings per step.			
Deep Survey	40 deg²	In at least 2 patches of > 10 deg ² 2 magnitudes deeper than wide survey			
Wavelength range	550– 900 nm	Y (920-1146nm),	J (1146-1372 nm)	H (1372-2000nm)	1100-2000 nm
Sensitivity	24.5 mag 10 σ extended source	24 mag 5 σ point source	24 mag 5 σ point source	24 mag 5 σ point source	3 10^{-16} erg cm ⁻² s ⁻¹ 3.5 σ unresolved line flux
Shapes + Photo-z of $n = 1.5 \times 10^9$ galaxies			z of $n = 5 \times 10^7$ galaxies		

Deepサーベイ

Euclid Deep Field North (NEP)

10 deg²



(銀河座標)

The Euclid Wide Survey and the Euclid Deep Survey [Mollweide Galactic]

Euclid Wide Survey : 15,000 deg.²

Euclid Deep Fields : North=10 deg.², Fornax=10 deg.², South=20 deg.²



Background: ESA/Gaia, PAC & Euclid Consortium

Euclid Deep Field South (SEP)

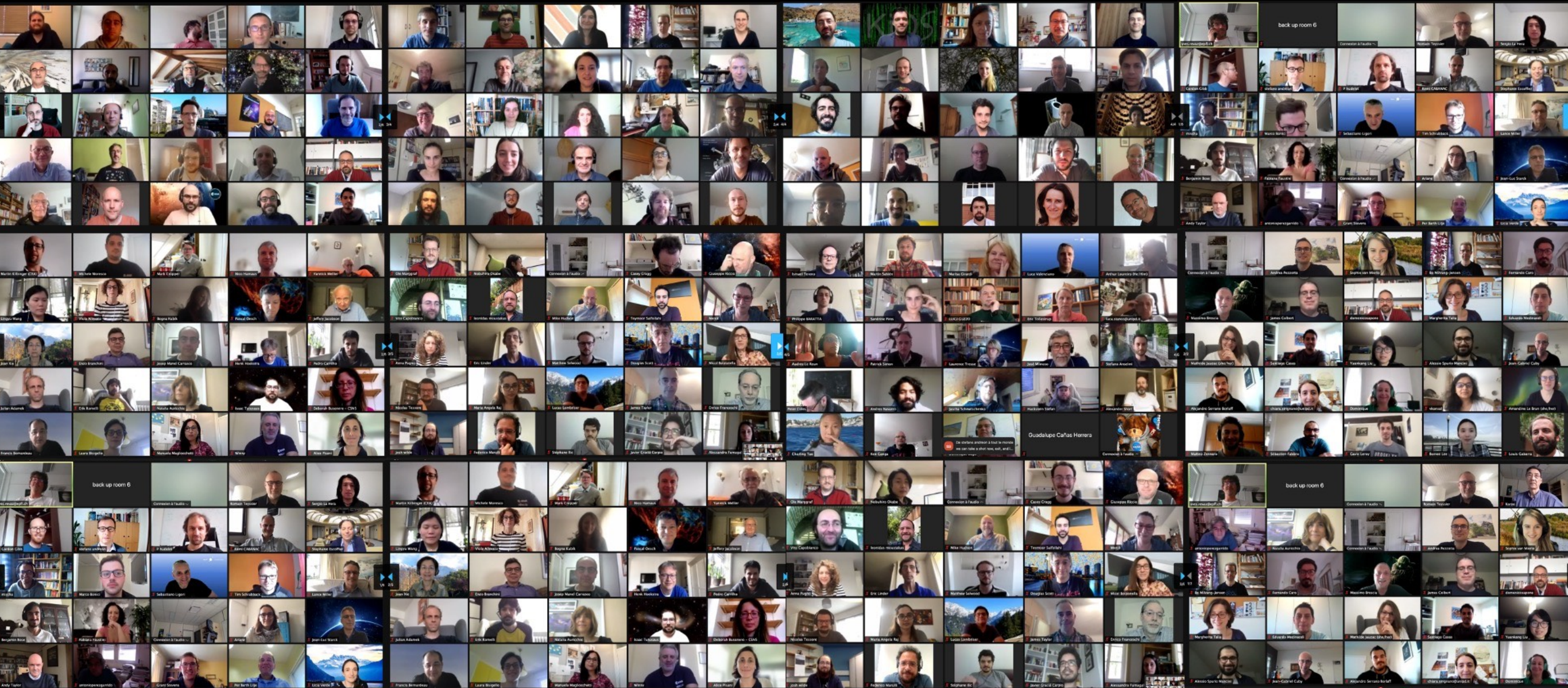
20 deg²

Euclid Deep Field Fornax (CDF-S)

10 deg²

Collaboration meeting

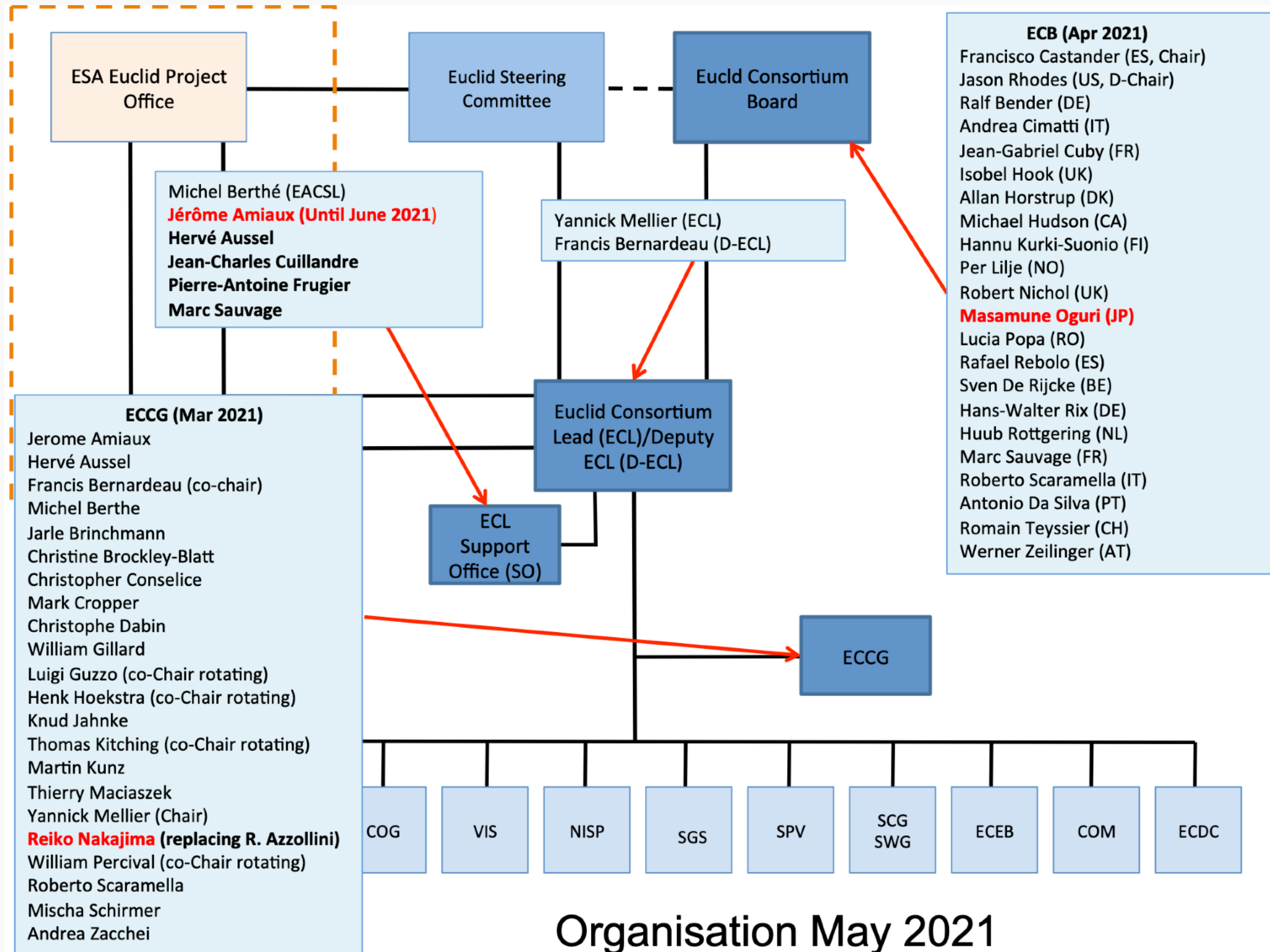
EUCLID 2021



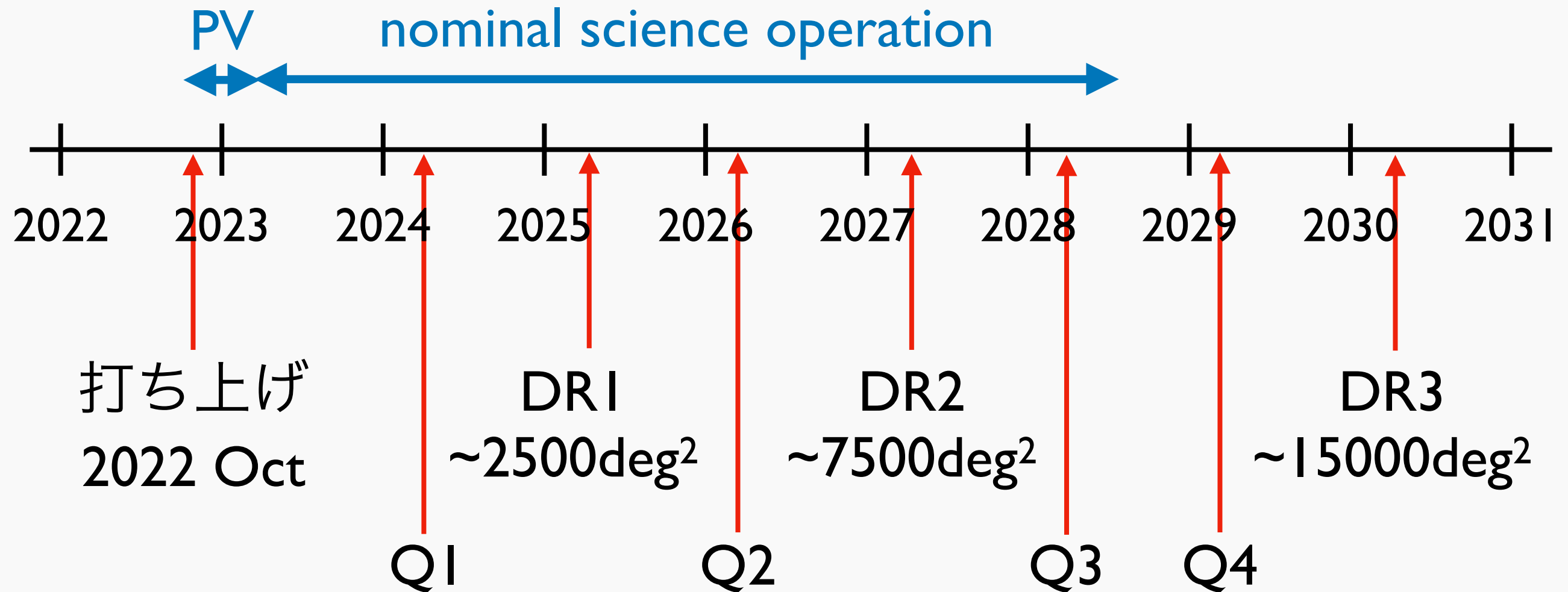
May 25-28 2021, at Lausanne (online)



組織

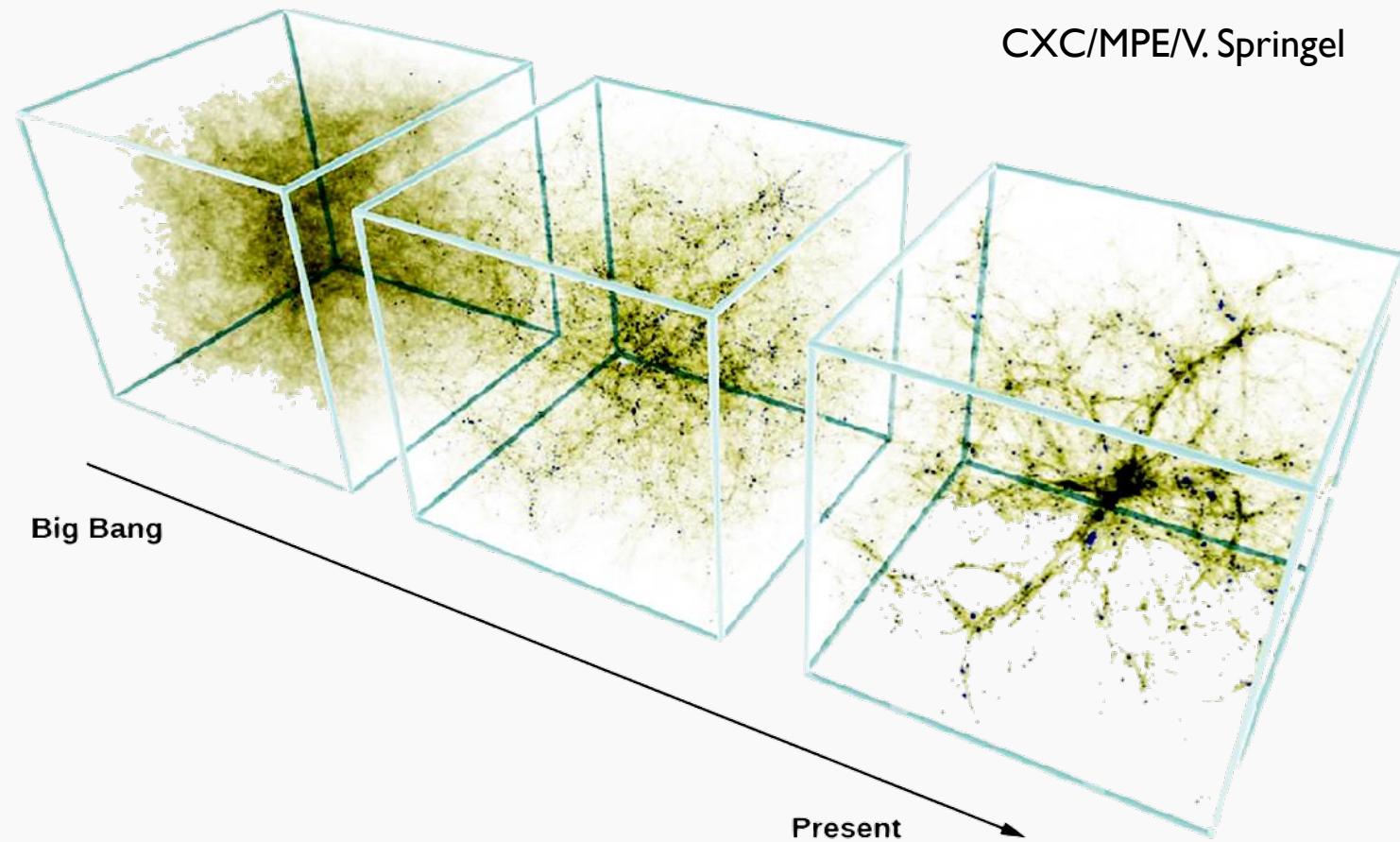
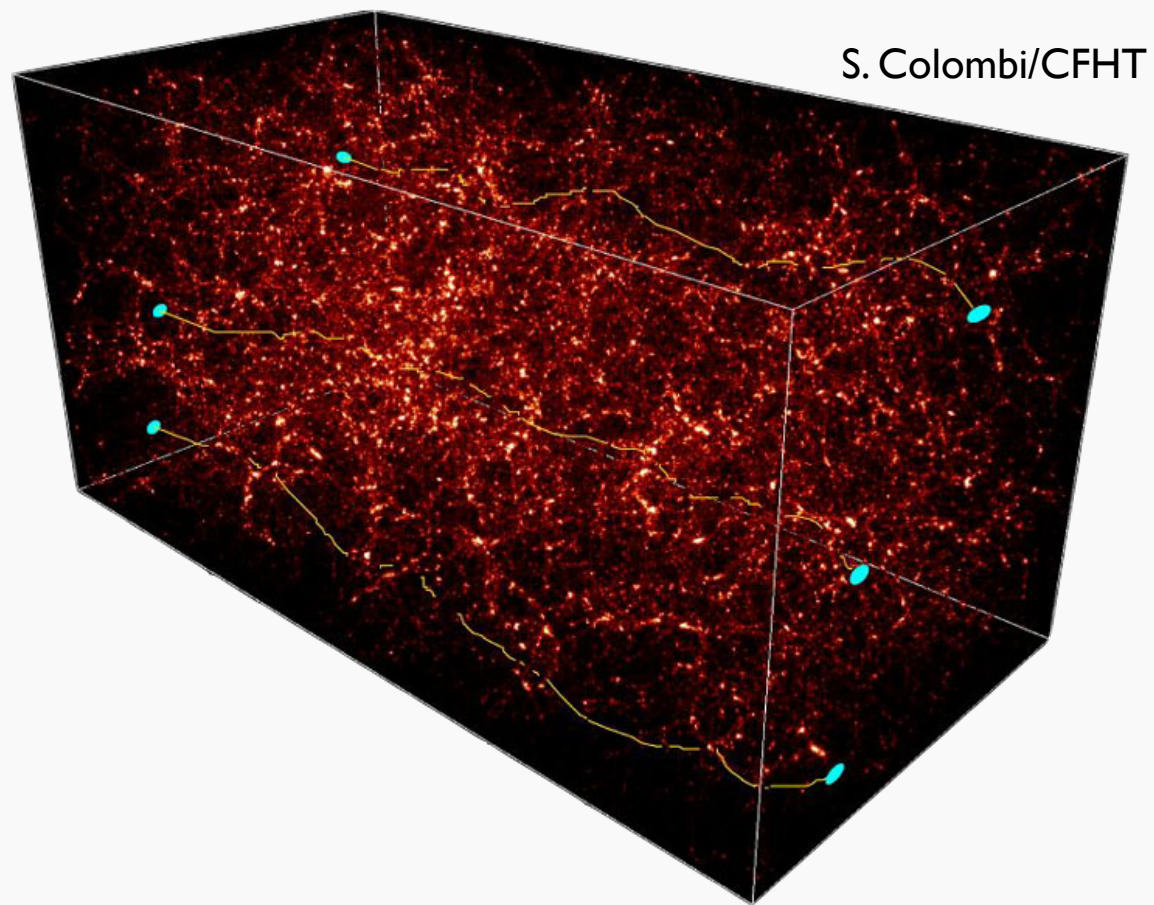


今後のスケジュール



- publicデータリリースの~1年前に内部データリリース

サイエンス



重力レンズ (cosmic shear)

銀河クラスタリング (BAO, RSD)

- その他, 高赤方偏移QSO, 高赤方偏移銀河団, 強重力レンズ, ...

宇宙論の制限

修正重力
(加速膨張)

ニュートリノ質量
(暗黒物質)

非ガウス性
(inflation)

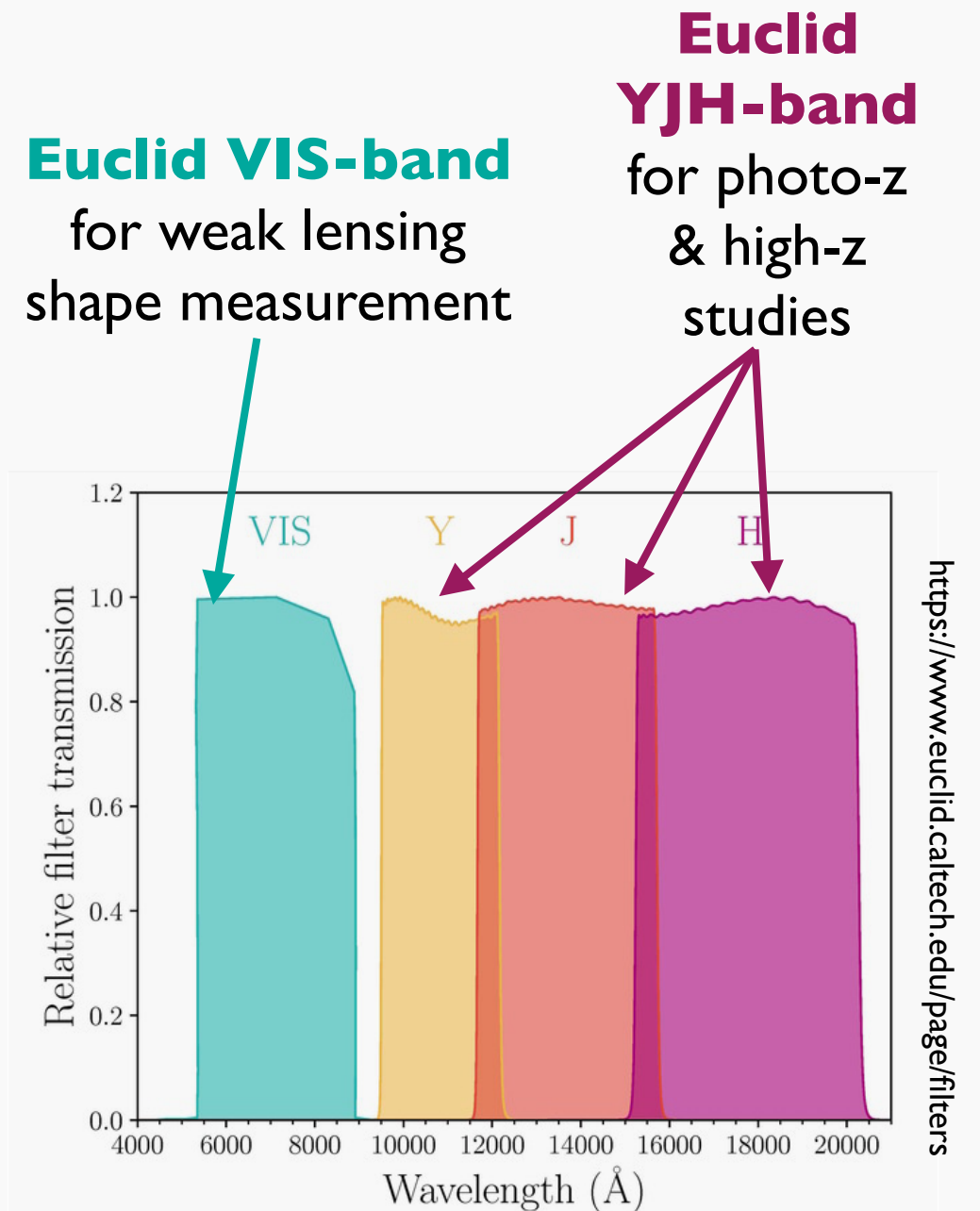
暗黒エネルギー
(加速膨張)

Ref: Euclid RB arXiv: 1110.3193	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν / eV	f_{NL}	w_p	w_a	FoM = $1/(\Delta w_p \times \Delta w_a)$
Euclid primary (WL+GC)	0.010	0.027	5.5	0.015	0.150	430
EuclidAll (clusters, ISW)	0.009	0.020	2.0	0.013	0.048	1540
Euclid+Planck	0.007	0.019	2.0	0.007	0.035	6000 →
Current (2009)	0.200	0.580	100	0.100	1.500	~10
Improvement Factor	30	30	50	>10	>40	>400

Laureijs et al 2011 (red book)

地上望遠鏡との連携

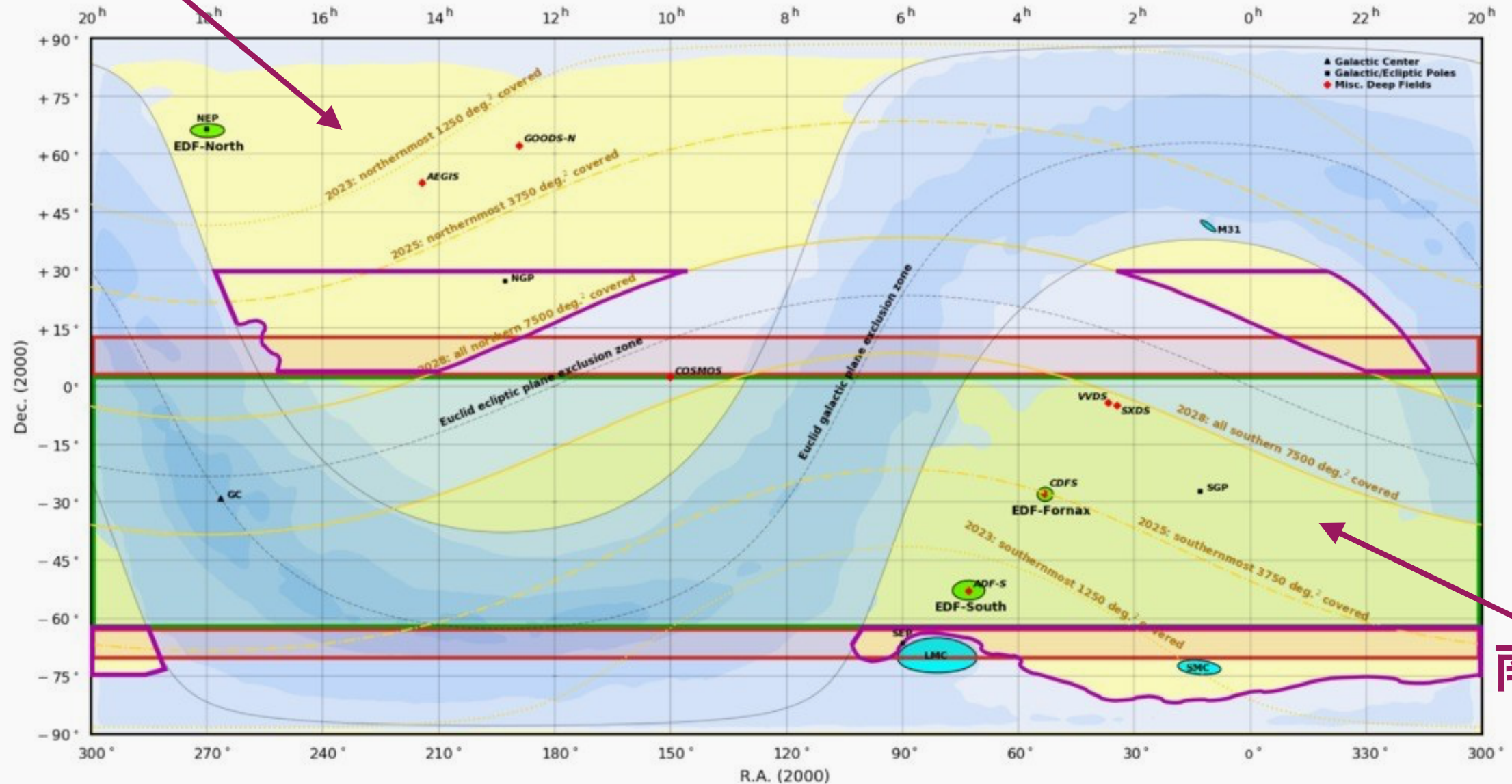
- スペースで大きなゲインがあるもののみスペースでやる、という思想
- ミッションゴール達成のために地上可視多色撮像データが必須



地上望遠鏡との連携

北天：CFHT, Pan-STARRS, ... (??)

Capak+2018



南天：
DES,
LSST

黄色: Euclid Wide Survey (15000平方度)

すばる望遠鏡とEuclid

- 北天でEuclidに必要な可視多色撮像データを得るために
すばる望遠鏡HSCの協力が必要不可欠であることは
Euclid側は早くから認識していた

協調の模索

- 2011-2012頃 検討の議論の開始、研究会開催
- 2013 有志によるHSC-Euclid白書 すばる小委員会提出
→ 観測時間の拠出には至らず
- 2016 HSC-NUWS intensive proposal提出 (PI: Takada)
→ 不成功
- 2019頃 再挑戦の機運高まる (Miyazaki+)
- 2019 HSC-NUWS (改) intensive proposal提出 (PI: Oguri)
→ 不成功



再々挑戦

(Page 1)

		Semester <u>S20B</u> Proposal ID <u>S20B0097I</u> Received <u>03/03/2020</u>	
Subaru Telescope National Astronomical Observatory of Japan			
Application Form for Telescope Time (Normal+Intensive Programs)			
1. Title of Proposal Wide Imaging with Subaru HSC of the Euclid Sky (WISHES)			
2. Principal Investigator Name: <u>Oguri Masamune</u> Institute: <u>Univ. of Tokyo</u> Mailing Address: <u>Research Center for the Early Universe, University of Tokyo, Tokyo 133-0033, Japan</u> E-mail Address: <u>masamune.oguri@ipmu.jp</u> Phone: <u>+81-3-5841-4191</u>			
3. Scientific Category ☐ Solar System ☐ Extrasolar Planets ☐ Star Formation and Young Disk ☐ ISM ☐ Normal Stars ☐ Metal-Poor Stars ☐ Compact Objects and SNe ☐ Milky Way ☐ Local Group ☐ Nearby Galaxies ☐ IGM and Abs.Line Systems ☒ Cosmology ☐ Gravitational Lenses ☐ Clusters and Proto-Clusters ☐ Galaxy Properties and Environment ☐ High- <i>z</i> Galaxies(LAEs, LBGs) ☐ High- <i>z</i> Galaxies(others) ☐ AGN and QSO Activity ☐ Miscellaneous			
4. Abstract (<i>approximately 200 words</i>) We request 40 nights to carry out WISHES, an HSC <i>z</i> -band imaging of 4,500 deg ² at high Galactic latitudes in the northern hemisphere down to $z \simeq 23.4$ mag (10σ within 2'' diameter). The primary goal of WISHES is to promote cosmology and high-redshift Universe studies for the Euclid space mission. The proposed deep <i>z</i> -band imaging is crucial for improving photometric redshifts to the acceptable level for cosmic shear cosmology, and also for turning the unique Euclid's near-infrared imaging capability into an efficient probe of the high-redshift Universe. WISHES propels Subaru's scientific community into the era of all-sky science by running a synergistic survey enabling countless studies once coupled to various space missions (eROSITA, WISE, Gaia, LiteBIRD, in addition to Euclid) and is a stepping stone to WFIRST. WISHES would however produce science even without these space missions, in combination with the <i>ur</i> -band CFHT images, <i>i</i> -band Pan-STARRS images, and <i>g</i> -band HSC images, all being currently acquired over the same footprint (UNIONS). WISHES immediately allows us to explore a broad range of innovative science topics, including reference images to locate optical counterparts of gravitational waves, finding rare objects, and mapping the Milky Way structure.			
5. Co-Investigators			
Name		Institute	
Satoshi Miyazaki		NAOJ	
Naoki Yasuda		Univ. of Tokyo	
Hisanori Furusawa		NAOJ	
Yusei Koyama		NAOJ	
Michitoshi Yoshida		NAOJ	
Nozomu Tominaga		Konan Univ.	
Masaomi Tanaka		Tohoku Univ.	
Yousuke Utsumi		Stanford Univ.	
Nobuhiro Okabe		Hiroshima Univ.	
Hironao Miyatake		Nagoya Univ.	
Name		Institute	
Tohru Nagao		Ehime Univ.	
Yoshiki Matsuoka		Ehime Univ.	
Masatoshi Imanishi		NAOJ	
Yoshiki Toba		Kyoto Univ.	
Masafusa Onoue		MPIA	
Masashi Chiba		Tohoku Univ.	
Kohei Hayashi		Univ. of Tokyo	
John Silverman		Univ. of Tokyo	
Nao Suzuki		Univ. of Tokyo	
Tomo Goto		NTHU	

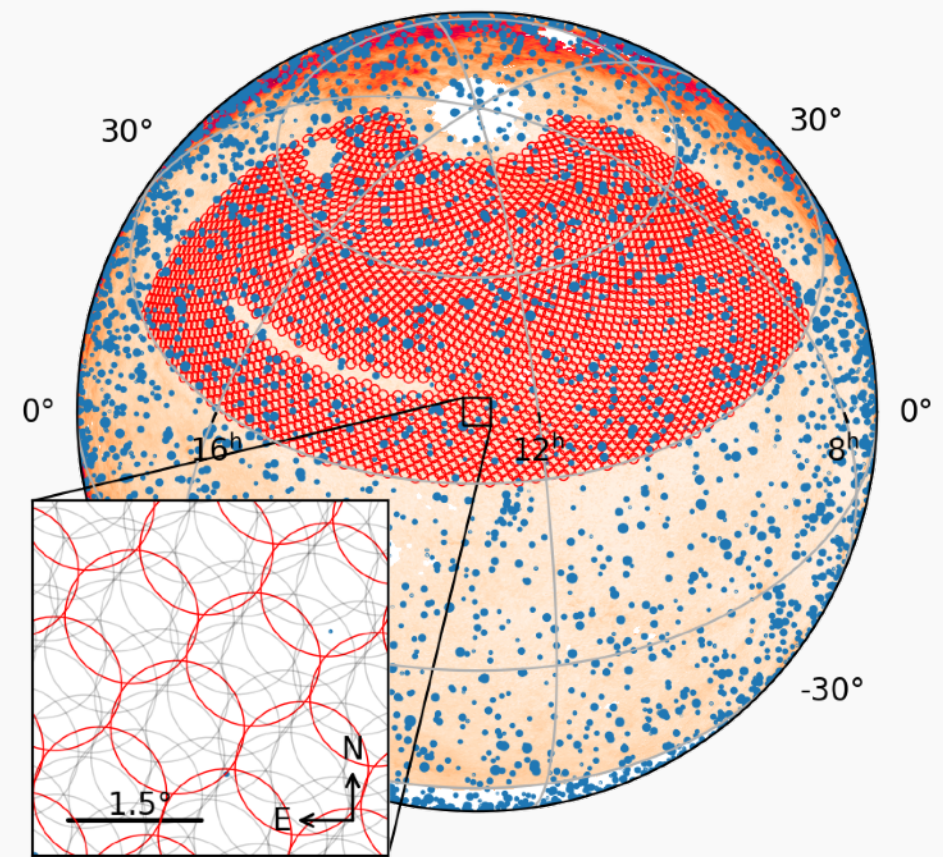
- 研究会「Euclid衛星とすばる望遠鏡とのシナジー」(2020年2月)
- 前回受けた批判をもとにプロポーザルを再構成
- サーベイ名称を**WISHES**に (named by J. Silverman)

→ 採択！



WISHES (Wide Imaging with Subaru HSC of the Euclid Sky)

- すばるHSCインテンシブ
キュー観測 (20B-23A, PI: Oguri)
 - 計40晩相当
 - 北天 (Dec > 30deg) の4500平方
度をzバンド観測
 - CFHT, Pan-STARRS等のデー
タと組み合わせugriz撮像
データ (UNIONS)
- (日本人は誰でも参加可能)



WISHES観測領域
(ポインティング)

UNIONS

Hawaiian
Islands



Pan-STARRS
2 x 1.8m



CFHT
3.6m

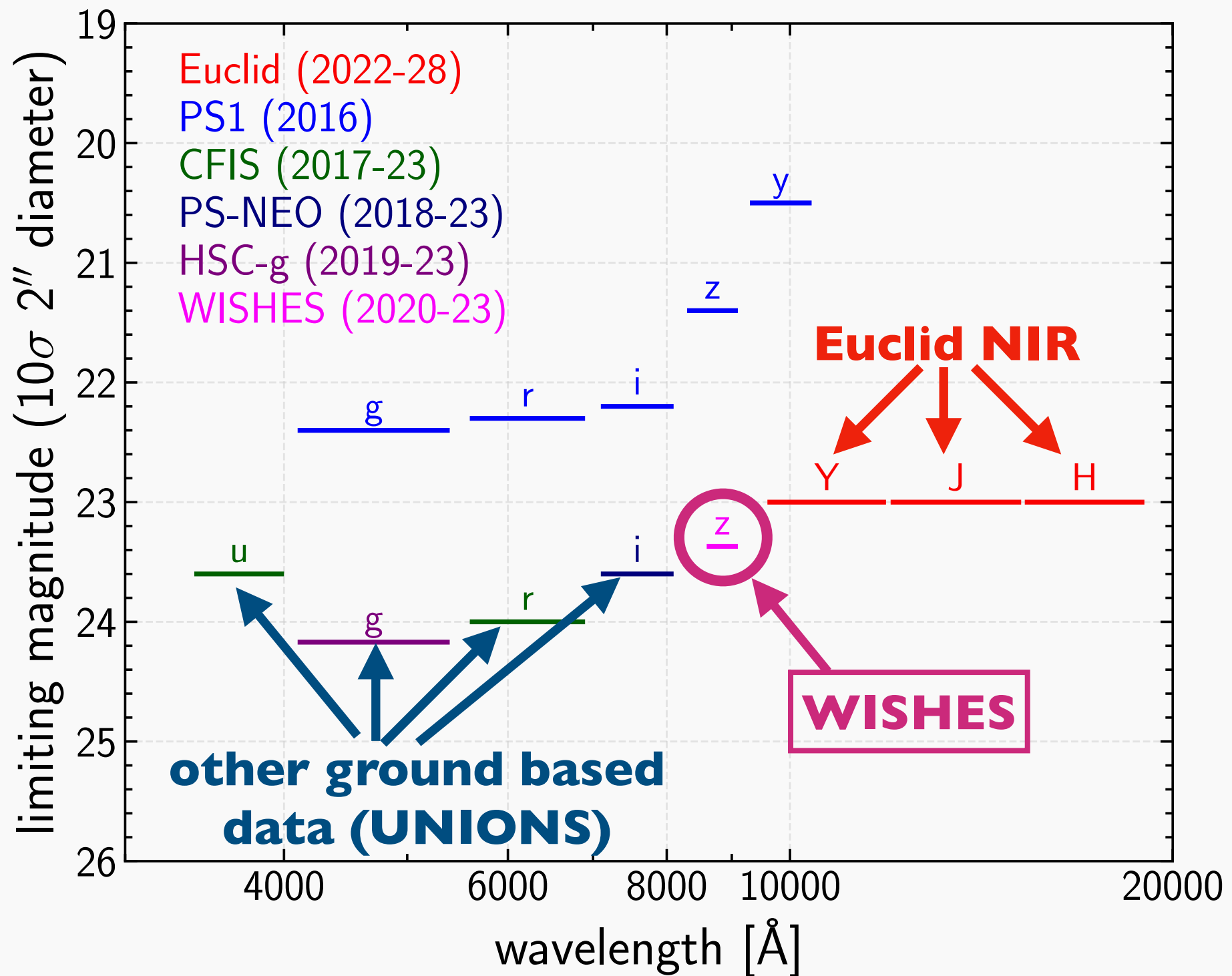


Subaru
Telescope
8.2m

from UNIONS wiki

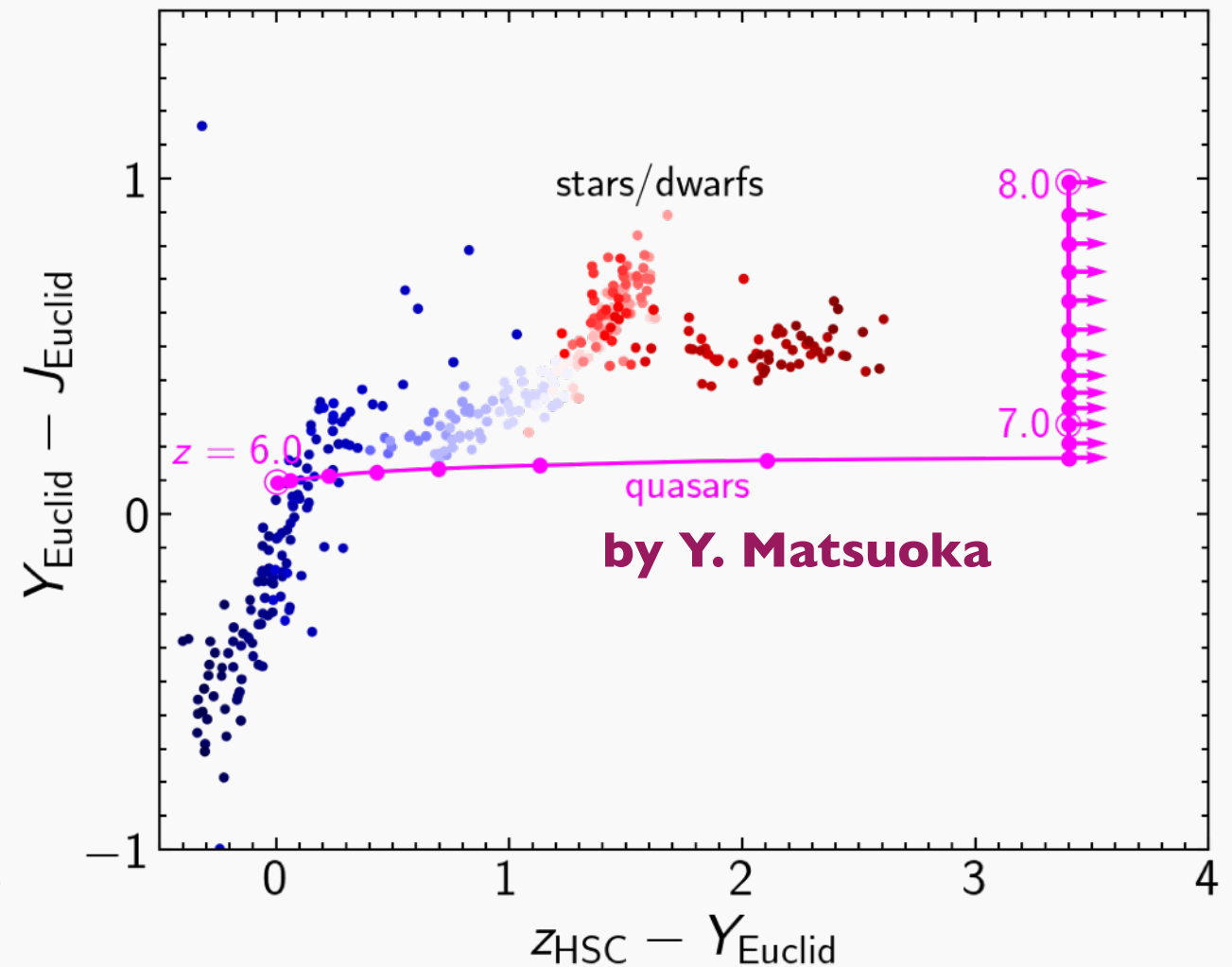
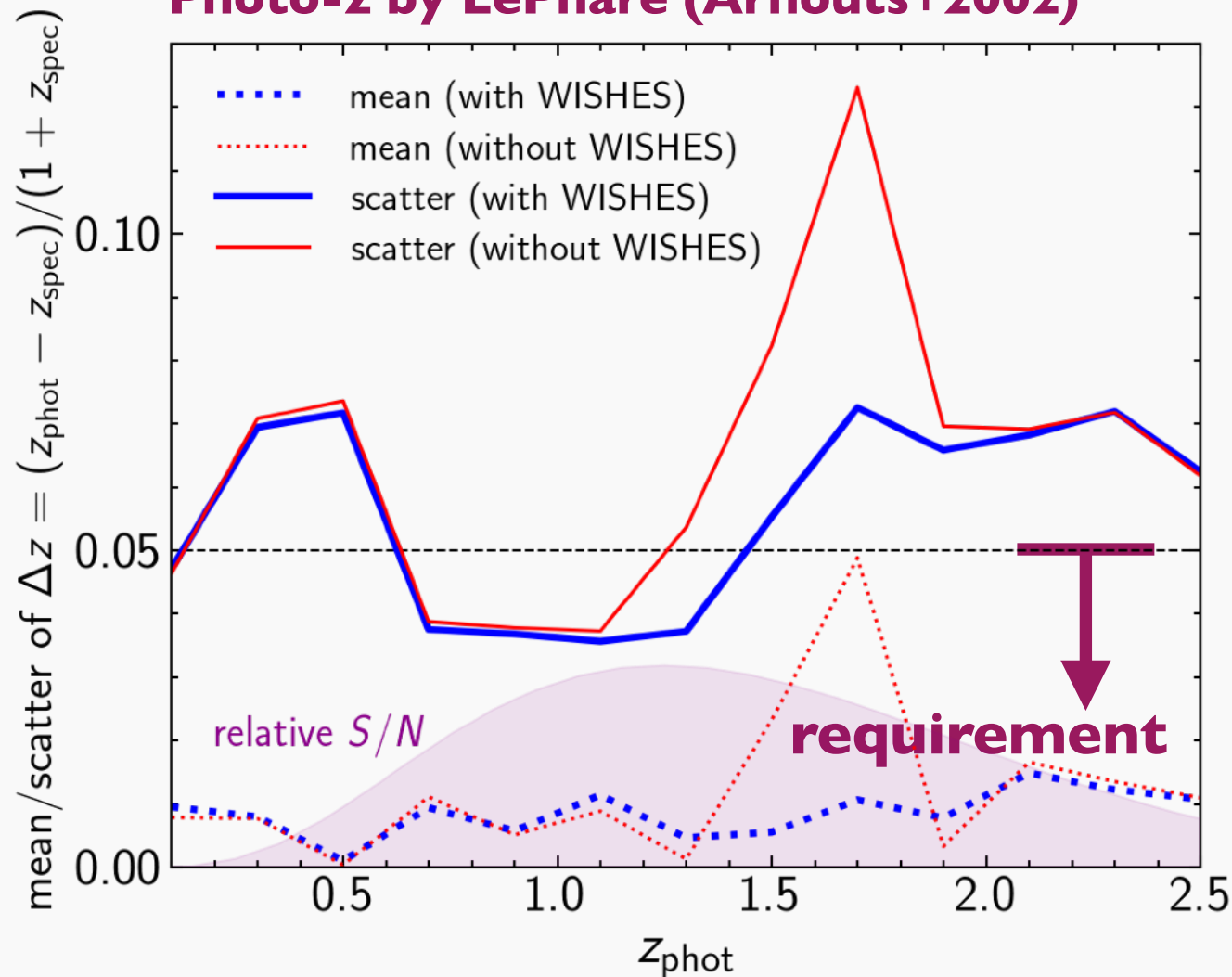
UNIONS = CFHT + Pan-STARRS + Subaru = ハワイ連合！

サーベイ限界等級



サイエンス (WISHES+Euclid)

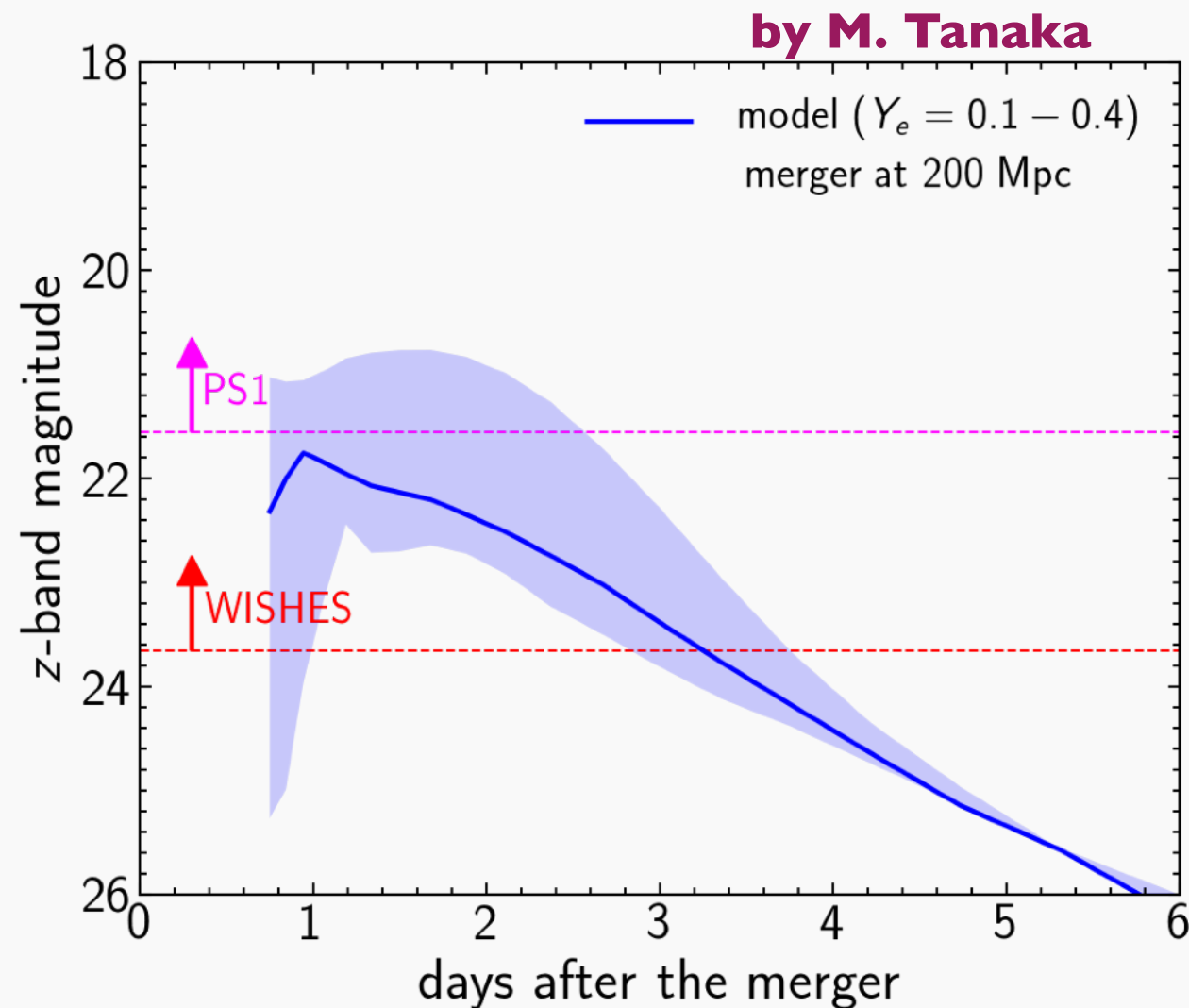
Photo-z by LePhare (Arnouts+2002)



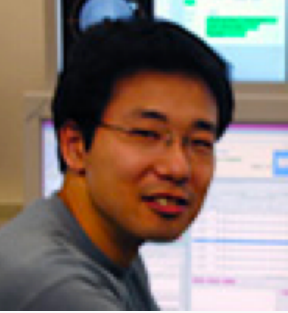
- 重力レンズ宇宙論に必要な測光的赤方偏移の改善

- 高赤方偏移QSO探査
(星との分離)

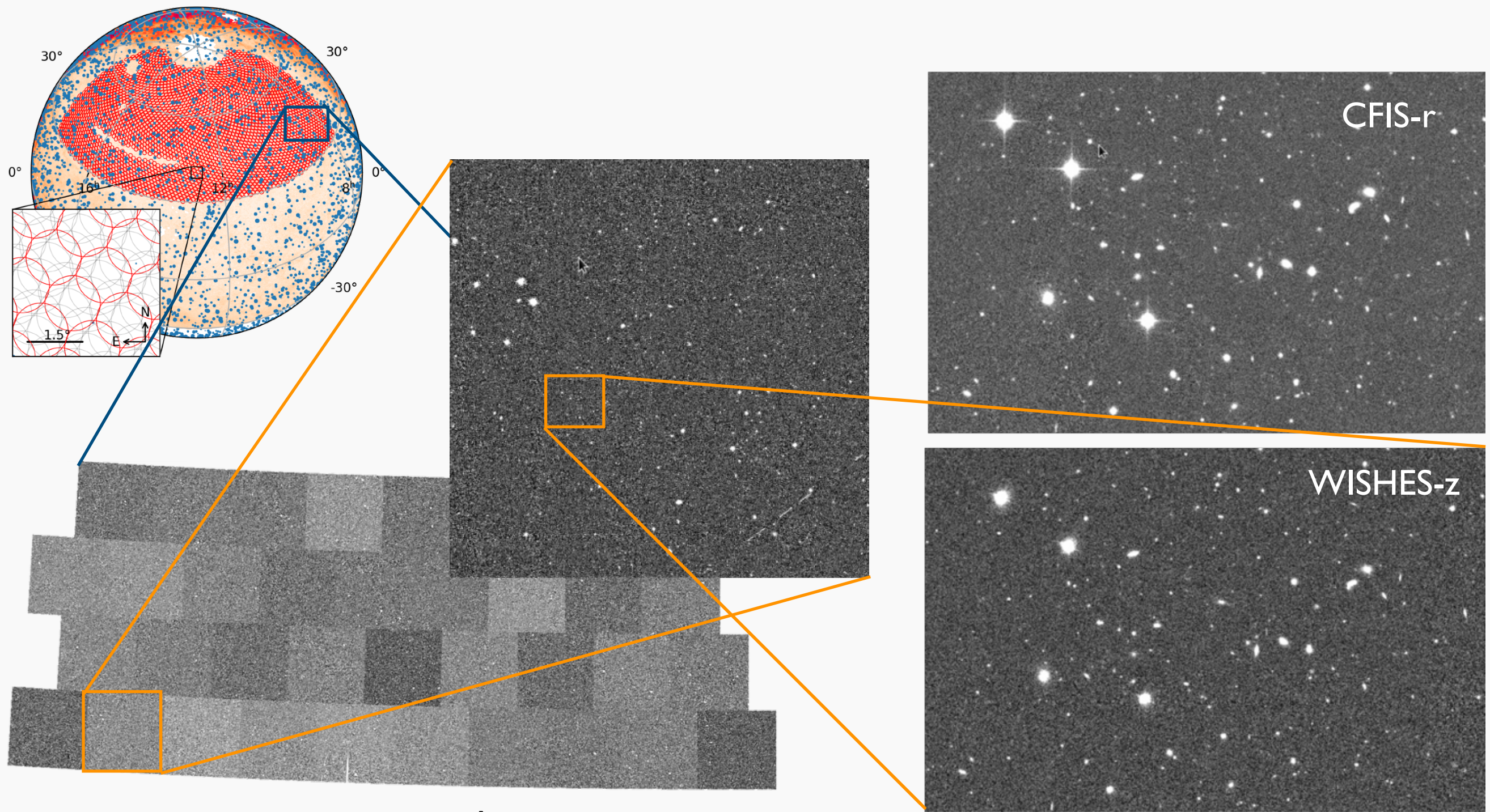
サイエンス (WISHES only)



- 連星合体重力波の電磁波対応天体 (kilonova) 同定
→ **rプロセス, 宇宙論 (H_0), ...**
- 暗いため探査はchallenging
- WISHESはkilonova探査に必要なreference imageを提供



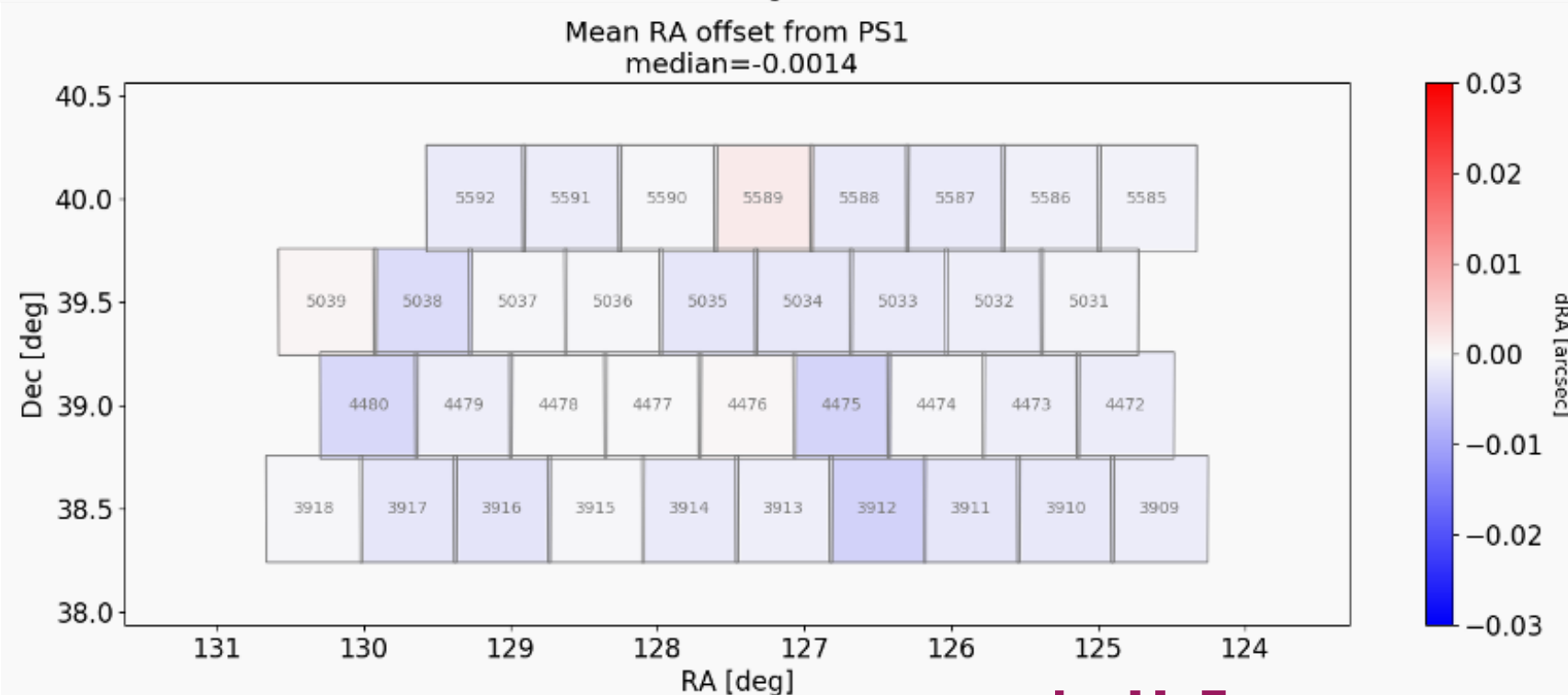
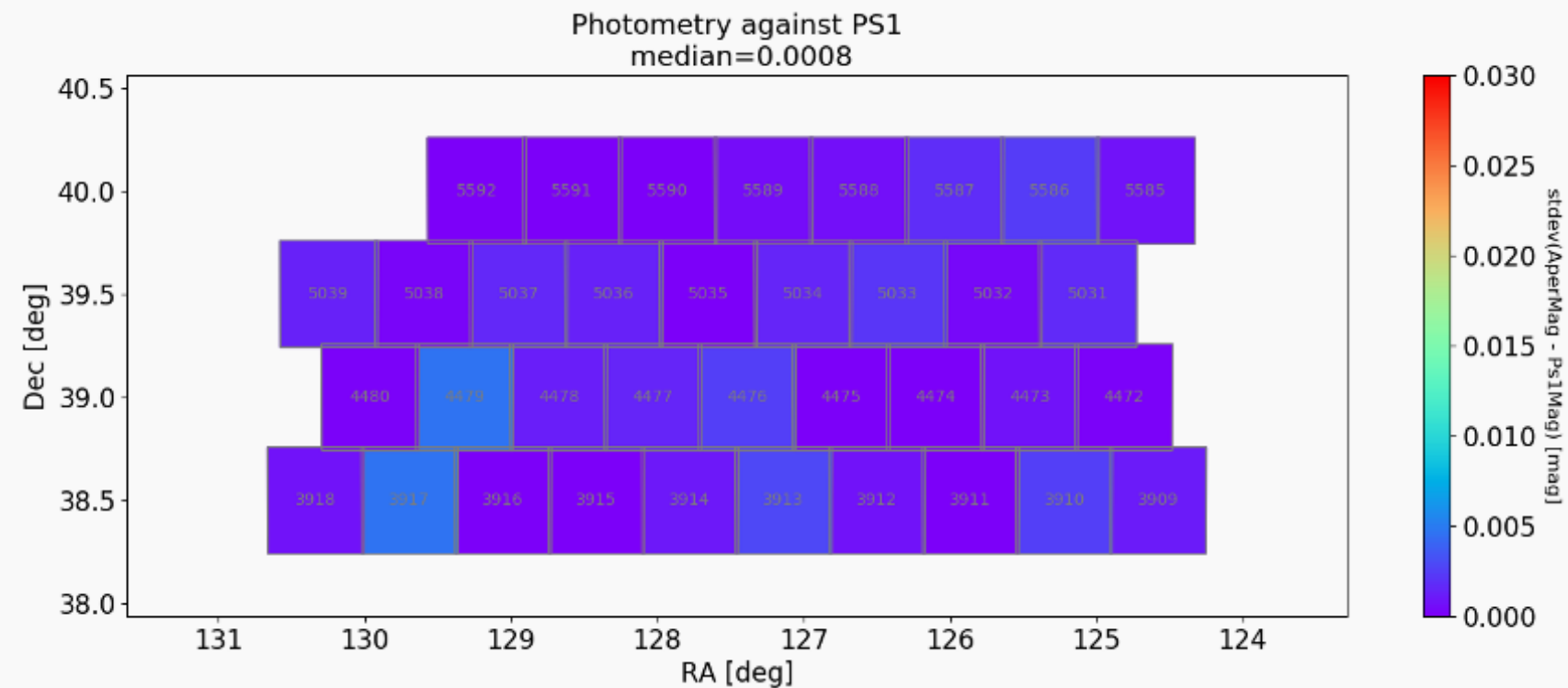
WISHESデータ解析



CFIS (CFHT) のtilingに合わせたcoadd

WISHESデータ品質評価

- preliminaryな解析
 - $\approx 1\%$ 測光精度
 - ≈ 10 mas 位置精度
- Iバンドのみだが
HSC-SSPと同等精度
- マルチバンドでこの品質達成が目標

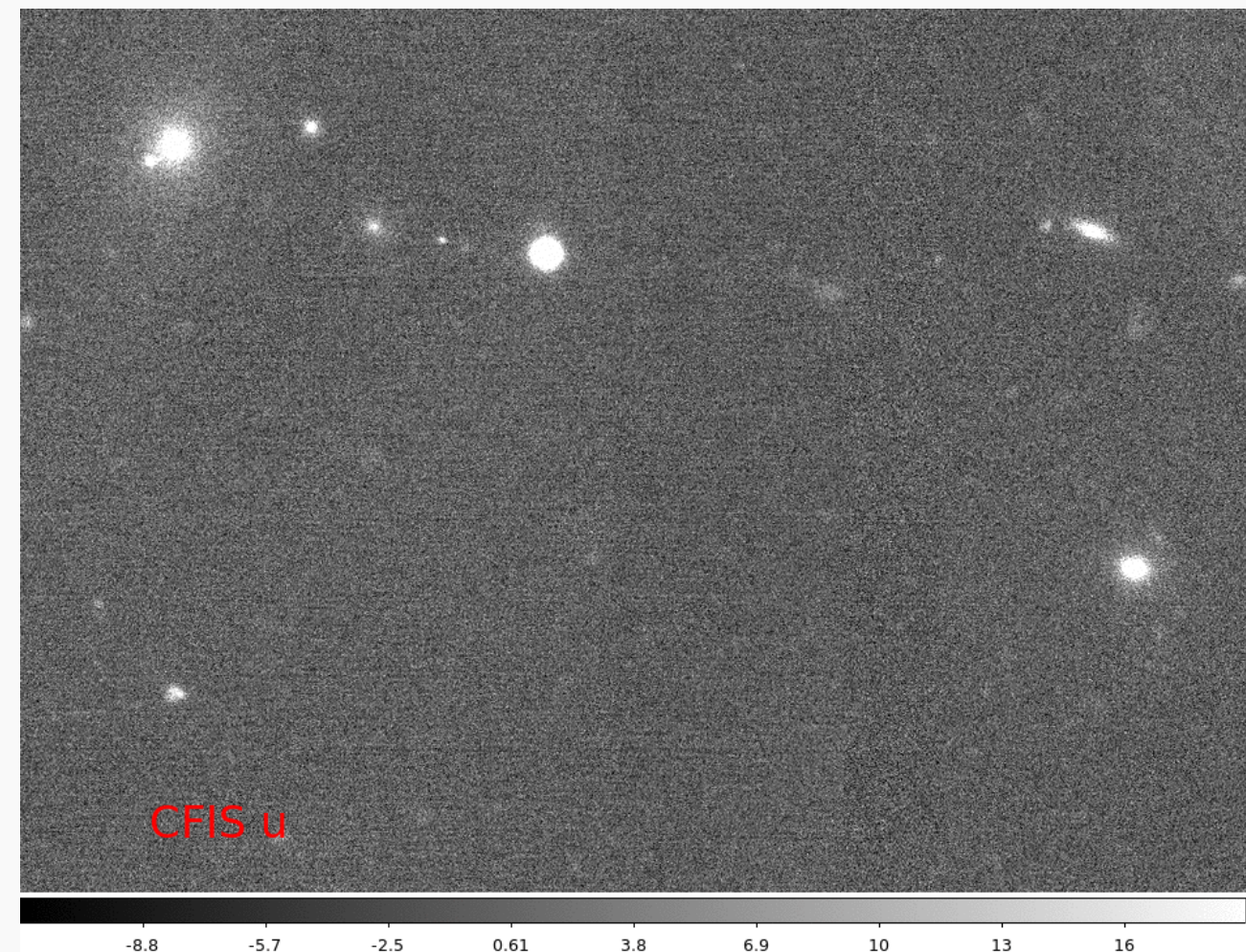


by H. Furusawa

マルチバンド合成カタログ作成

- CFIS (CFHT) のtilingで合成
およびcross-matching
 - CFIS
 - Pan-STARRS
 - HSC (WISHES-z, g)
 - PSI, SDSS, Gaia
- まずはカタログベースの
matching
- 最終的にforced photometry

by Stephen Gwyn



Euclidへの参加

- 2020/02 Letter of Support 受取
(Y. Mellier氏から)
- 2020/06 MoUの議論, 交渉開始
- 2021/03 MoUサイン, Japanese
Euclid Consortium (JEC) 公募
- 2021/04 JECメンバー決定

MEMORANDUM OF UNDERSTANDING

BETWEEN

THE EUCLID CONSORTIUM

AND

THE JAPANESE EUCLID CONSORTIUM

CONCERNING GROUND BASED OBSERVATIONS FOR THE EUCLID MISSION

The Euclid Consortium (EC) is an international organization that brings together teams of scientists and engineers in the fields of theoretical physics, particle physics, astrophysics, space astronomy and space engineering working in public research laboratories and contributing to the Euclid mission. The EC was selected by ESA in July 2012 as the single official scientific consortium in charge of leading the scientific exploitation of the mission until completion. It is funded by national space agencies and national research organizations and led by the Euclid Consortium Lead (ECL) and a Euclid Consortium Board (ECB). It entered into force in July 2012.

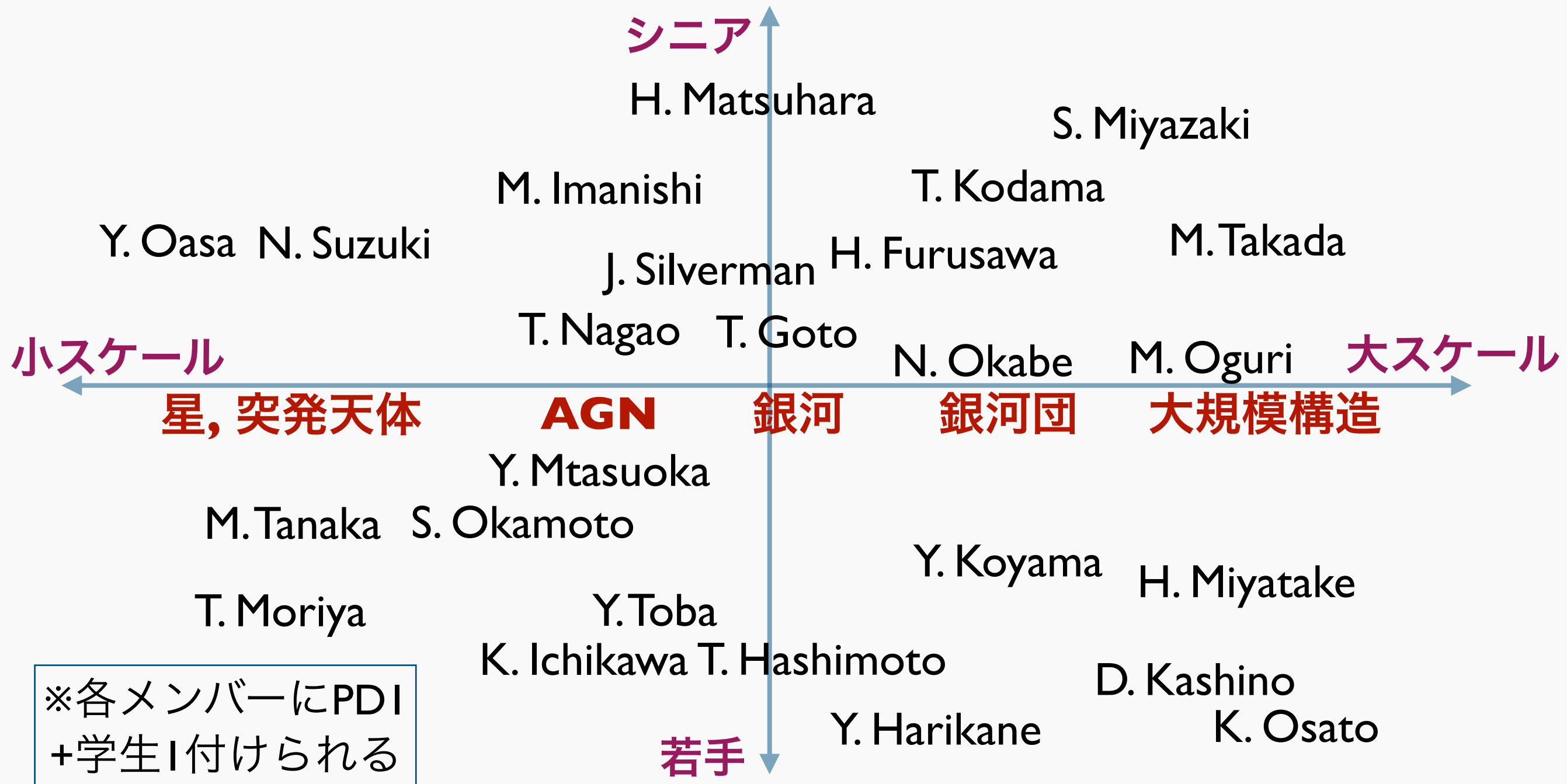
The Japanese Euclid Consortium (JEC) is a group of astrophysicists in Japan who have joined together to enable participation in the Euclid Consortium. The JEC helped enable the approval of the Wide Imaging with Subaru HSC of the Euclid Sky (WISHES) at the Subaru telescope.

The EC and JEC are hereinafter individually referred to as a “Party” and jointly referred to as the “Parties”.

CONSIDERING that cooperation on the Euclid mission between the Parties would enhance the science value of the Euclid mission, the JEC scientific projects and provide mutual benefits;

The Parties HAVE AGREED as follows:

Japanese Euclid Consortium (JEC)



[NAOJ 6, 東大 5, 東北大 3, 名大 2, 京大 2, 愛媛大 2, その他 5]

教訓 (?)

- 交渉でそんなに問題になるようなことはなかった (すんなり好条件を提示してもらえた)
- 私が偉いからではなく、すばるHSCという替えの効かない強力な「武器」があったから
- 月並みだが、唯一無二の装置、技術を持つことの重要性

コミュニティの役割と期待

- インテンシブ枠の拡大により、このような共同利用枠での国際計画の参加が可能になった
- このようなボトムアップ的な国際計画参画の可能性を拓いた枠組みへの支持、理解に感謝します
- WISHESキューー観測の遂行への理解と支持をよろしく願います

まとめ

- Euclid衛星計画は、多くの研究分野で大きな進展が見込める欧州主導の衛星サーベイ観測計画
- 2022年打ち上げ予定
- すばる望遠鏡HSCインテンシブ観測WISHESの貢献により日本から参加できることとなった