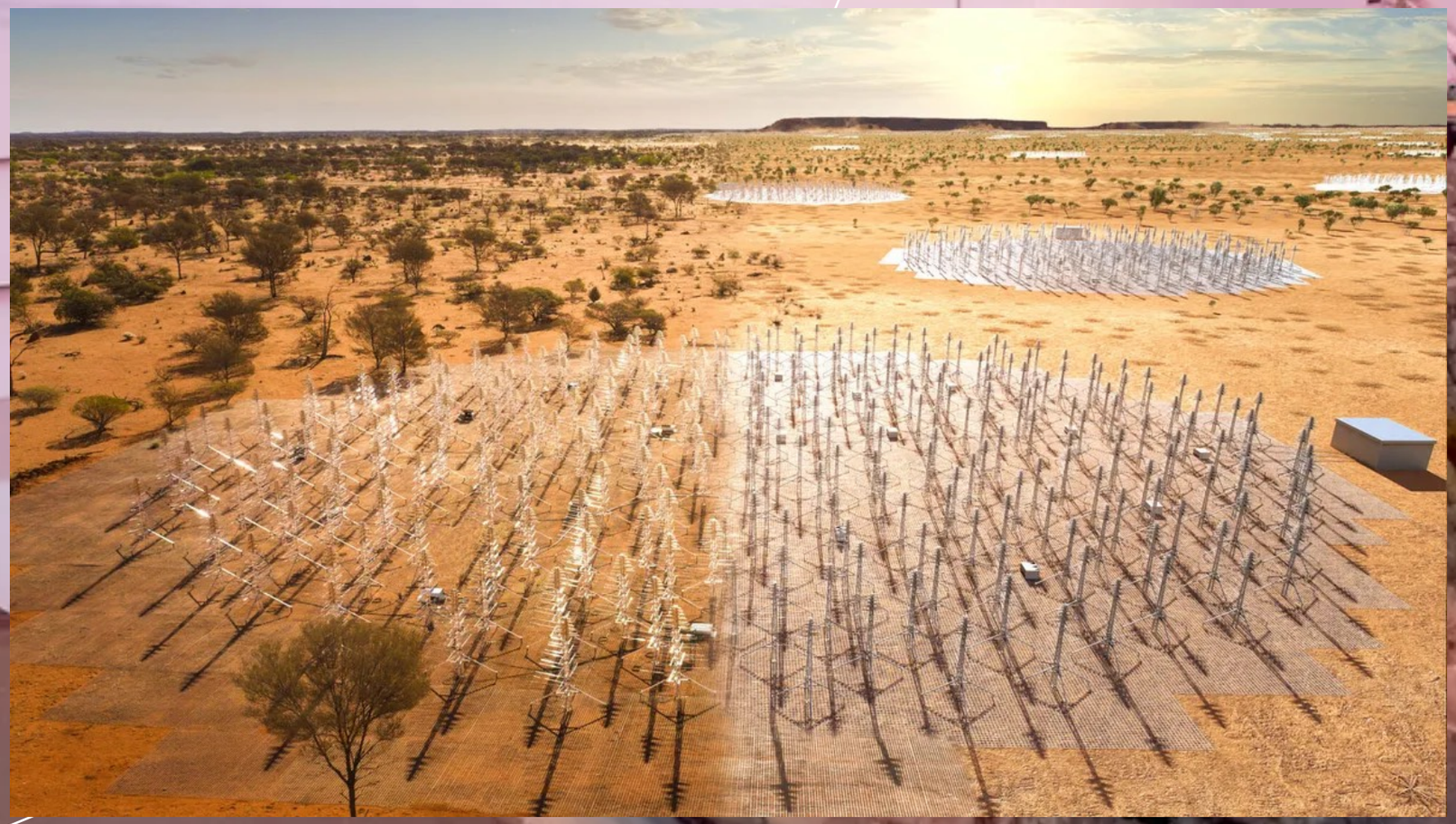
DUNLAP INSTITUTE
for ASTRONOMY & ASTROPHYSICS

SKAO

VERA C. RUBIN OBSERVATORY

Dunlap Institute for Astronomy & Astrophysics
UNIVERSITY OF TORONTO

The Universe in Real Time Through The Canadian Data Intensive Astrophysics PLatform (CanDIAPL)



Renée Hložek
Associate Professor
University of Toronto

Image: Jared Levy

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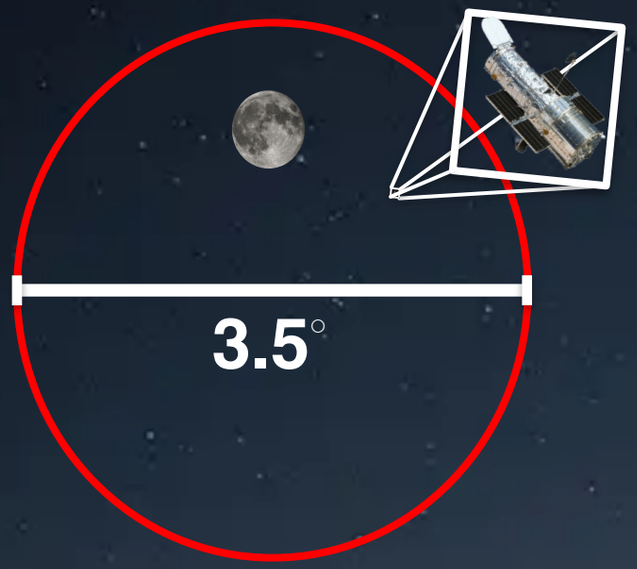
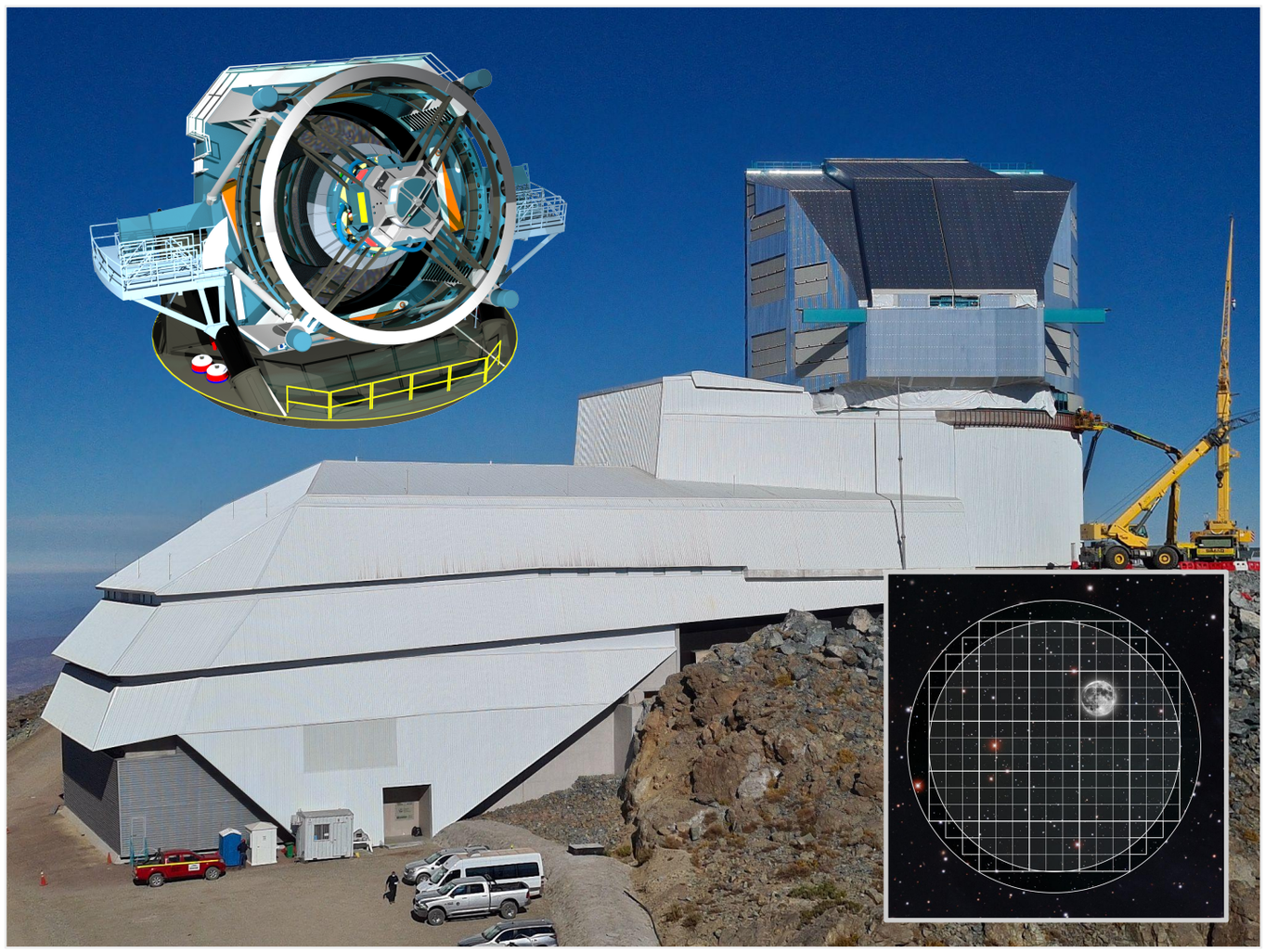
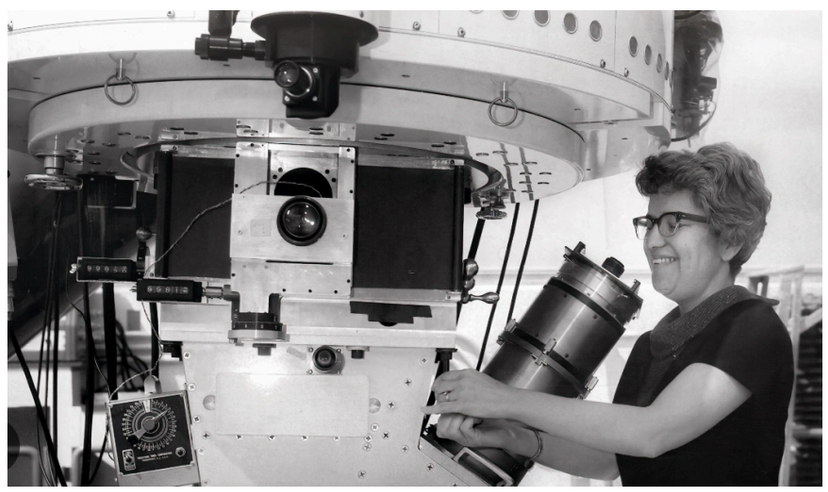
movie: LSST Corporation


3.5°

The Vera C. Rubin Observatory





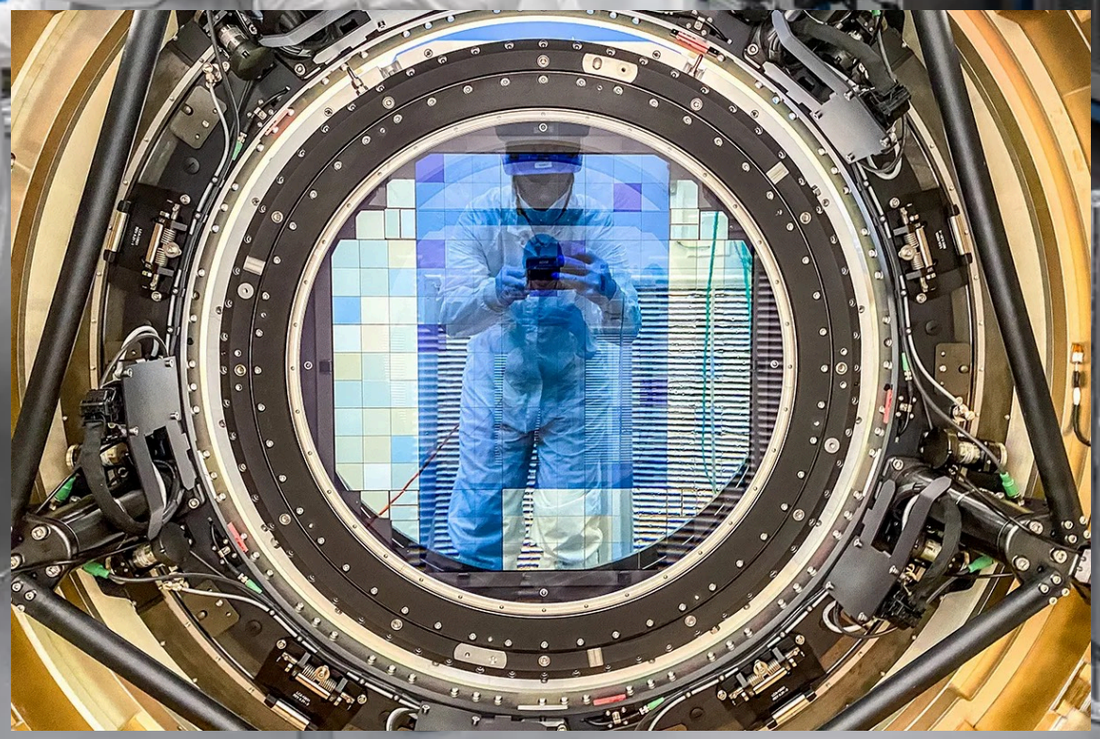
The Vera C. Rubin Observatory is located on Cerro Pachón in Chile. The Simonyi Survey Telescope's primary mirror has a 6.7 meter *effective* diameter and its camera a 9.6 deg^2 field-of-view and six optical-NIR filters: *ugrizy*.

Once construction and commissioning are complete, Rubin Observatory will execute the 10-year Legacy Survey of Space and Time (LSST):

- single-image depths (point source; AB)
  - *ugrizy* = 23.9, 25.0, 24.7, 24.0, 23.3, 22.1 mag
- 10-year LSST depths (point source; AB)
  - *ugrizy* = 26.1, 27.4, 27.5, 26.8, 26.1, 24.9 mag

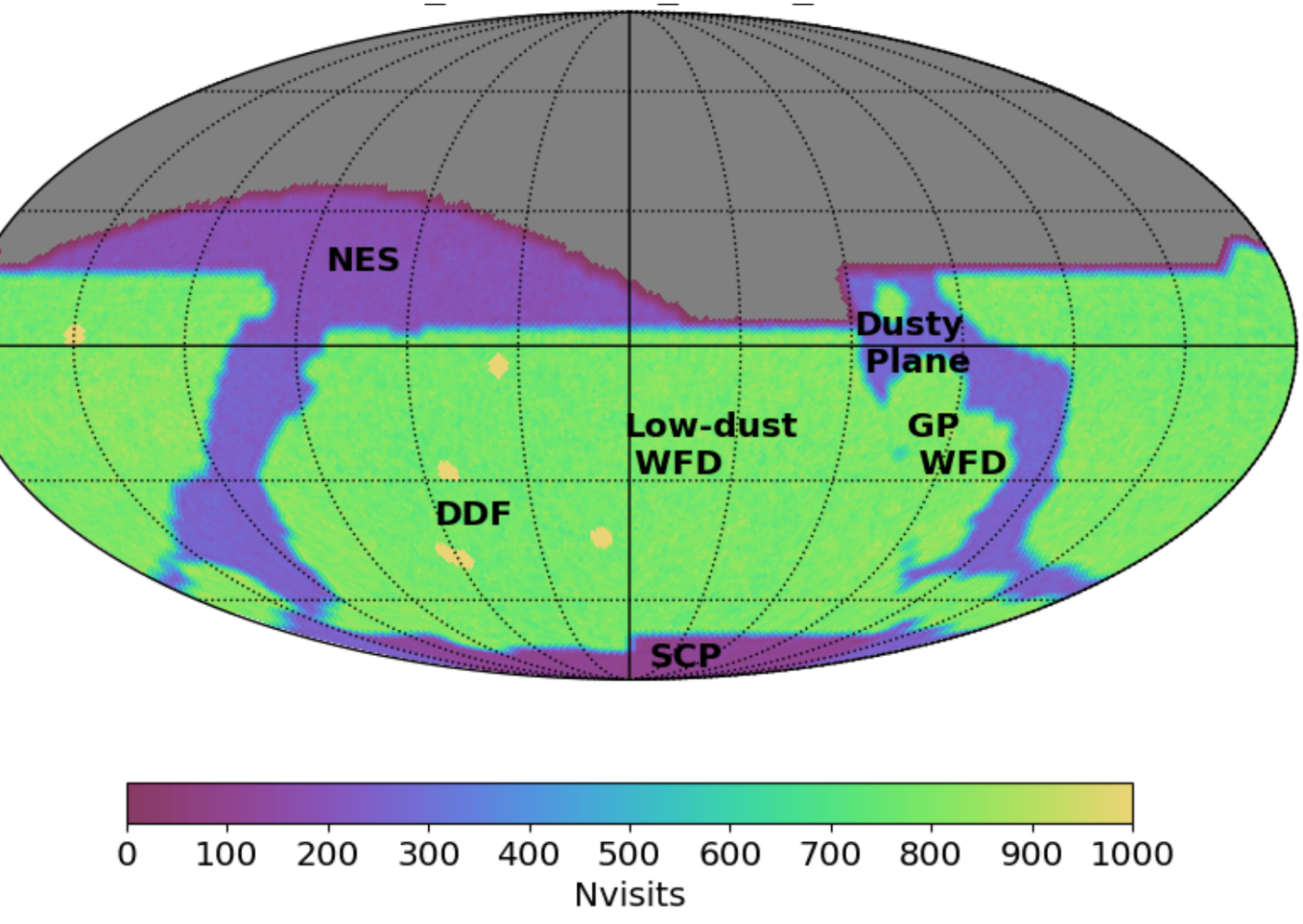
See Ivezić et al. (2019) for technical details about the design and the science goals.

3,200,000,000 pixels



Survey Strategy Basics

One of the most recent baseline survey simulations.



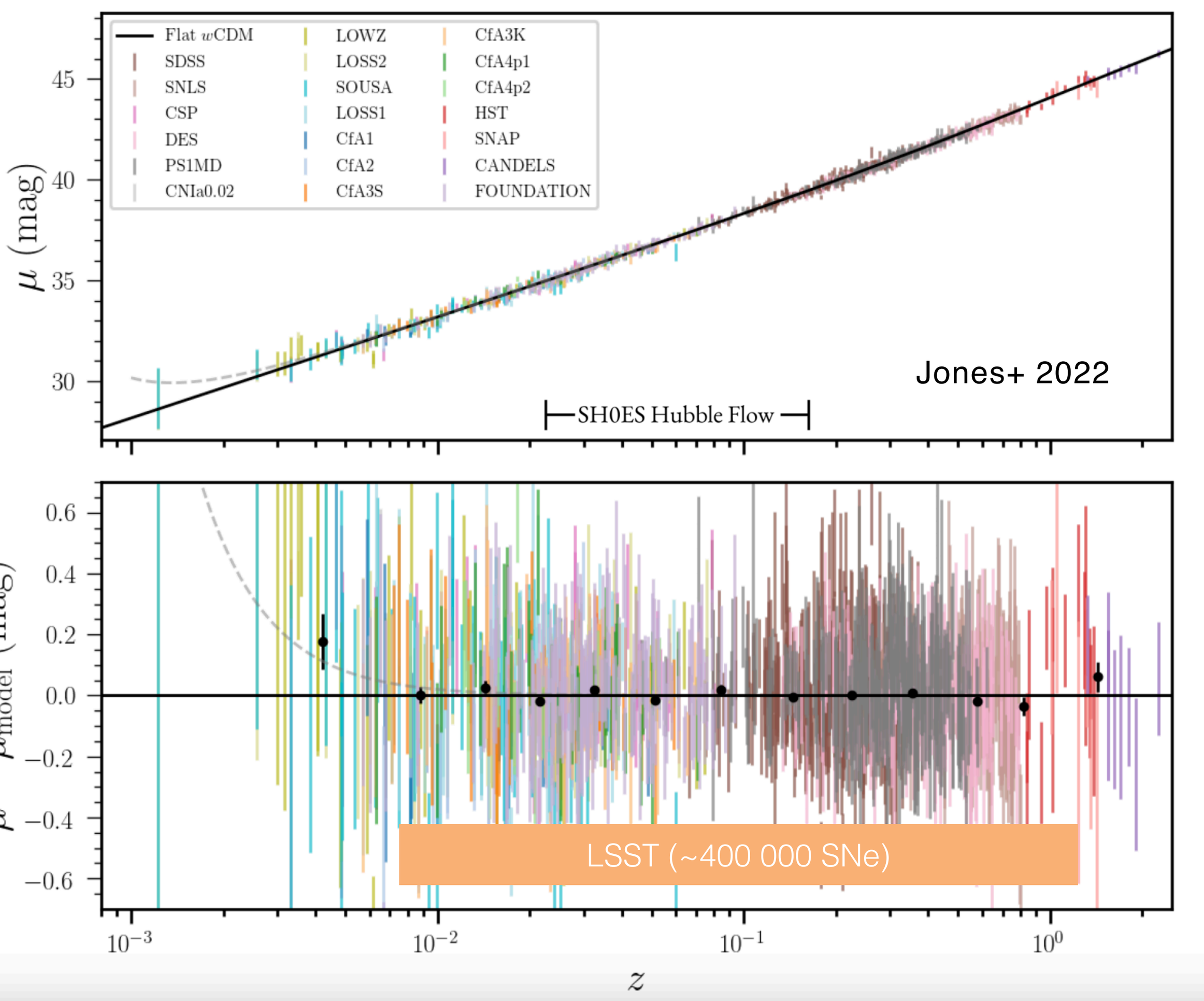
The **Baseline Survey Strategy** was designed to meet the basic requirements to achieve the core science goals of the **Legacy Survey of Space and Time** (LSST; requirements described in ls.st/srd).

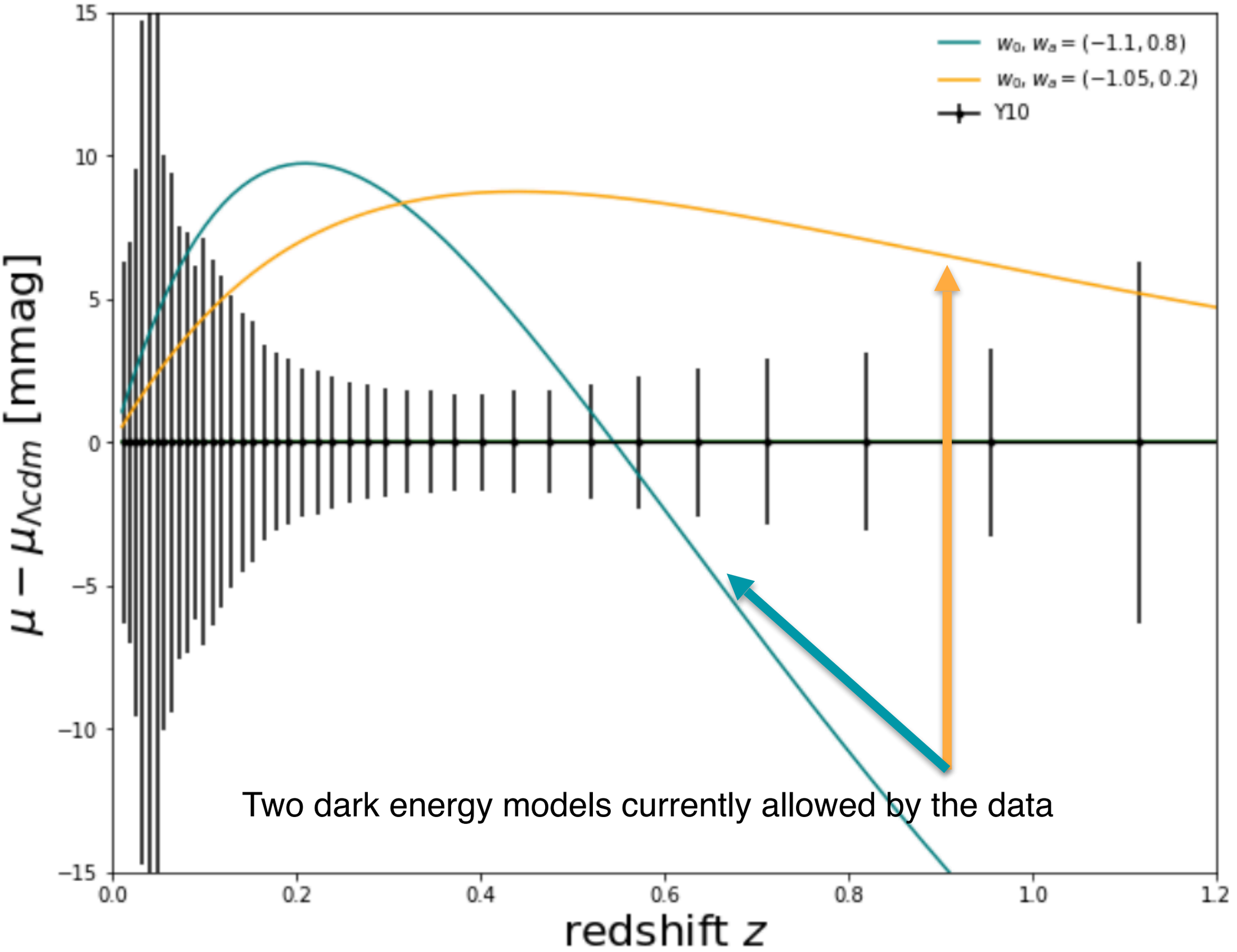
Baseline design elements for the WFD area:

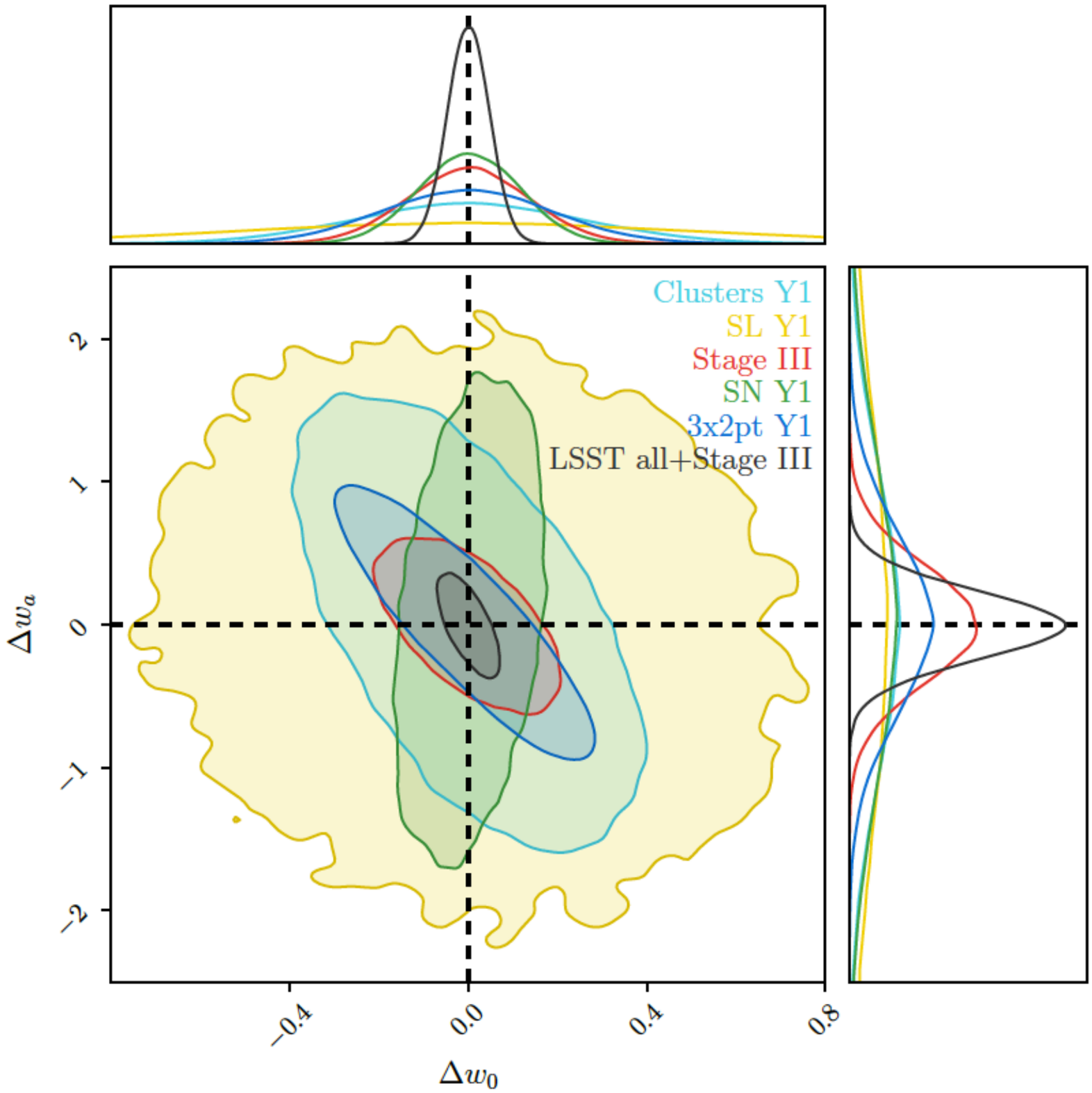
- should cover at least 18000 deg^2
- average of 825 visits per field over 10 years
- same-night same-field re-visit “pairs”

Additional areas covered should include:

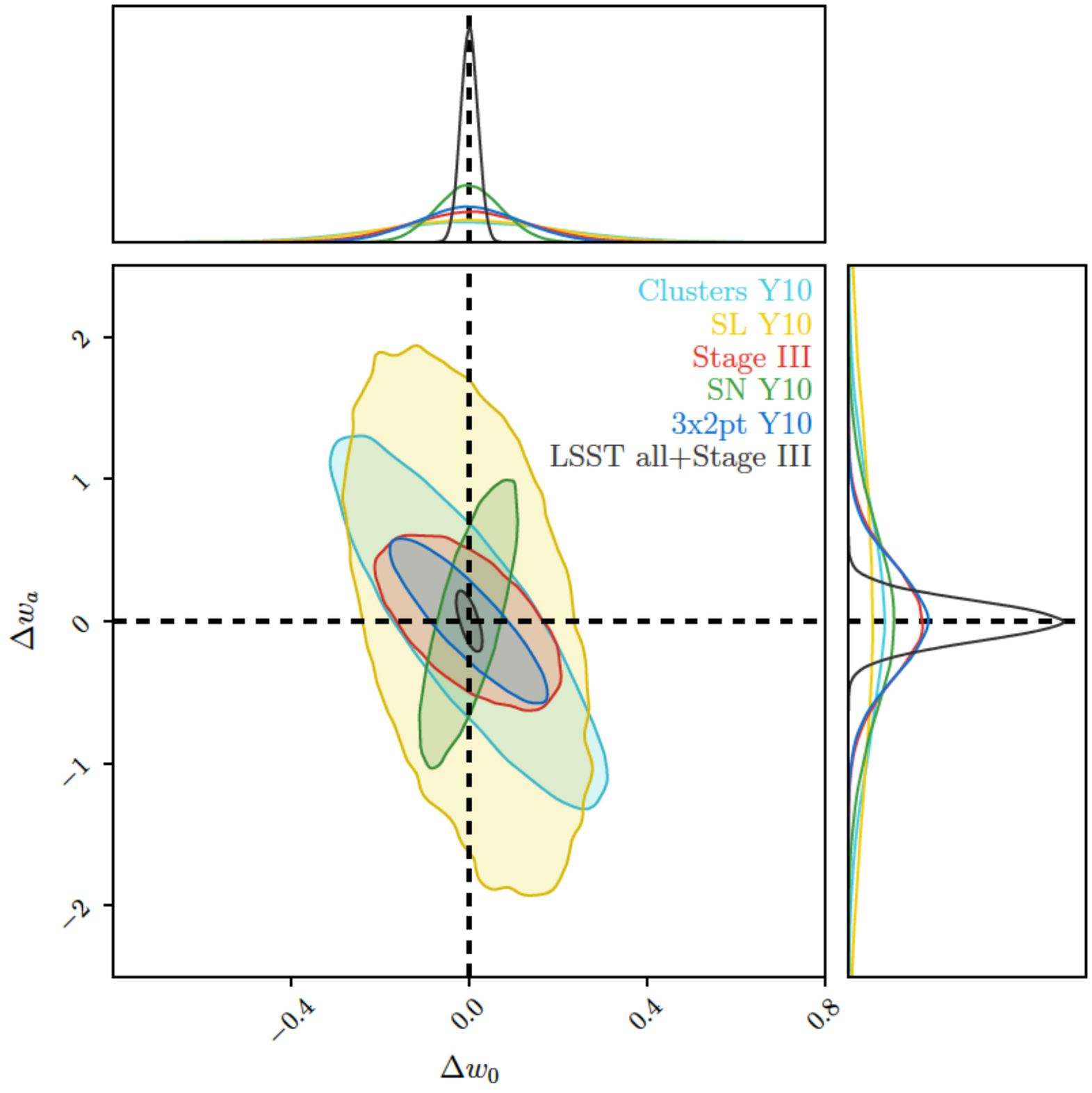
- at least 5 deep drilling fields
- the North Ecliptic Spur, the Galactic Plane, and the South Celestial Pole


Flat wCDM
SDSS
SNLS
CSP
DES
PS1MD
CNIa0.02
LOWZ
LOSS2
SOUSA
LOSS1
CfA1
CfA2
CfA3S
CfA3K
CfA4p1
CfA4p2
HST
SNAP
CANDELS
FOUNDATION
μ (mag)
45
40
35
30
SH0ES Hubble Flow
Jones+ 2022
$\mu - \mu_{\rm model}$ (mag)
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
LSST (~400 000 SNe)
10^{-3}
10^{-2}
10^{-1}
10^{0}
z


$w_0, w_a = (-1.1, 0.8)$
$w_0, w_a = (-1.05, 0.2)$
Y10
15
10
5
0
−5
−10
−15
0.0
0.2
0.4
0.6
0.8
1.0
1.2
$\mu - \mu_{\Lambda cdm}$ [mmag]
redshift z
Two dark energy models currently allowed by the data



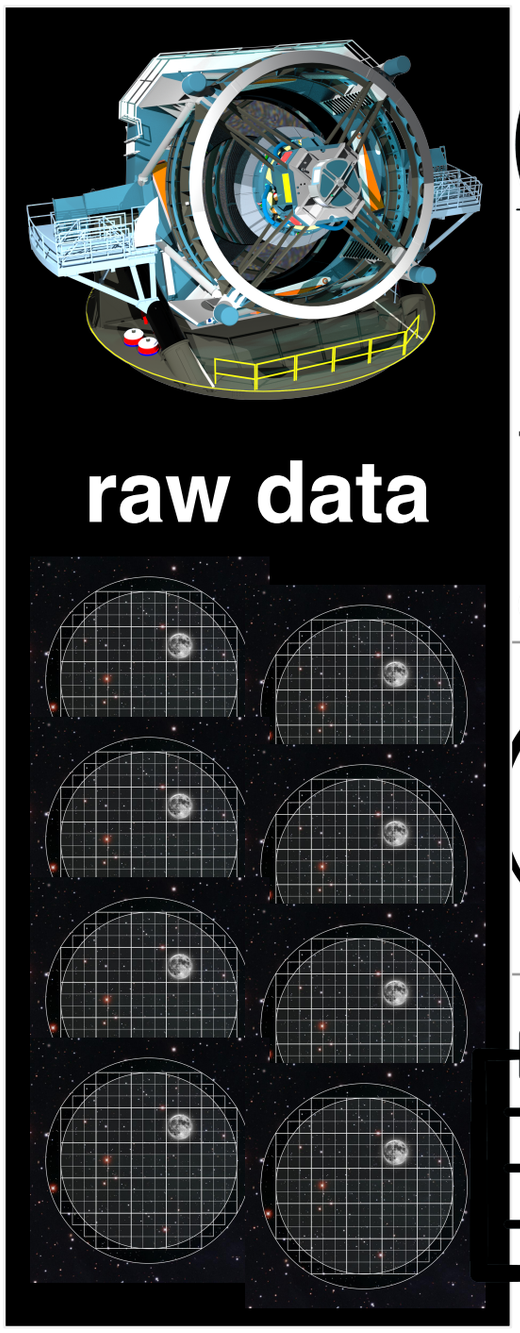
Mandelbaum, Hložek ++ (2019)

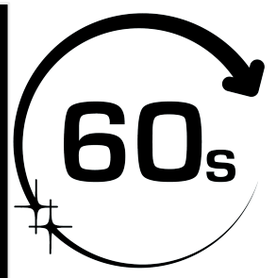


Mandelbaum, Hložek ++ (2019)

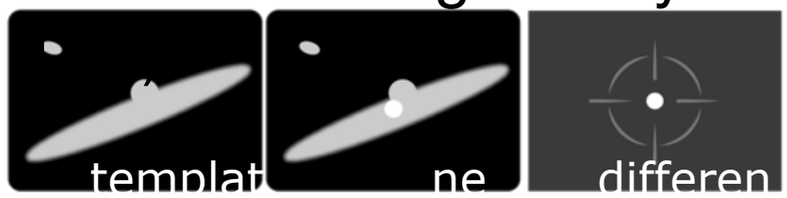
Data Products

Data Products Definitions Document: ls.st/dpdd

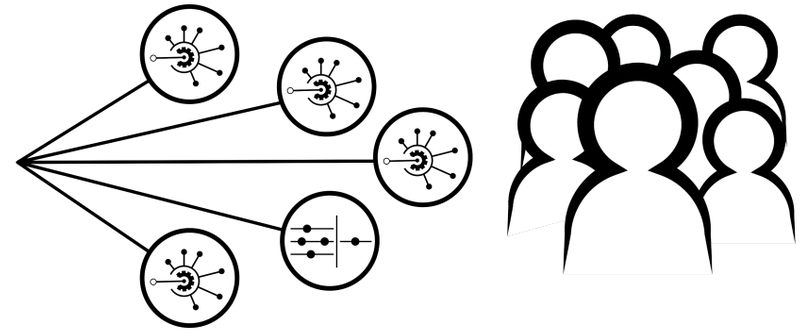




Difference Image Analysis

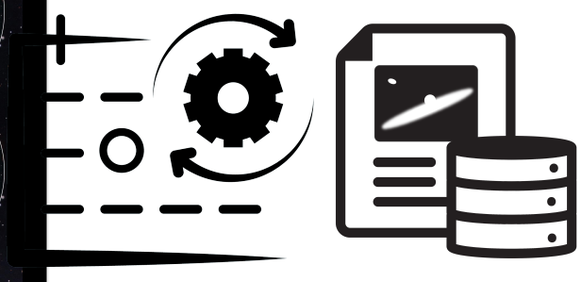


In 60s, raw images are processed, a template is subtracted, and difference-image sources are detected, associated, characterized, and…



…distributed as alerts to brokers, where they can be rapidly analyzed by users.

In 24h, the Prompt Products Database (PPDB) is updated with the DIA data products.



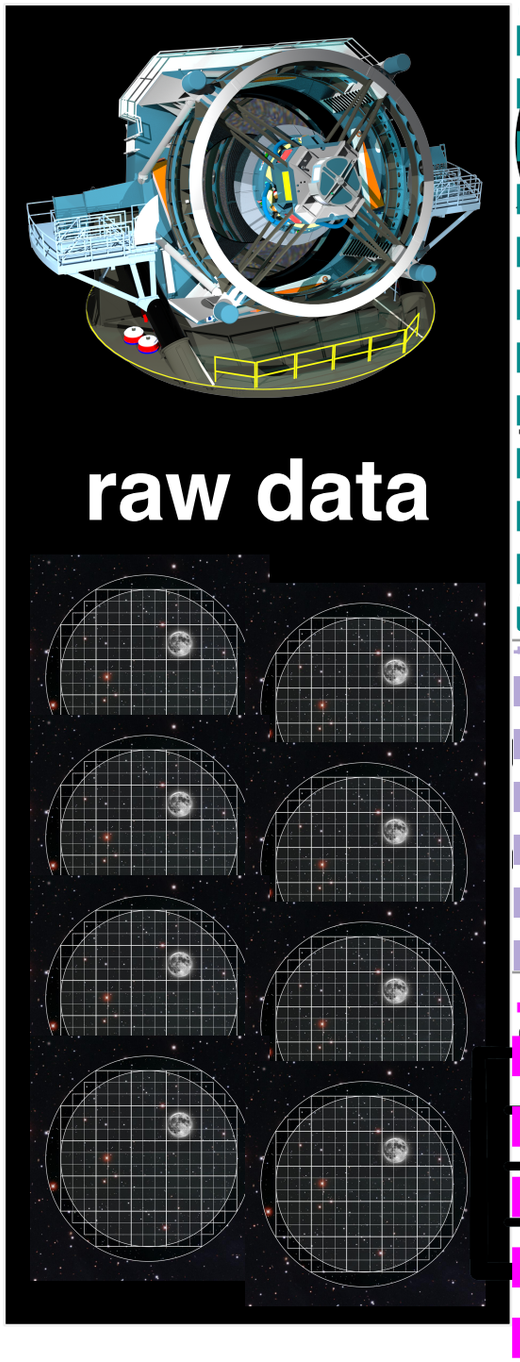
Yearly data releases include DIA, coadded images, and catalogs for all data to date.

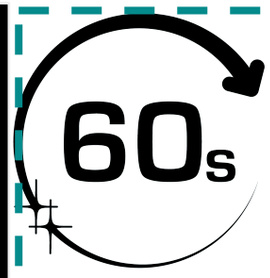
The Prompt (24h) and Data Release (annual) data products will be available for users to analyze via the Rubin Science Platform.

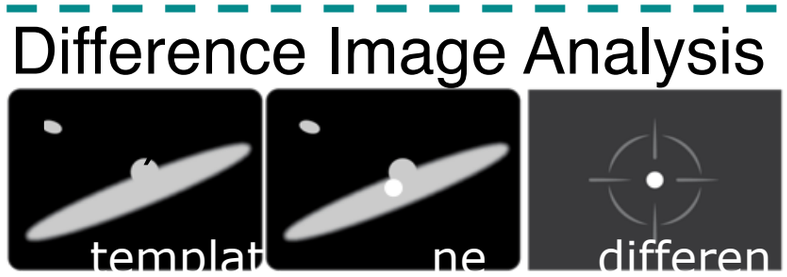
Data Products

Data Products Definitions Document: ls.st/dpdd

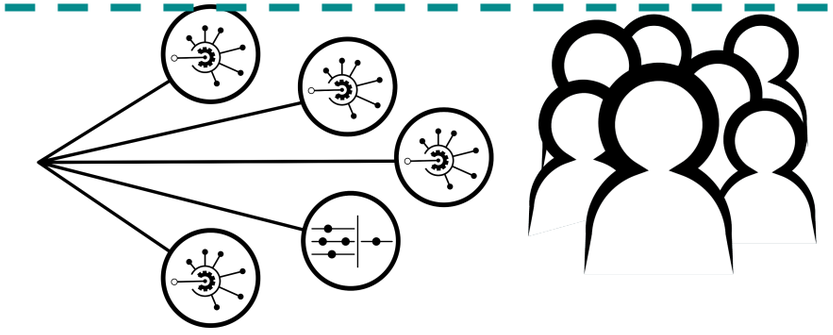
world public







In 60s, raw images are processed, a template is subtracted, and difference-image sources are detected, associated, characterized, and…

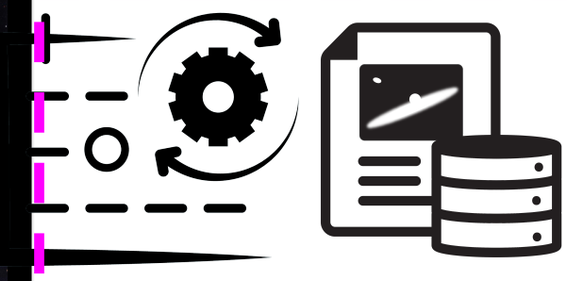


…distributed as alerts to brokers, where they can be rapidly analyzed by users.

PPDB contents are public

all images are proprietary

In 24h, the Prompt Products Database (PPDB) is updated with the DIA data products.



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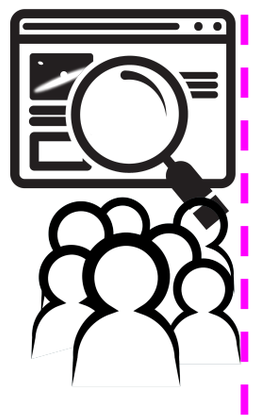
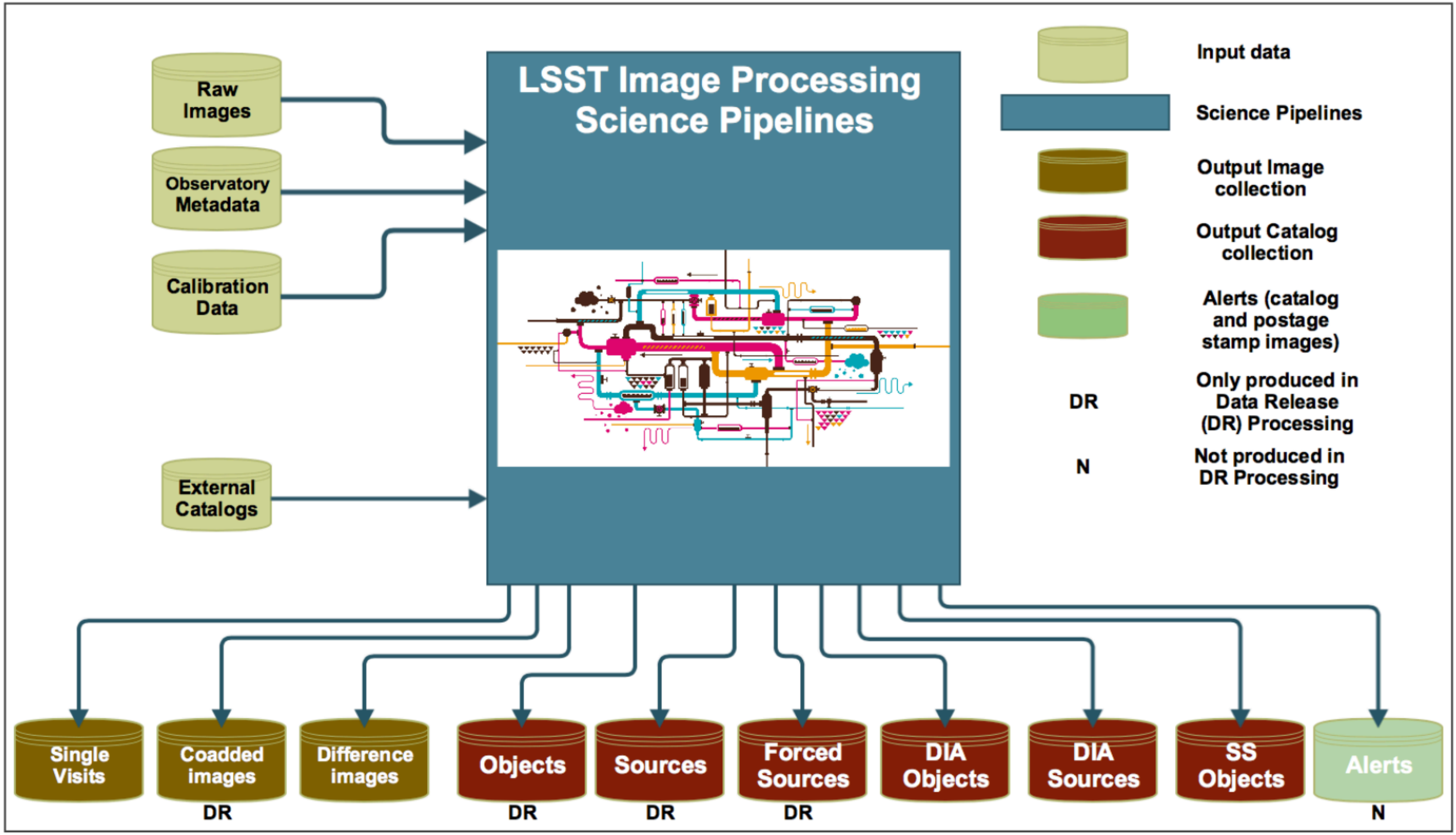


proprietary to data rights holders



Imgae: Rubin Observatory Data Products Definition Guide LSE-163

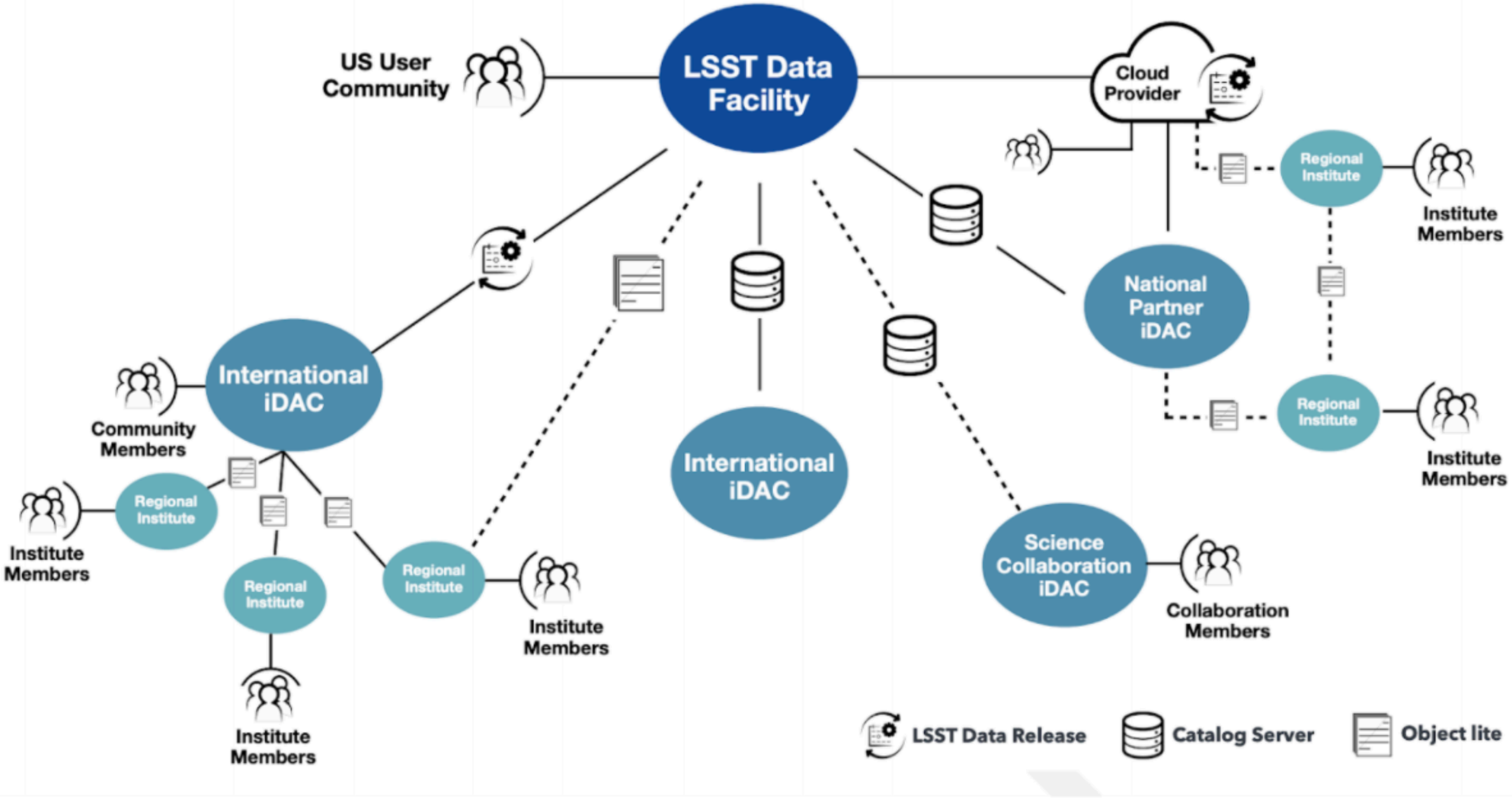
Rubin needs to reliably process unprecedented data volumes:18,000 square degree survey with 2000 images per patch of sky over ten years = 37 billion rows in the Rubin Object table; 350 billion rows in the Source table). The tables must be extensible, partitioned and indexed to facilitate high query performance, and replicated across multiple centers.

Ensure **consistent data quality** without manual intervention and meet stringent **near-real-time transient alerting deadlines**

Accommodate both **scientific and computing technology evolution** over at least a decade

Serve Rubin Observatory data products to a diverse community of **users located across several continents**.

Image of the National Center for Supercomputing Applications courtesy NCSA



LSST international iDACs will also distribute data load for other groups.

SKA Observatory

Building the two largest telescope arrays in the world, located in South Africa and Australia, made possible through a global collaboration.

SKAO

How does SKA1 compare with the world's biggest radio telescopes?

SKAO

SKA1 LOW
Australia

419,000m²

~130,000 antennas

SKA1 MID
South Africa

33,000m²

~200 dishes

MWA
Murchison Widefield Array, Australia

2,500m²

2048 antennas

LOFAR
Low Frequency Array for Radio astronomy, Netherlands

52,000m²

34,000 antennas

GMRT
Giant Metrewave Radio Telescope, India

48,000m²

30 dishes

At 110 MHz

MeerKAT
South Africa

9,000m²

64 dishes

ASKAP
Australian SKA Pathfinder, Australia

4,000m²

36 dishes

JVLA
Karl G. Jansky Very Large Array, USA

13,200m²

27 dishes

NRT
Nancay Radio Telescope, France

7,000m²

300m x 35m antenna

FAST
Five Hundred Meter Aperture Spherical Telescope, China

71,000m²

500m dish

Lovell
UK

4,500m²

76m dish

Parkes
Australia

3,200m²

64m dish

SRT
Sardinia Radio Telescope, Italy

3,200m²

64m dish

Effelsberg
Germany

7,800m²

100m dish

GBT
Green Bank Telescope, USA

7,800m²

100m dish

Arecibo
Puerto Rico

42,000m²

305m dish

ALMA
Atacama Large Millimeter/ submillimeter Array, Chile

6,500m²

66 dishes

IRAM NOEMA
Northern Extended Millimeter Array, France

2,100m²

12 dishes

IRAM 30m
Spain

700m²

30m dish

ARRAYS

SINGLE DISHES

NON-STEERABLE

LOW FREQUENCIES

MID FREQUENCIES

HIGH FREQUENCIES

The Square Kilometre Array (SKA) will be the world's largest radio telescope, revolutionising our understanding of the Universe. The SKA will be built in two phases - SKA1 and SKA2 - starting in 2018, with SKA1 representing a fraction of the full SKA. SKA1 will include two instruments - SKA1 MID and SKA1 LOW - observing the Universe at different frequencies.

A telescope's capacity to receive faint signals - called sensitivity - depends on its collecting area, the bigger the better. But just like you can't compare radio telescopes and optical telescopes, comparison only works between telescopes working in similar frequencies, hence the different categories above.

The collecting area is just one aspect of a telescope's capability though. Arrays like the SKA have an advantage over single dish telescopes: by being spread over long distances, they simulate a virtual dish the size of that distance and so can see smaller details in the sky, this is called resolution.

www.skao.int @skao SKA Observatory SKA Observatory SKA Observatory @skaobservatory

SKA1-low

— 7.2 Tb/s →

SKA SQUARE KILOMETRE ARRAY

CSP

CENTRAL SIGNAL PROCESSORS

~5 Tb/s ↓

~250 PFlops

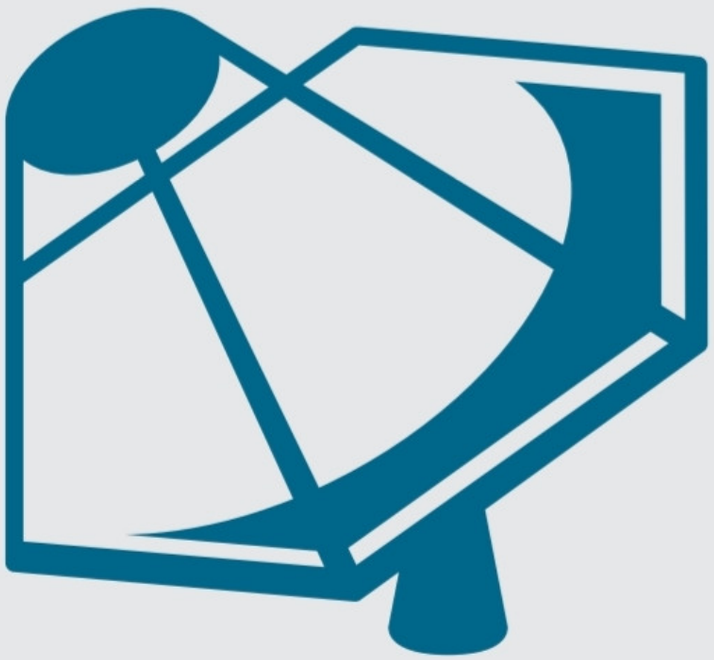
SKA SQUARE KILOMETRE ARRAY

SDP

SCIENCE DATA PROCESSORS

~600 PB/yr ↓

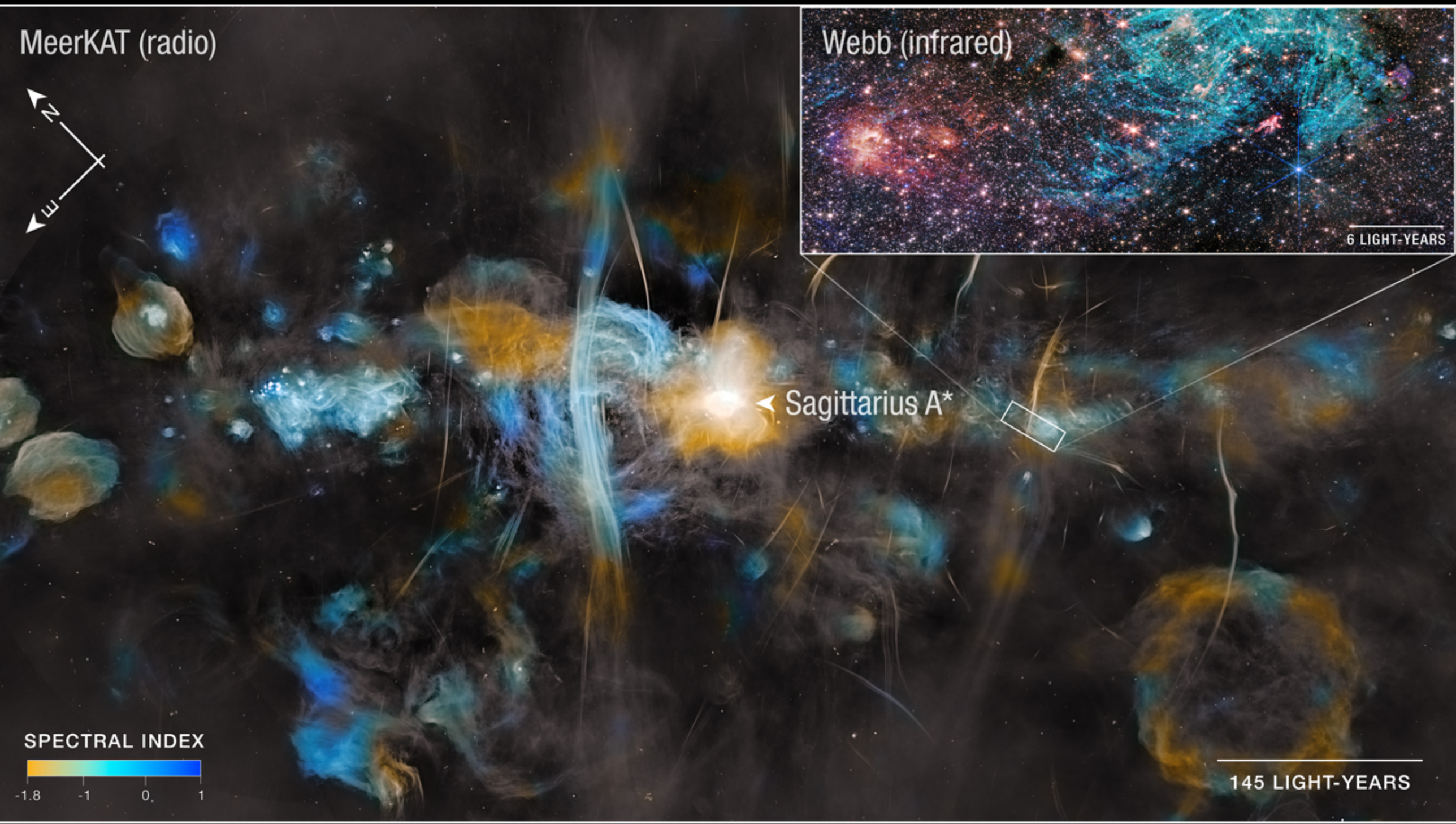
SKA Regional Centres



— 8.8 Tb/s →

SKA1-mid

SKAO


MeerKAT (radio)
N
E
Webb (infrared)
6 LIGHT-YEARS
Sagittarius A*
SPECTRAL INDEX
-1.8
-1
0
1
145 LIGHT-YEARS

Publications of the Astronomical Society of Australia (2025), , 1–32
doi:10.1017/pas.2025.xxx

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CAMBRIDGE UNIVERSITY PRESS

RESEARCH PAPER

The Polarisation Sky Survey of the Universe's Magnetism (POSSUM): Science Goals and Survey Description

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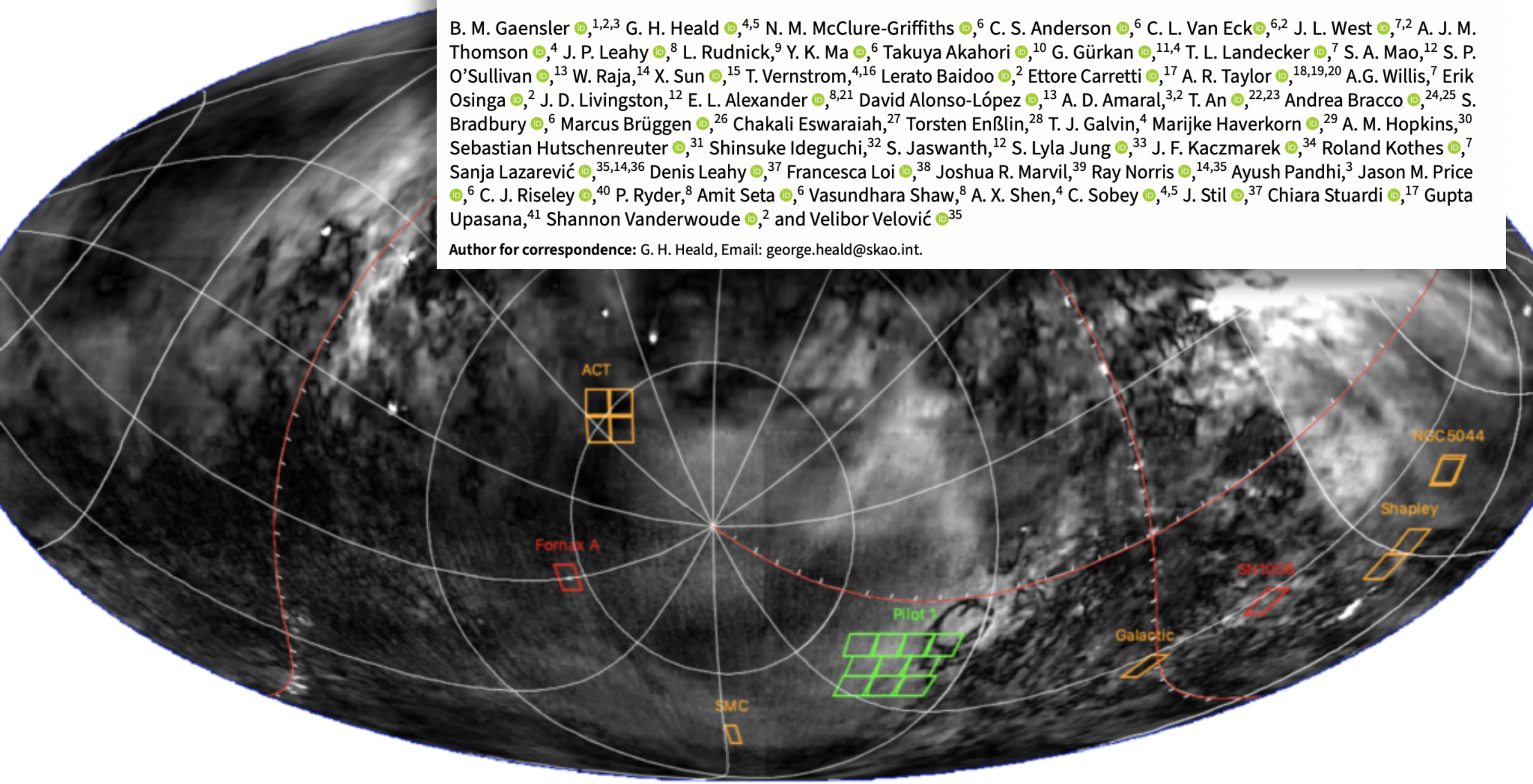
Author for correspondence: G. H. Heald, Email: george.heald@skao.int.



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Challenges of coordinating big survey science

CanDIAPL

Challenges

- Limited data access
- Unprecedented data volumes
- Insufficiently processed data
- Bespoke data formats

HARDWARE

A. On-site hardware

B. Off-site hardware

SOFTWARE

C. Real-time analysis

D. Dynamic data sets

E. Multi-messenger portal

INCLUSIVE PRACTICES — Leadership model, Mentoring network & Hiring guide

Breakthrough Science

I. Cosmic explosions & the transient Universe

II. Galaxies, gas, & dark matter

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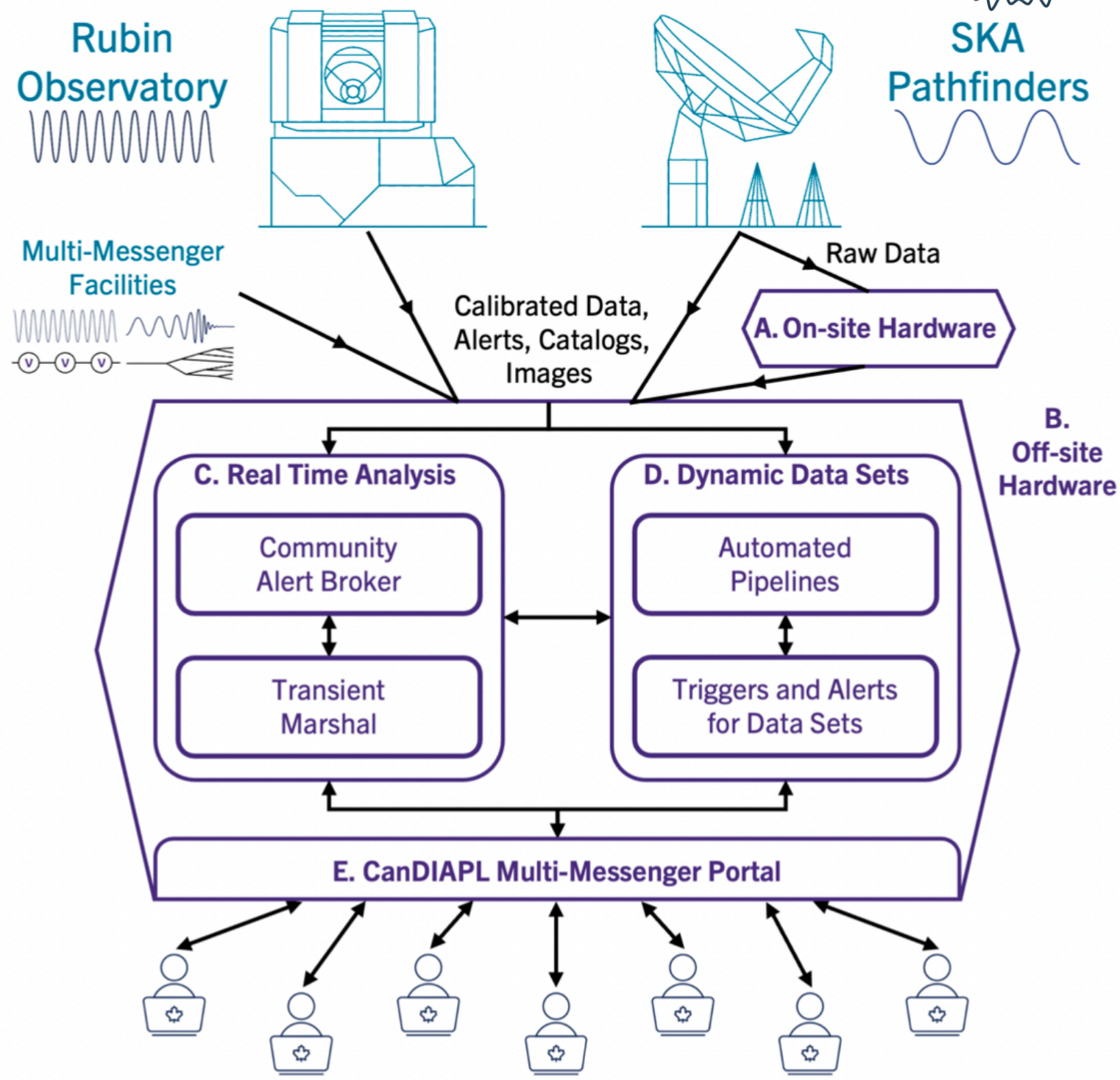
for ASTRONOMY & ASTROPHYSICS

Dunlap Institute for
Astronomy & Astrophysics
UNIVERSITY OF TORONTO

Canadian Data-Intensive Astrophysics Platform (CanDIAPL, “candy apple”)

We are building a data centre and tools to serve/combine and process data from Rubin and also SKA precursors like MeerKAT, enabling multi-wavelength analysis.



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