

The ARIEL Science Ground Segment and the Instrument Operations and Science Data Centre (IOSDC)

Chris Pearson: UKRI STFC RAL Space

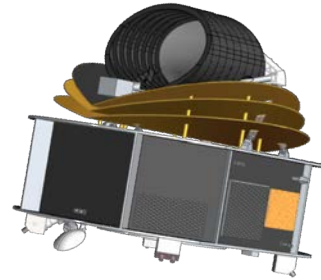
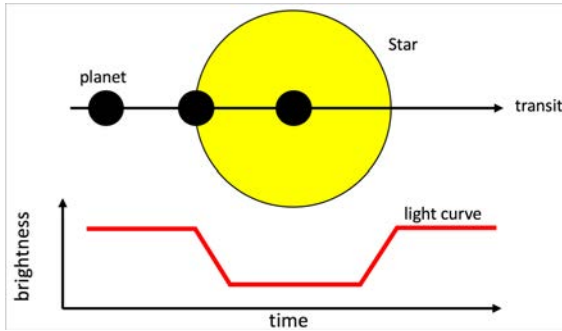
Pino Malaguti: INAF

On behalf of the ARIEL Ground Segment

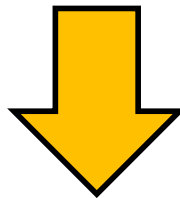


15th January 2020: ARIEL Science, Mission and Community Conference

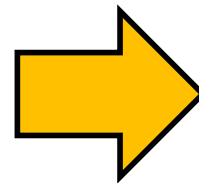
The ARIEL Ground Segment



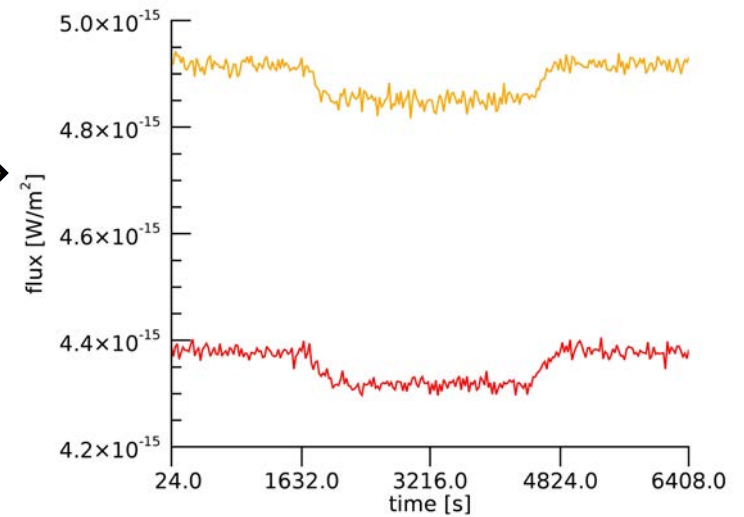
Satellite



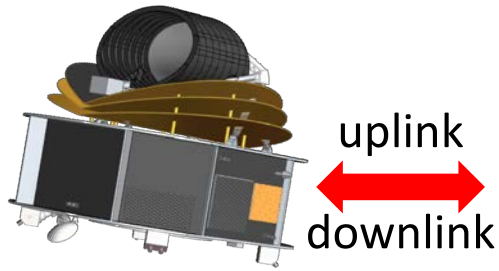
**ARIEL
GROUND
SEGMENT**



Data



The ARIEL Ground Segment



Operations Ground Segment OGS

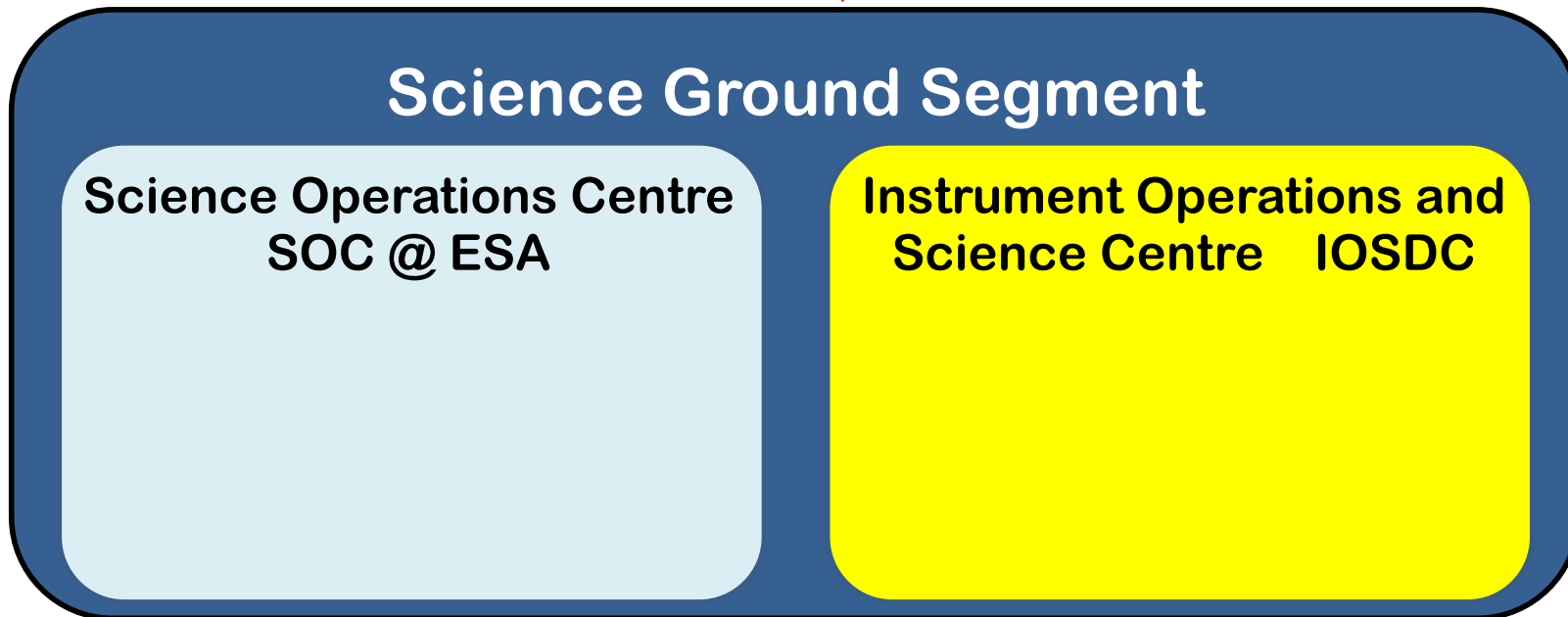
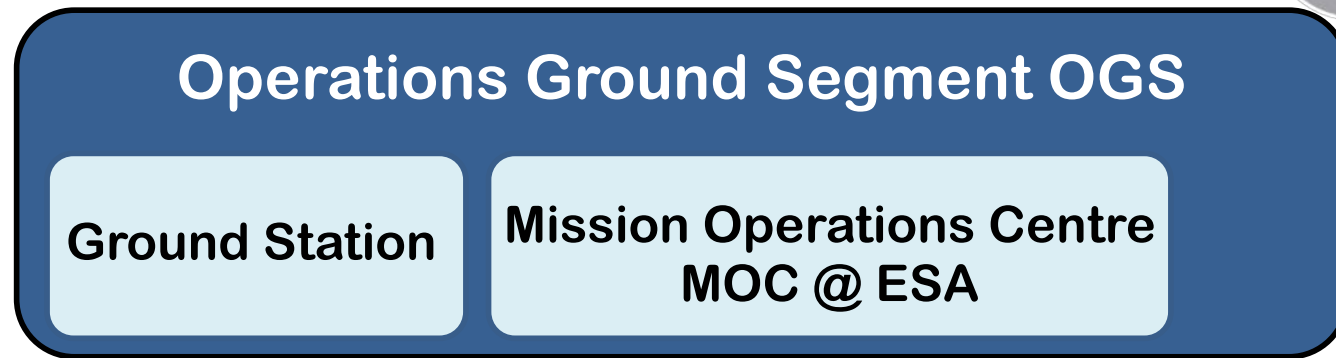
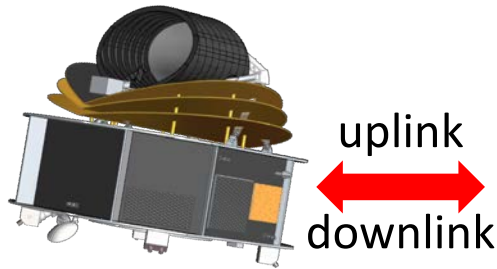
uplink ↓ downlink

Science Ground Segment

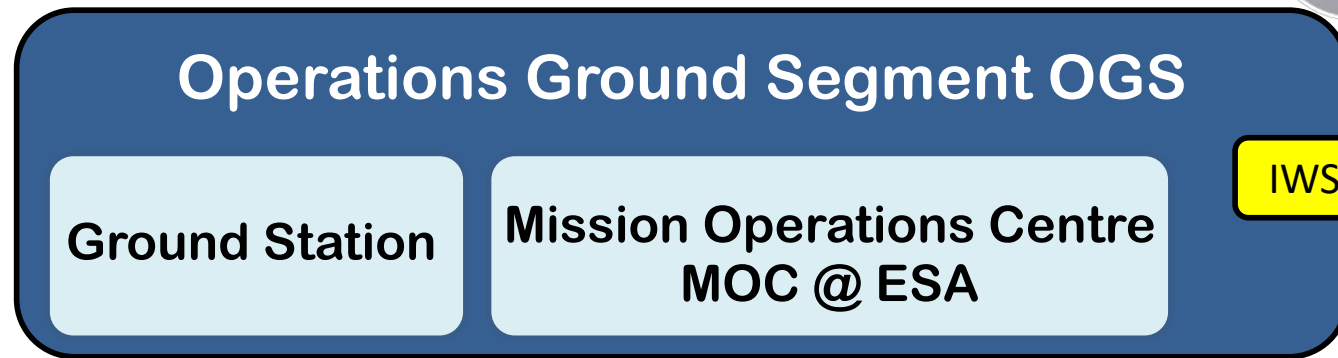
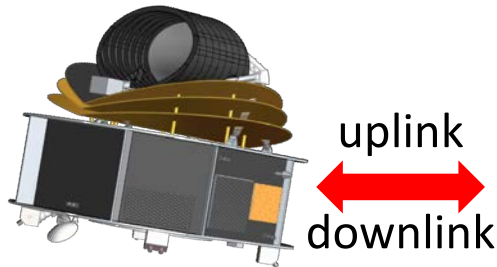
data ↓ interactions

Open Science Community

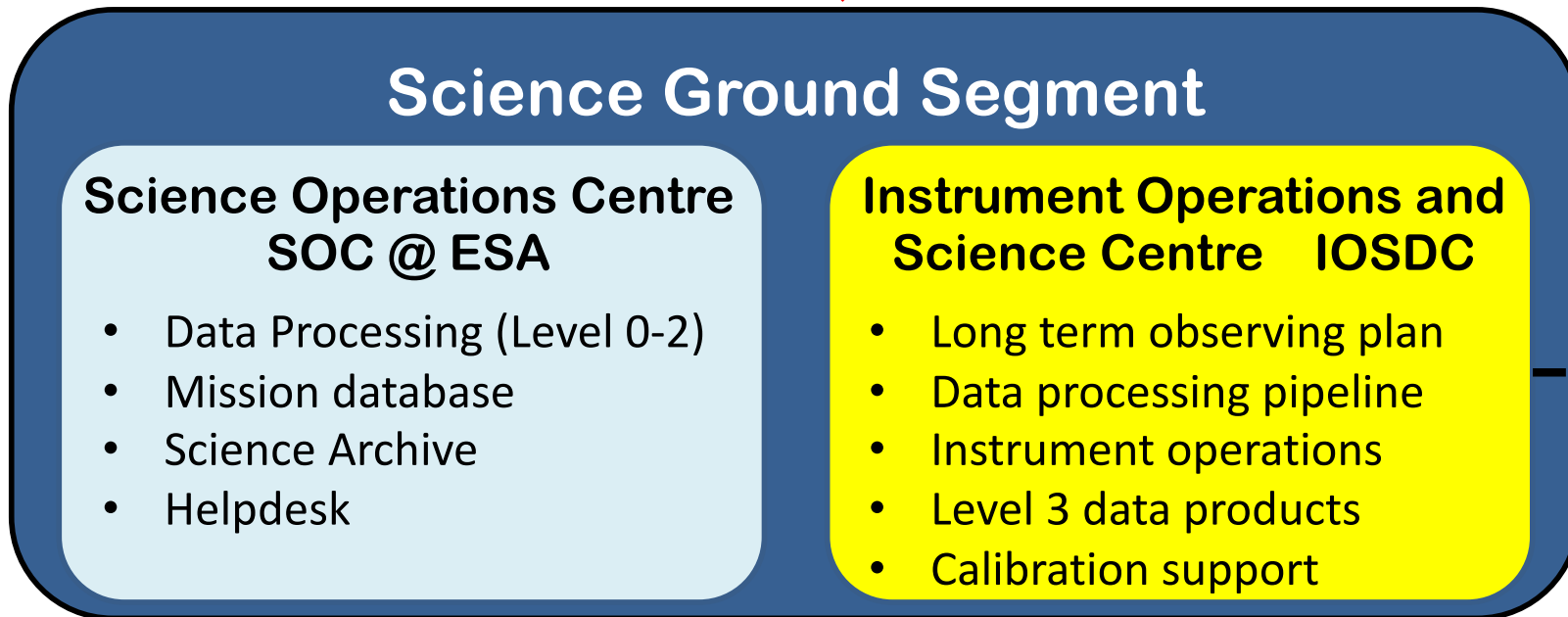
The ARIEL Ground Segment



The ARIEL Ground Segment



uplink ↓ downlink



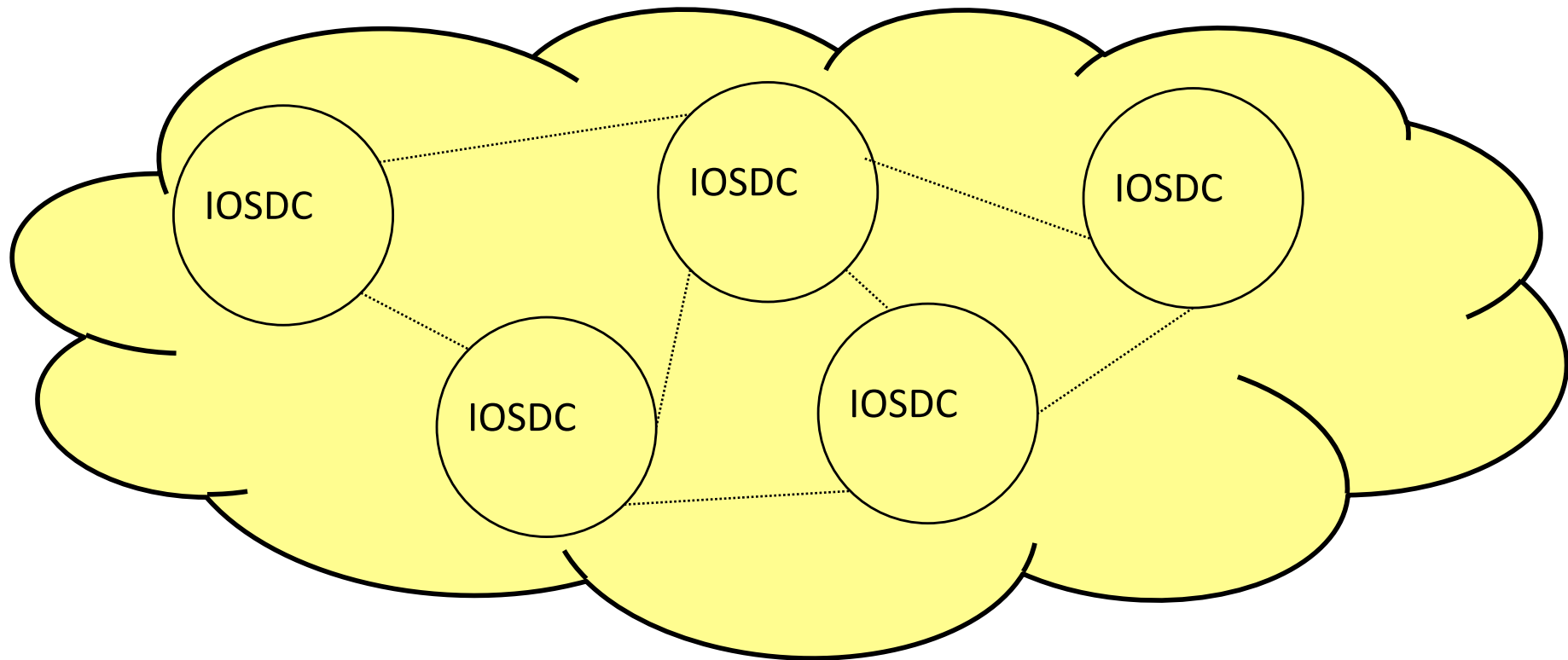
data ↑ interactions

Open Science Community

The ARIEL IOSDC



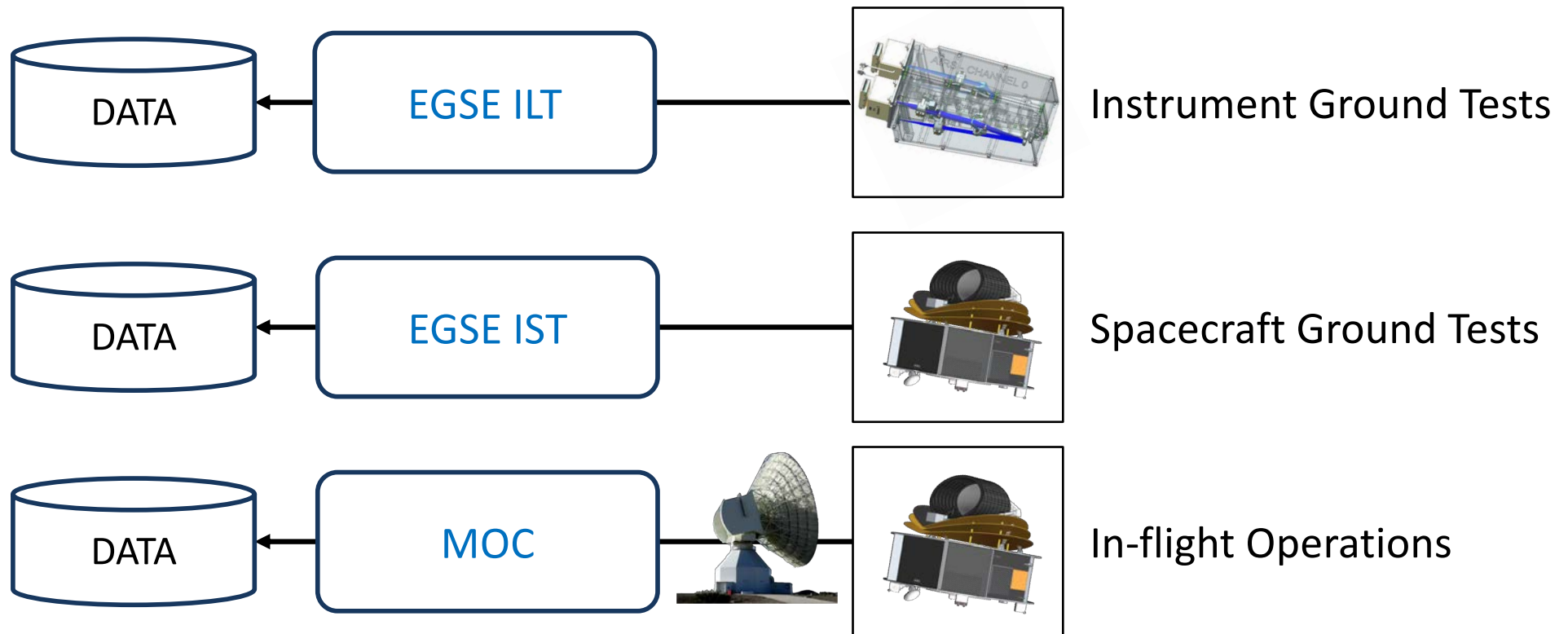
IOSDC Distributed Model



The ARIEL IOSDC



IOSDC Smooth Transition between mission phases



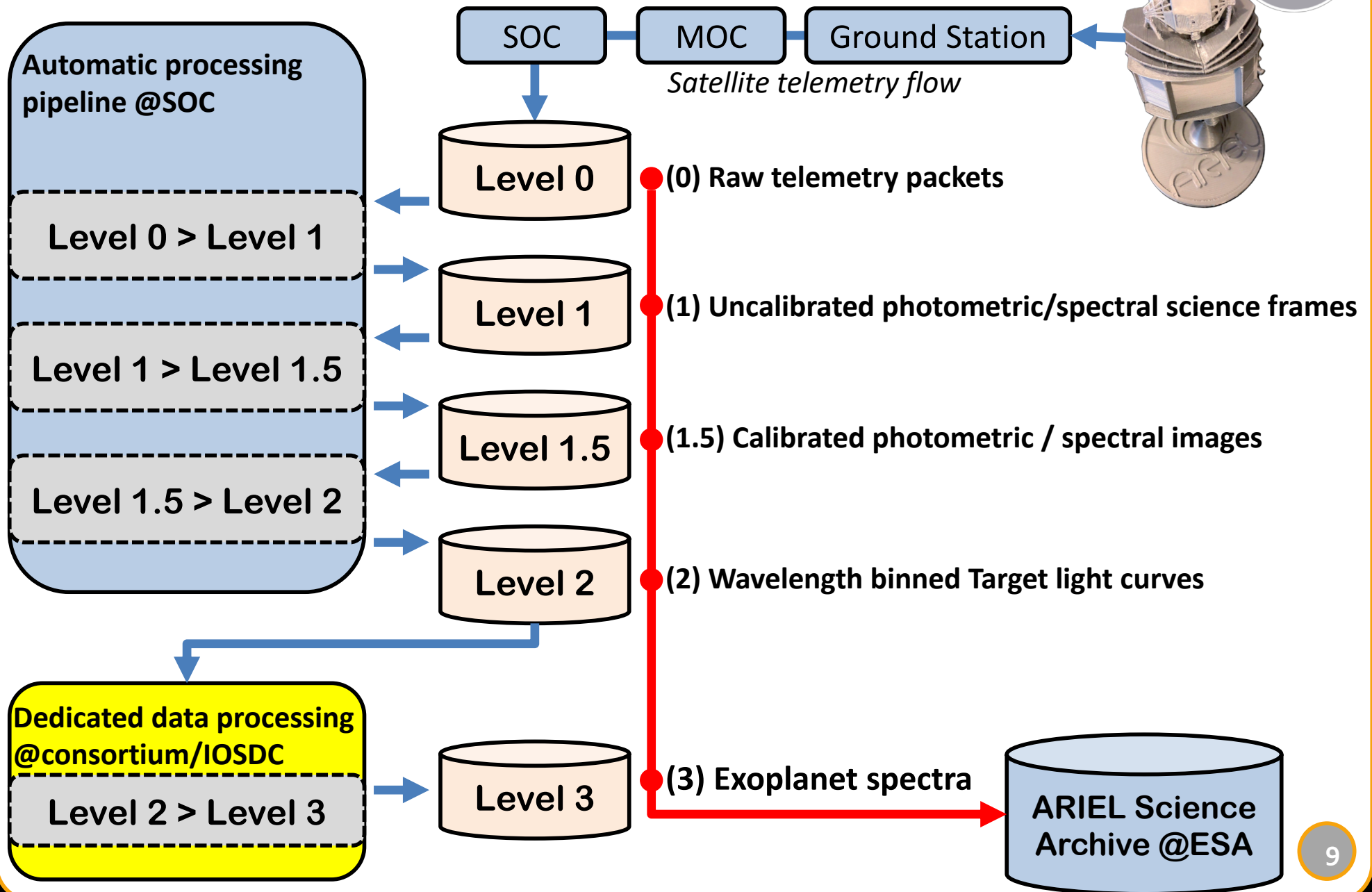
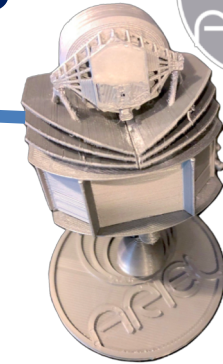
Under the smooth transition philosophy, the initial ground testing and calibration will closely resemble, and smoothly adapt/evolve, to the final operational environment

Data Flow and Data Products



- The ARIEL Data Reduction Pipeline (ADaRP) will be developed by the IOSDC.
- The **Pipeline** will be delivered to and automatically run at ESA-SOC.
- In the science pipeline Data Levels define break points along the processing, at which specific science **Data Products** are generated.
- These products will be made available to the scientific community via the ESA **ARIEL Science Archive**.
- The Pipeline begins from the raw Level 0 data, processing through to the Level 2 data products (the target light curves).
- **Level 3 data products** (exoplanets spectra) will be delivered directly from the ARIEL Consortium to the ESA ARIEL science archive

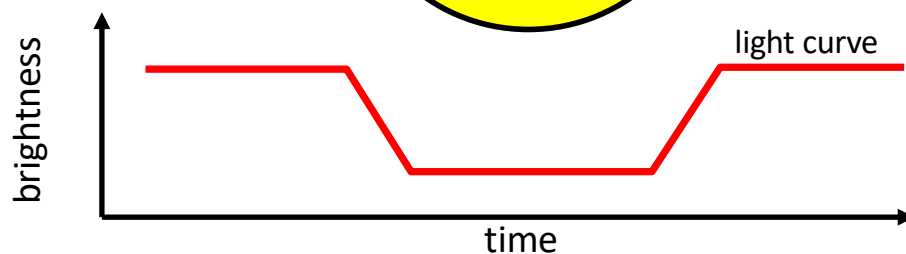
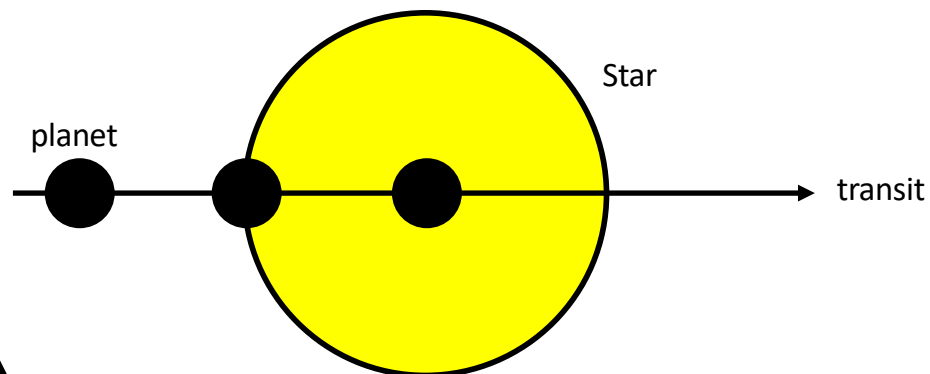
Data Flow and Data Products



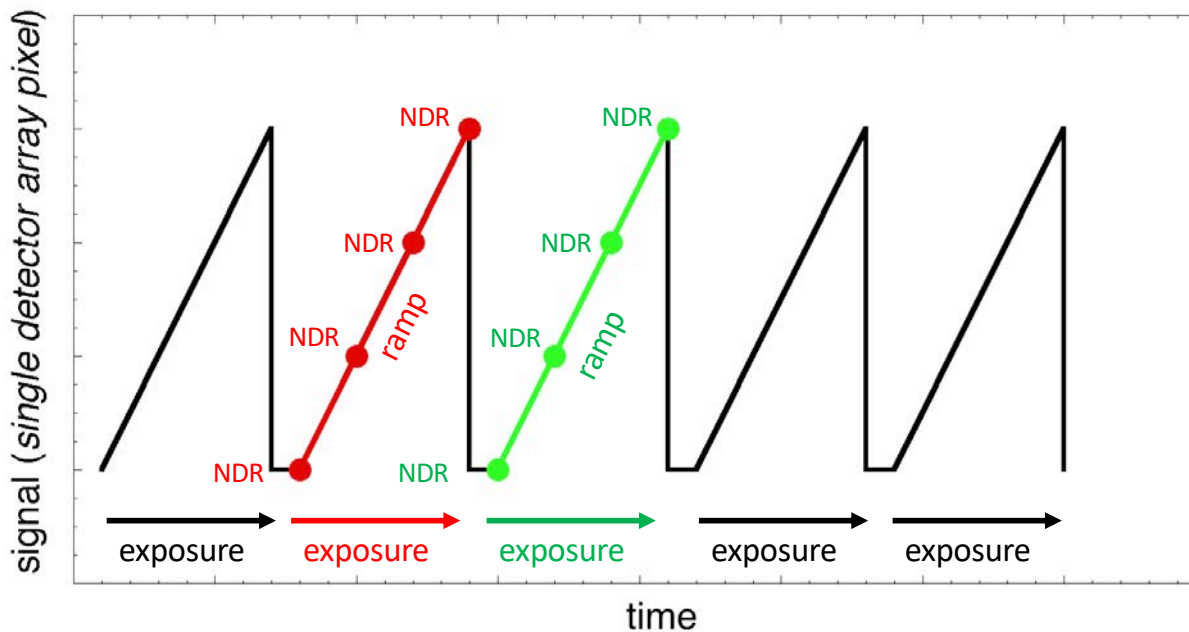
Level 0 Data Product

observation visualization

detector signal visualization



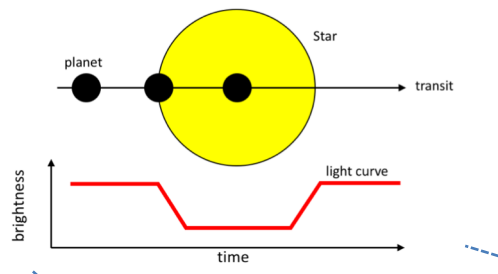
← Observation →





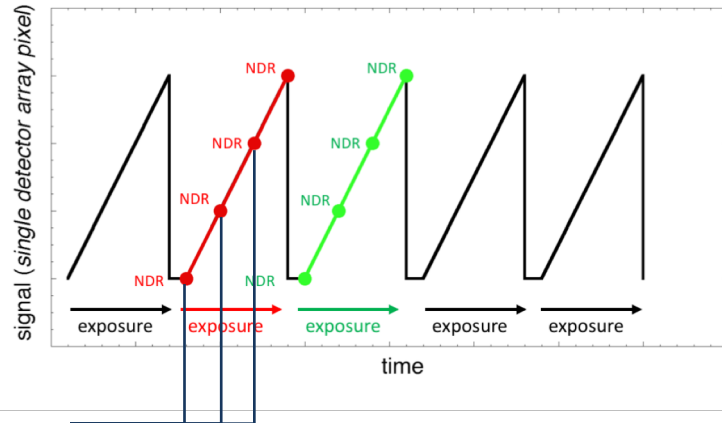
Level 0 Data Product

observation visualization

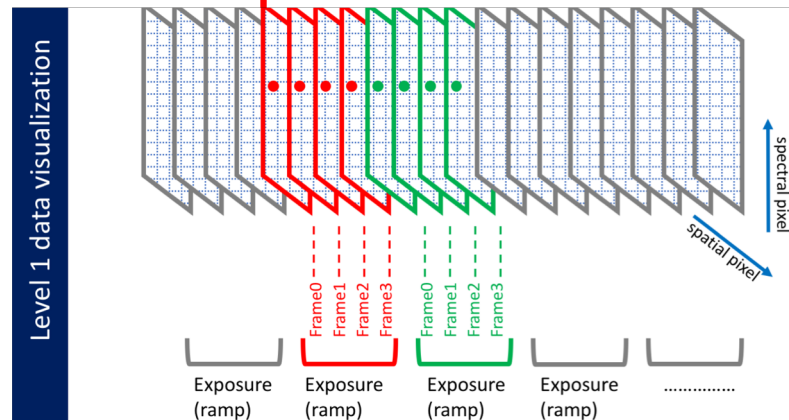
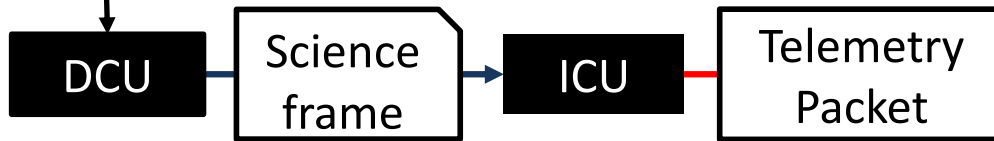


observation

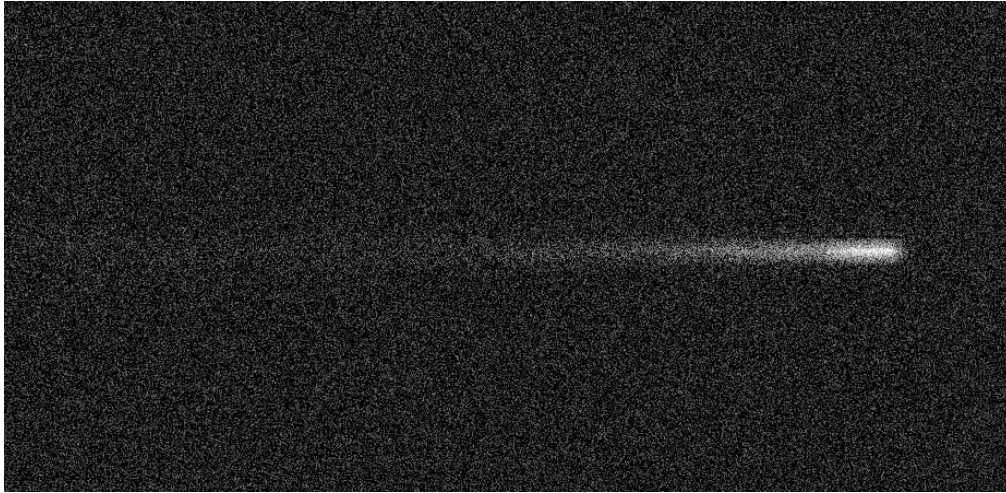
detector signal visualization



observation

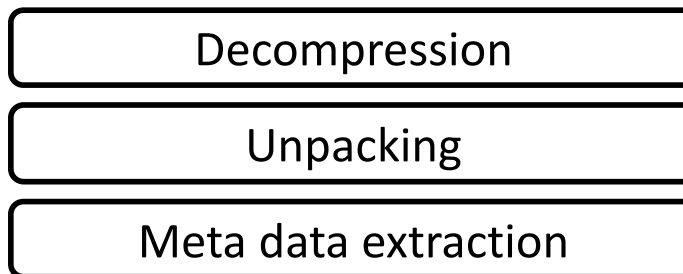


Level 0 Data Product



- Raw compressed data files derived from spacecraft telemetry packets
- Delivered from MOC to SOC

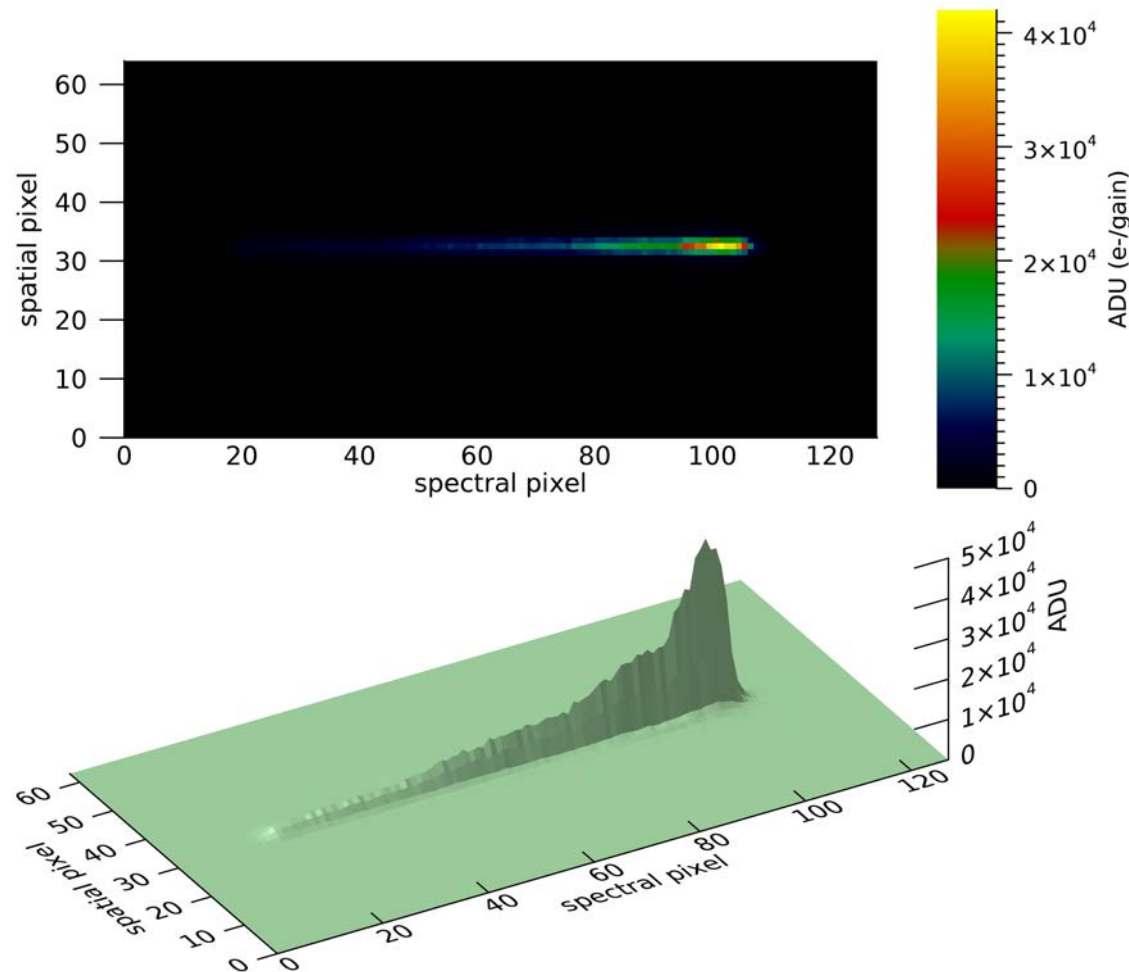
Level 0 > Level 1 Processing



Level 1 Data Product



Unpacked, uncompressed, time-ordered, uncalibrated, meta enriched, data cubes of Target, containing Science Frames for each Exposure taken during an Observation



Spectroscopic Channels: raw data spectral image time stamped 3D cube of which each slice is a Science Frame:

- spatial pixel (pixel number)
- spectral pixel (pixel number)
- integrated signal value in ADU

Photometric Channels: raw data image time stamped 3D cube of which each slice is a Science Frame:

- spatial pixel (pixel number)
- spatial pixel (pixel number)
- Integrated signal value in ADU

Possible representations of one temporal slice (i.e.: one Science Frame) of an ARIEL Data Level 1 data product, for the spectroscopy channel AIRS CHO

Level 1 > Level 1.5 Processing

Level 1

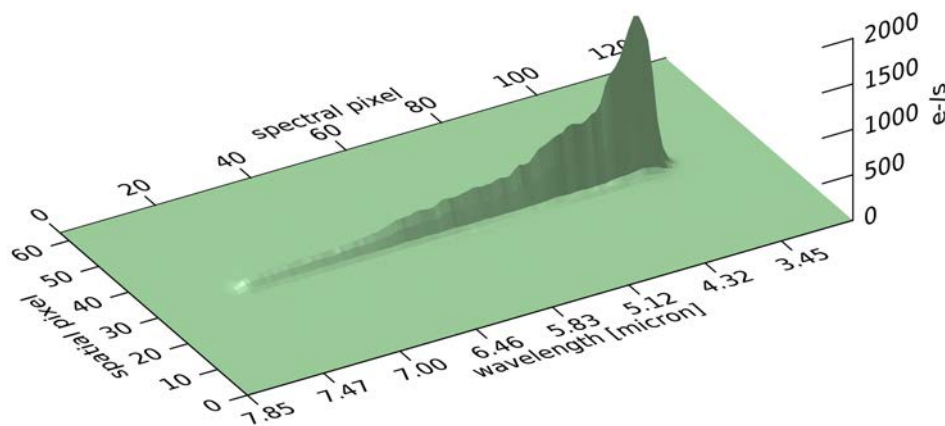
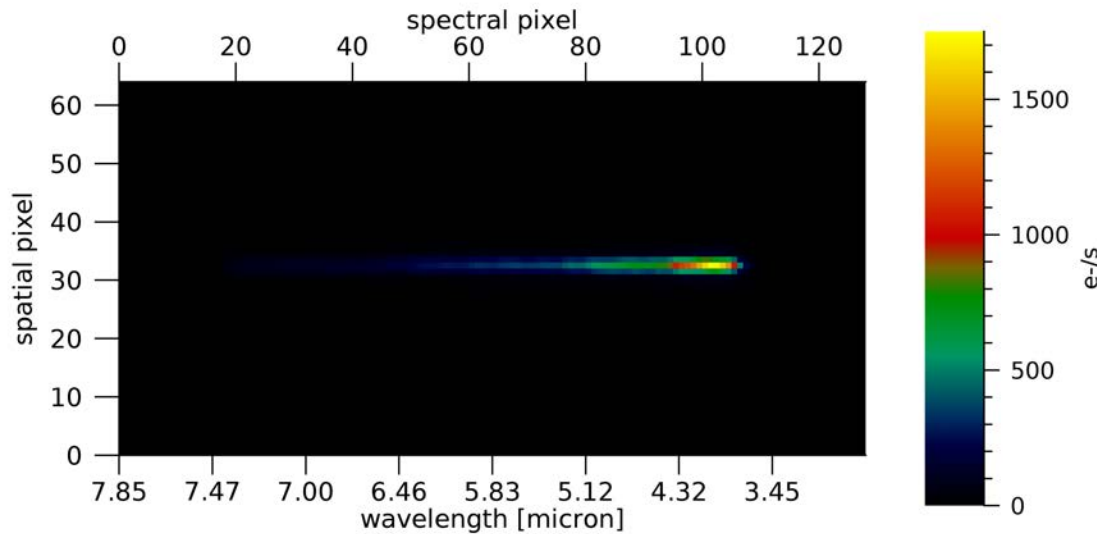
- Flag saturated pixels
- ADU to e⁻ unit conversion
- non-linearity correction
- Pixel cross-talk correction
- Dark current subtraction
- Wavelength assignment
- Flat fielding
- Offset correction
- Persistence correction
- Background subtraction
- e⁻ to e⁻/s unit conversion
- Bad pixel correction
- pointing jitter correction

Level 1.5

Level 1.5 Data Product



Calibrated, background subtracted, instrument artefact corrected, fitted ramps of Exposures of a Target observation



Spectroscopic Channels: time stamped spectral image 3D cube with each slice an array of fitted ramps (slopes):

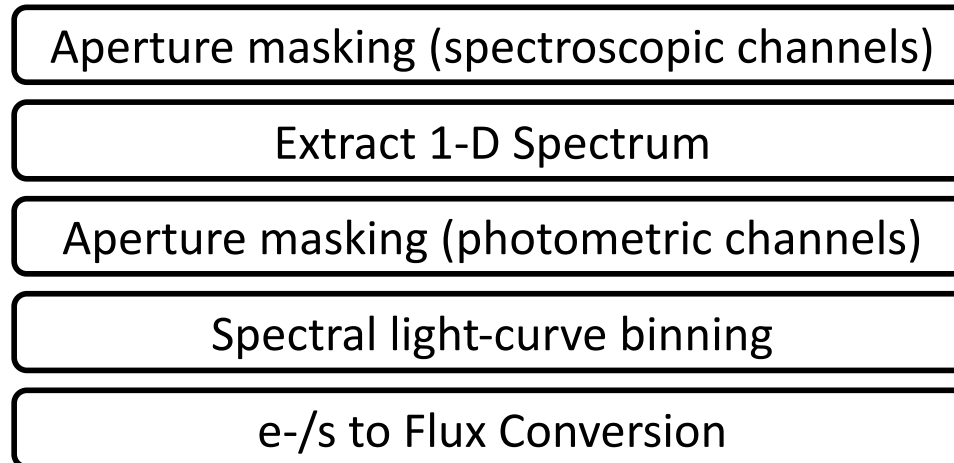
- spectral pixel (microns)
- spatial pixel (pixel number)
- signal (slope) in e^-/s

Photometric Channels: Time stamped image 3D cube of which each slice is an array of fitted ramps:

- spectral pixel (pixel number)
- spatial pixel (pixel number)
- signal (slope) in e^-/s

Possible representations of a single temporal slice (corresponding to a single exposure) of an ARIEL Level 1.5 data Product, for the spectroscopy channel AIRS CH0

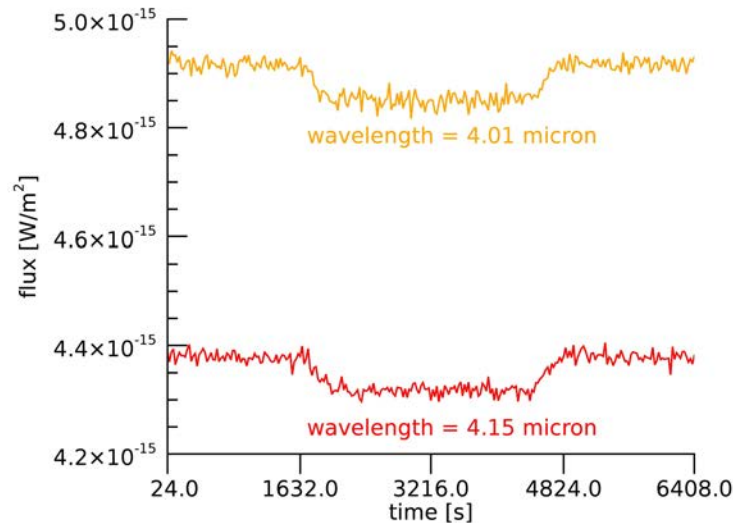
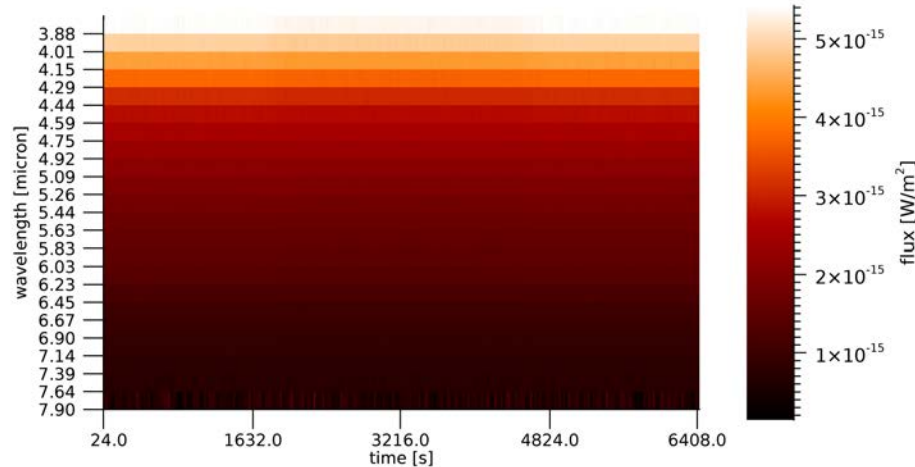
Level 1.5 > Level 2 Processing



Level 2 Data Product



Spectrally resolved light-curves of the Target (star + planet(s))



Spectroscopic Channels: wavelength binned 2D set of light curves of the Target:

- Time axis (s)
- Wavelength axis (microns)
- Flux (W/m^2)

Photometric Channels: One broad-band light curve per channel of the Target:

- Time axis (s)
- Photometric band (FGS1/2 , VisPhot)
- Flux (W/m^2)

Possible representations of ARIEL Data Level 2 for the spectroscopy channel AIRS CH0. The overall Level 2 data array and slices through wavelength to show the measured light curve for selected spectral bins.

Level 2 > Level 3 Processing



Instrumental systematics correction (detrending)

Stellar activity correction 1 (lightcurves)

Lightcurves transit models fitting

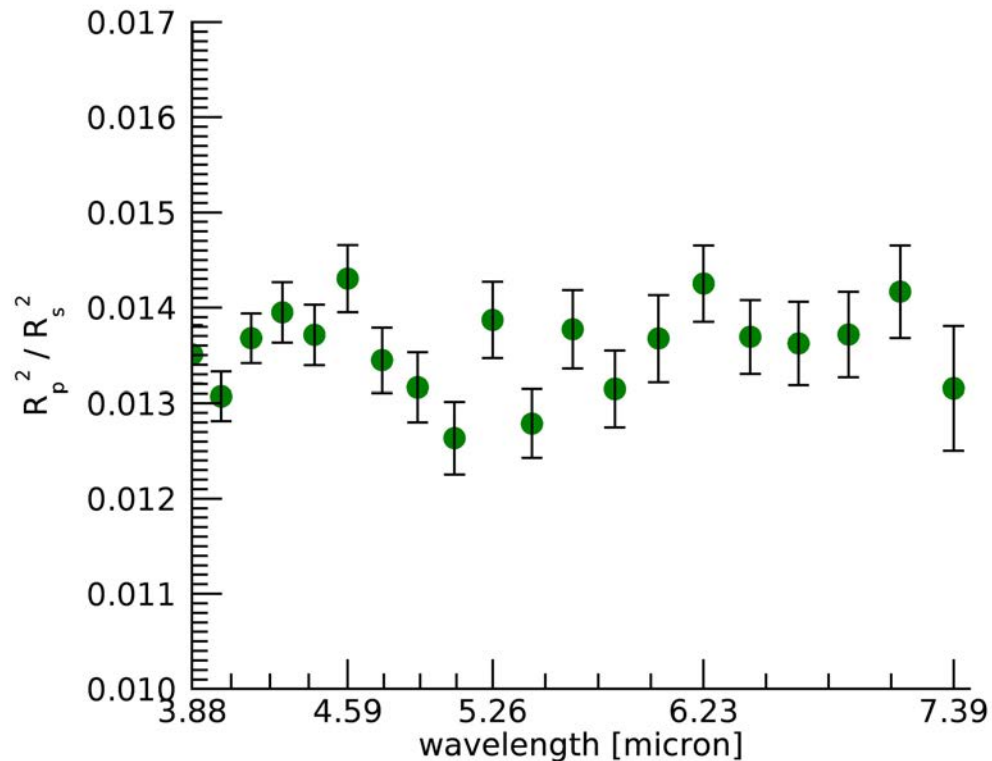
Stellar activity correction 2(spectra)



Level 3 Data Product



Exoplanet broad-band spectra



All Channels (AIRS and VNIR):

- Individual planet(s) spectrum (e.g.: ppm vs wavelength) for each observation with time (s)
- Legacy Co-added planet(s) spectrum (e.g.: ppm vs wavelength) for all observations
- stellar properties

Possible representations of ARIEL Data Level 3 showing exoplanet spectrum with wavelength.

ARIEL Mission Phases



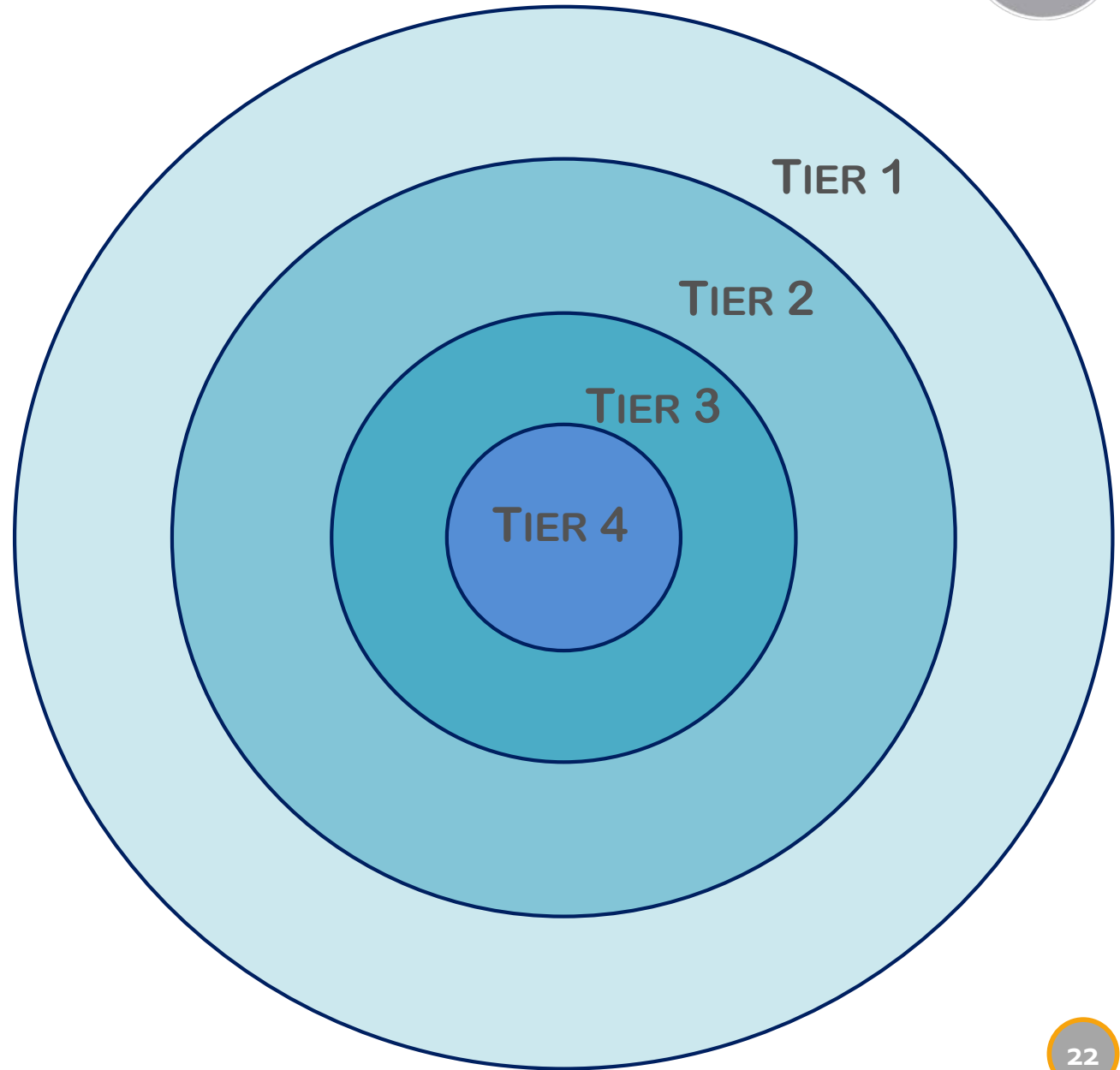
ARIEL nominal mission lifetime 4 years

All observations reprocessed in 6 month intervals by automatic pipeline

month	launch-6	>6	>12	>18	>24	>30	>36	>42	48
	Early	cycle1	cycle2	cycle3	cycle4	cycle5	cycle6	cycle7	End

month	1	2	3	4	5	6
launch	Commissioning			Performance Verification (PV)		Science Demonstration

ARIEL Survey and Data Products

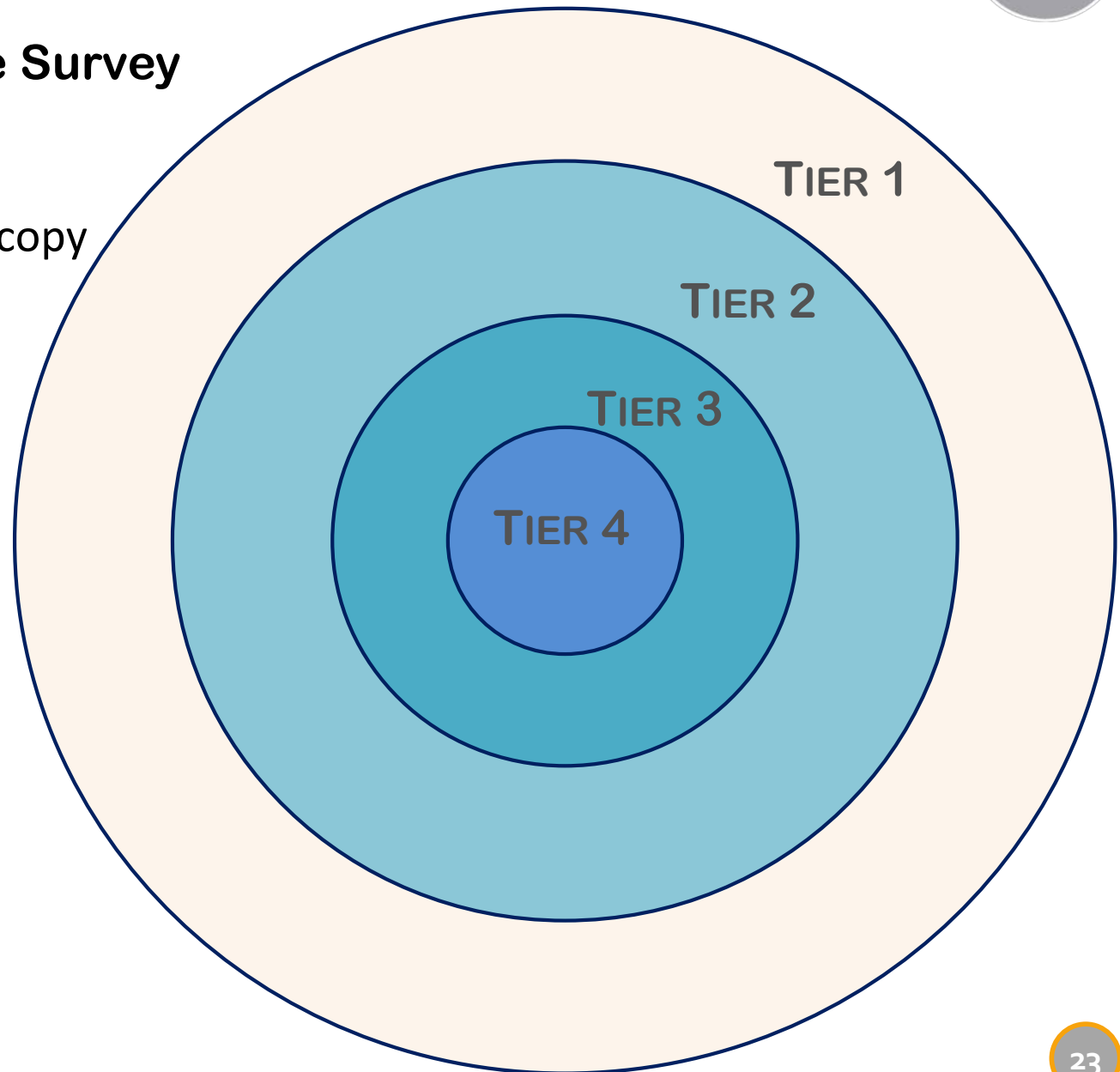


ARIEL Survey and Data Products



Tier 1 Reconnaissance Survey

- ~1000+ targets
- Low resolution spectroscopy (5+ spectral elements)
- S/N >7
- All Planets in sample
- Transit or eclipse

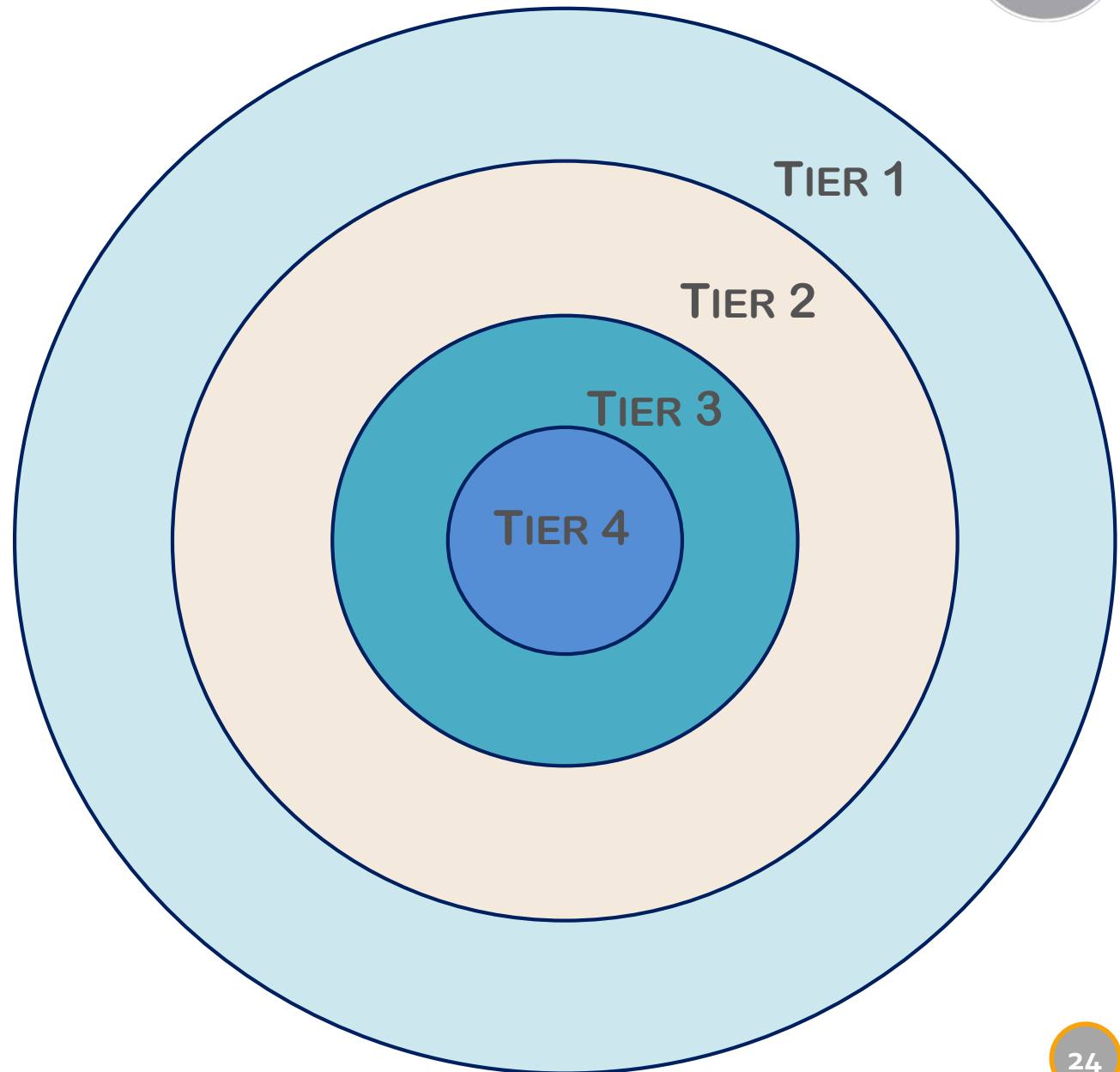


ARIEL Survey and Data Products



Tier 2 Deep Survey

- ~500 + targets
- $R \sim 10$ for $1.10 < \lambda < 1.90 \mu\text{m}$
- $R \sim 50$ for $1.95 < \lambda < 3.90 \mu\text{m}$
- $R \sim 15$ for $3.90 < \lambda < 7.80 \mu\text{m}$
- $S/N > 7$
- Transit and/or eclipse

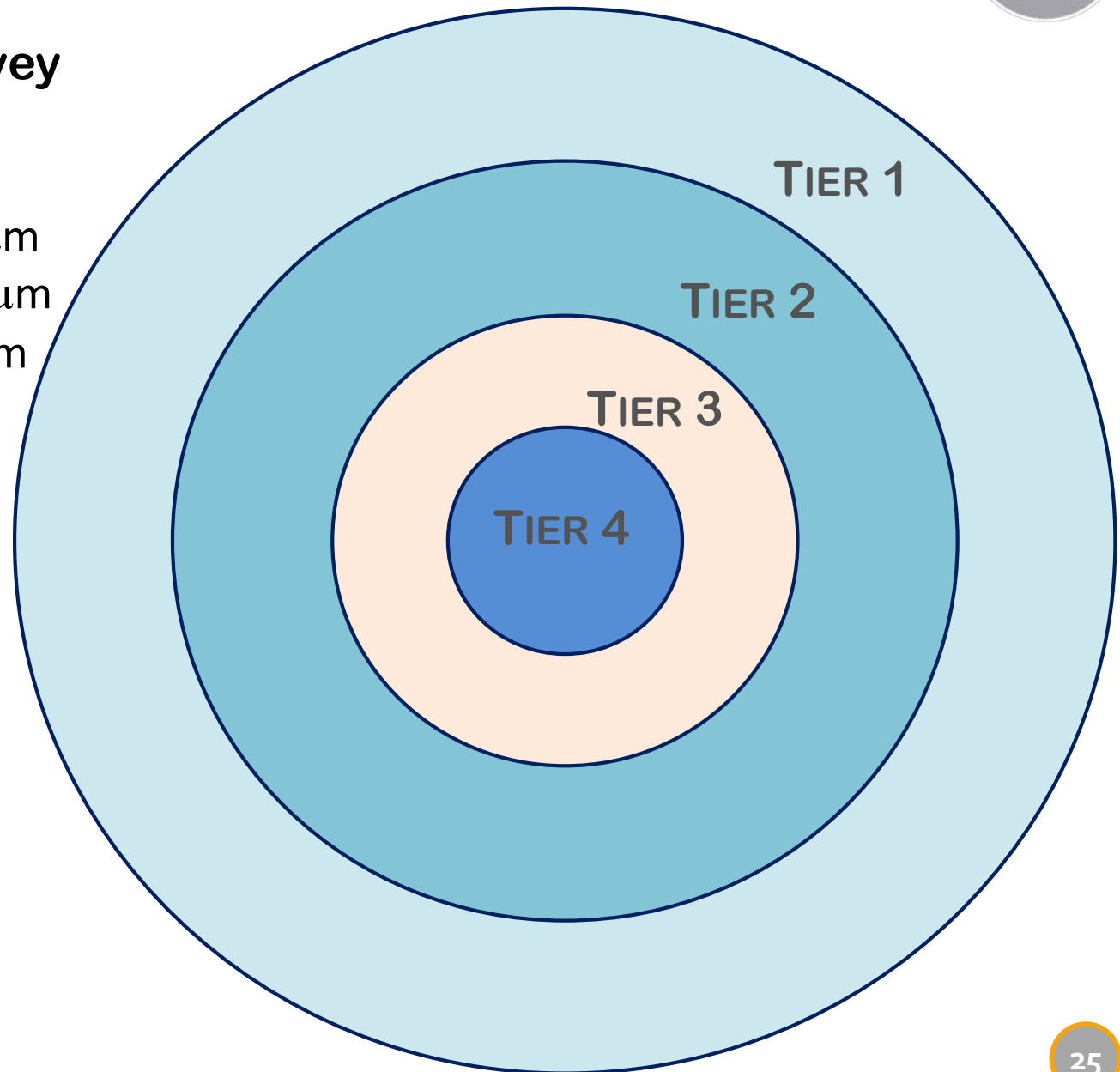


ARIEL Survey and Data Products



Tier 3 Benchmark Survey

- 50 + targets
- $R \sim 15$ for $1.10 < \lambda < 1.90 \mu\text{m}$
- $R \sim 100$ for $1.95 < \lambda < 3.90 \mu\text{m}$
- $R \sim 30$ for $3.90 < \lambda < 7.80 \mu\text{m}$
- $S/N > 7$
achievable in 1-2 obs
- Transit or eclipse
repeated in time

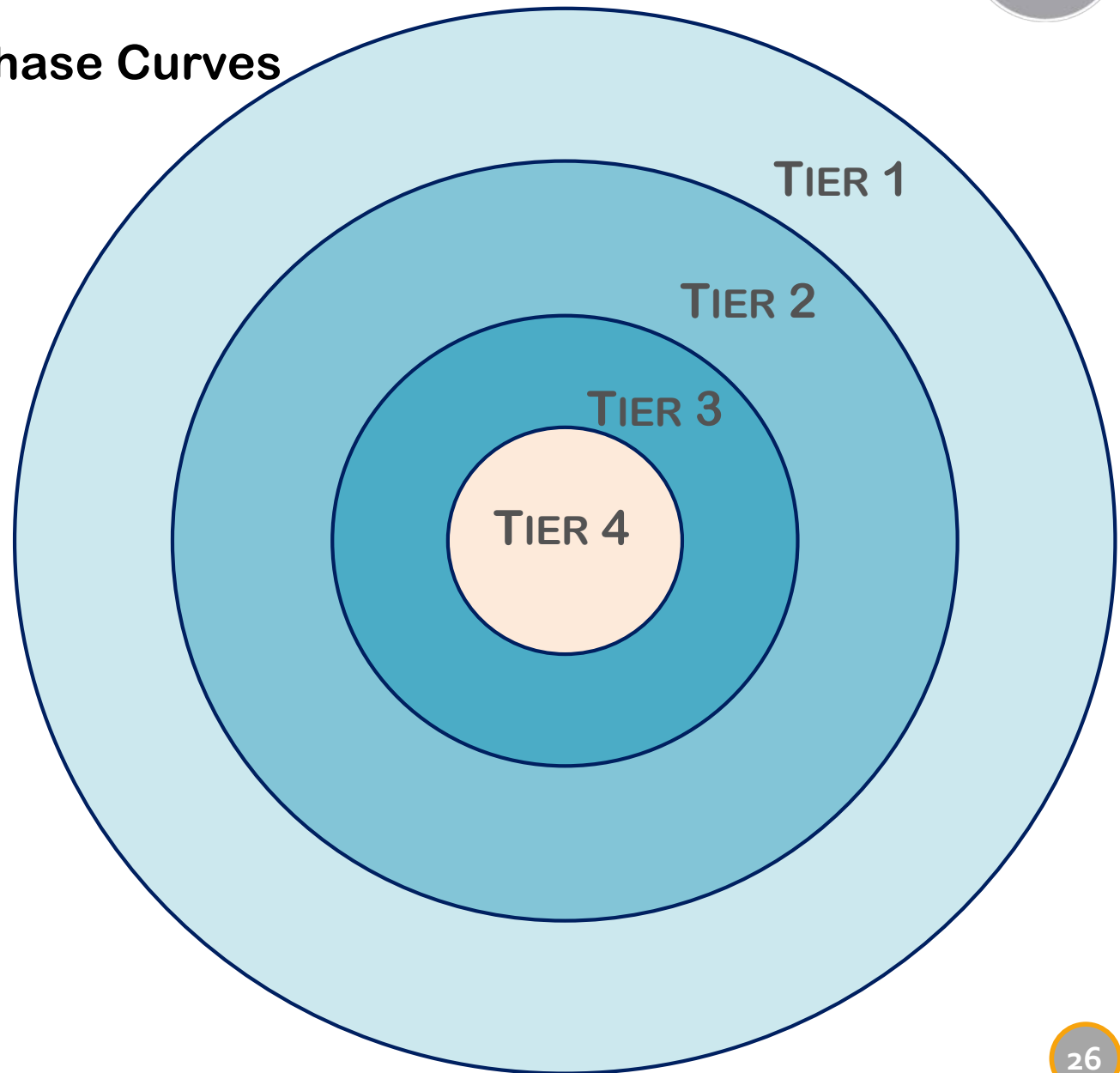


ARIEL Survey and Data Products



Tier 4 Bespoke obs / Phase Curves

- 10 + targets
- Phase-curves
- eclipse mapping
- bespoke observations
- photometry/spectroscopy
- SNR ≥ 7



ARIEL Survey and Data Products



Estimated data volumes for Data Level Products and HK Data over mission lifetime.
 After 4 years of mission, plus final reprocessing 6 months after the end of nominal life.
 Expected data volume budgets is ≈ 74 TBytes

Data Level	Overall Data Archive Volume (TB) along ARIEL Mission lifetime								
	after 0.5 years	after 1.0 years	after 1.5 years	after 2.0 years	after 2.5 years	after 3.0 years	after 3.5 years	after 4.0 years	after 4.5 years
Level 0	0.77	1.54	2.31	3.08	3.85	4.61	5.38	6.15	6.92
Level 1	1.54	3.08	4.61	6.15	7.69	9.23	10.77	12.30	13.84
Level 1.5	1.15	3.46	6.92	11.54	17.30	24.22	32.30	41.53	51.91
Level 2	0.02	0.07	0.14	0.23	0.35	0.48	0.65	0.83	1.04
Level 3	2×10^{-5}	6×10^{-5}	1×10^{-4}	2×10^{-4}	3×10^{-4}	4×10^{-4}	5×10^{-4}	7×10^{-4}	9×10^{-4}
HK	5×10^{-3}	9×10^{-3}	1×10^{-2}	2×10^{-2}	2×10^{-2}	3×10^{-2}	3×10^{-2}	4×10^{-2}	4×10^{-2}
Total	3.49	8.15	13.99	21.01	29.21	38.58	49.13	60.85	73.75

ARIEL Survey and Data Products



- Data processing up to Level 2 and archive ingestion done continuously throughout the mission.
- All data will be released after processing, consolidation and quality control are completed, approximately 1-2 months after the last required observation is taken
- All data products will be accessed from the ARIEL Science Archive @SOC (ESA) via web interface
- A fraction of Tier 2 or 3 data, will be observed and Level 2 products released as part of the Science Demonstration Phase.
- The data release up to Level 2 products during the routine mission phase is envisioned as:
 - Tier 1 data public immediately after quality control is completed;
 - Tier 2 data public 6 months after quality control is completed;
 - Tier 3 data public 6 months after quality control is completed;
 - Tier 4 data public 1 year after quality control is completed.
- Level 3 science products will be made public after their publication in peer review journals



ARIEL 2028

Enabling planetary science across light-years

