



The European Southern Observatory



Paolo Padovani

ESO, Garching bei München, ELT Science Office

- Introduction to ESO and its facilities
- ESO instrumentation
- ESO archive(s)
- Some (selected!) science results



European Southern Observatory

■ Mission

- Develop and operate world-class observing facilities for astronomical research
- Organize collaborations in astronomy (e.g., with ESA and CERN)

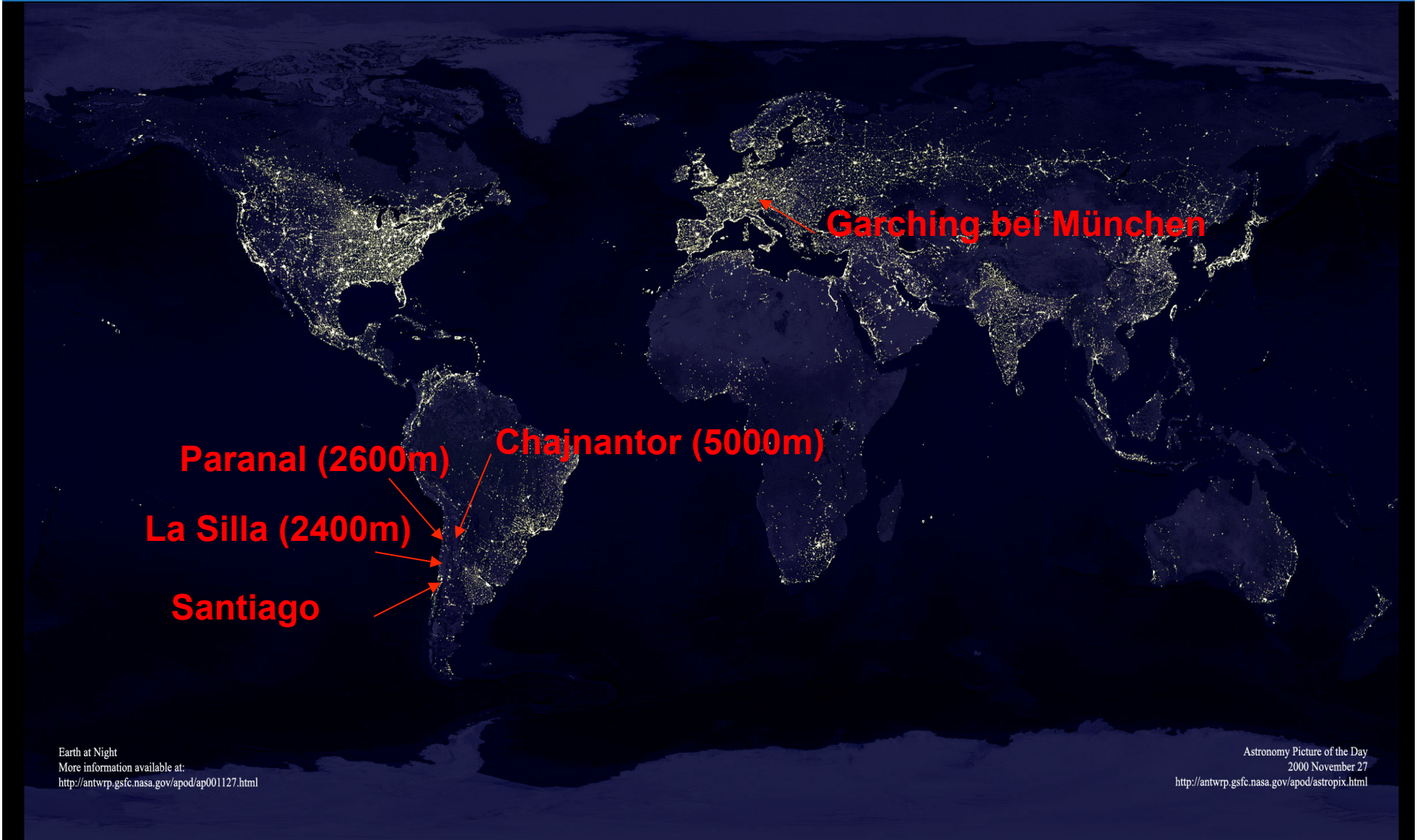
■ Intergovernmental treaty-level organization

- Founded in 1962 by 5 countries
- Today 15 member states (Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Italy, The Netherlands, Poland, **Portugal**, Spain, Sweden, Switzerland, United Kingdom + Chile + Australia [10-year partner]) and ~ 680 employees
- Observatories in Chile:
 - [La Silla](#) + Paranal: [3.6m](#), [NTT \(3.6m\)](#), VLT (8.2m), VLTI, VISTA (4.1m), VST (2.6m) [optical/near-IR]
 - Chajnantor: APEX and ALMA partnerships [mm]
 - *Paranal/Armazones: Cherenkov Telescope Array (CTA)-South [gamma-ray]*
 - *Armazones: Extremely Large Telescope (ELT) [optical/mid-IR]*

■ Headquarters in Garching and Office in Santiago



ESO



Earth at Night
More information available at:
<http://antwrp.gsfc.nasa.gov/apod/ap001127.html>

Astronomy Picture of the Day
2000 November 27
<http://antwrp.gsfc.nasa.gov/apod/astropix.html>





ESO

Observatories La Silla and Paranal in operation

8 Telescopes, plus 4 telescopes for interferometry

APEX in operation on Chajnantor

Atacama Large Millimeter Array (ALMA)

Public data archive

Extremely Large Telescope (ELT) under construction

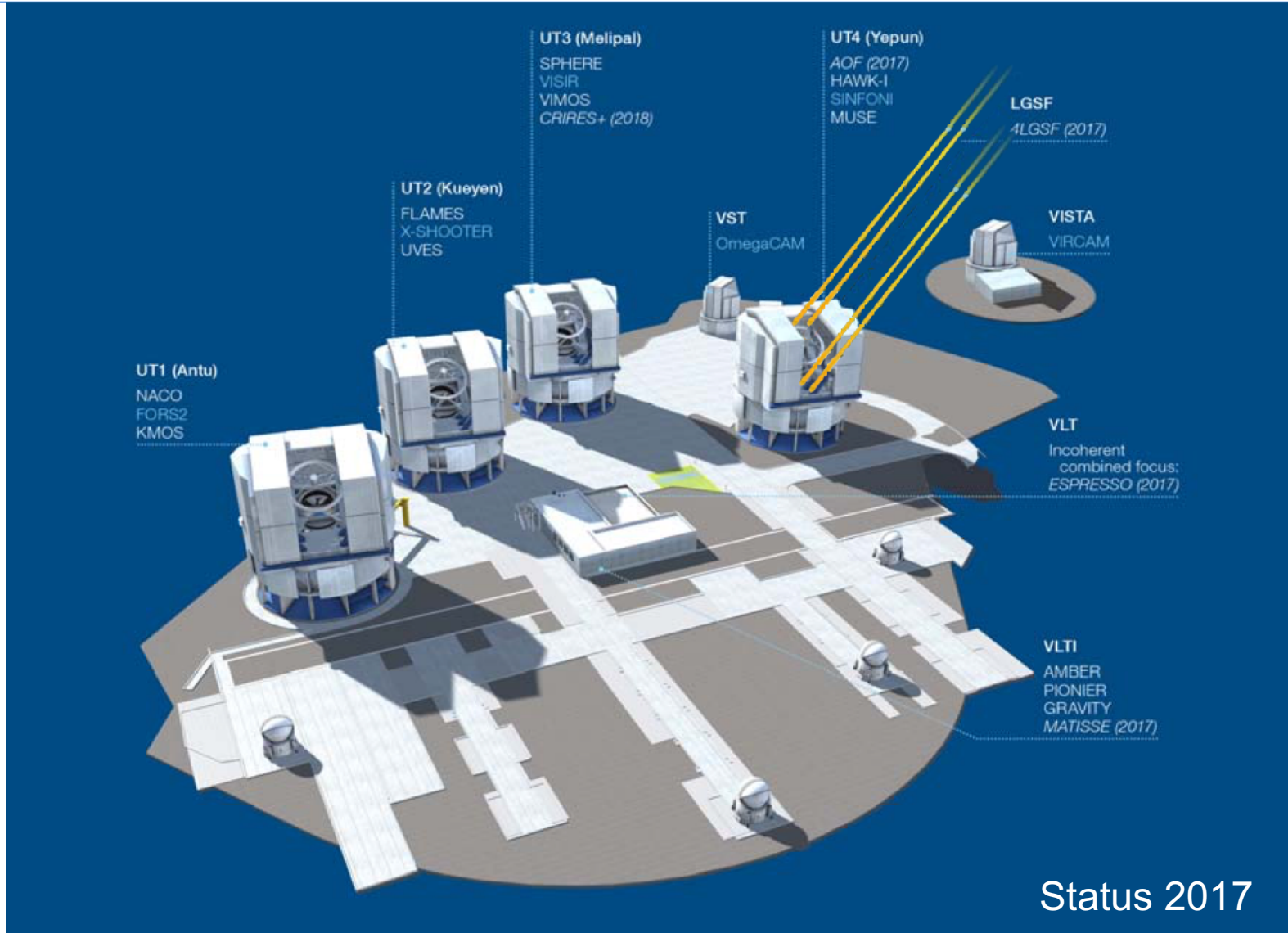
Headquarters in Garching, Germany

Representation in Santiago de Chile

Joint ALMA Office in Santiago

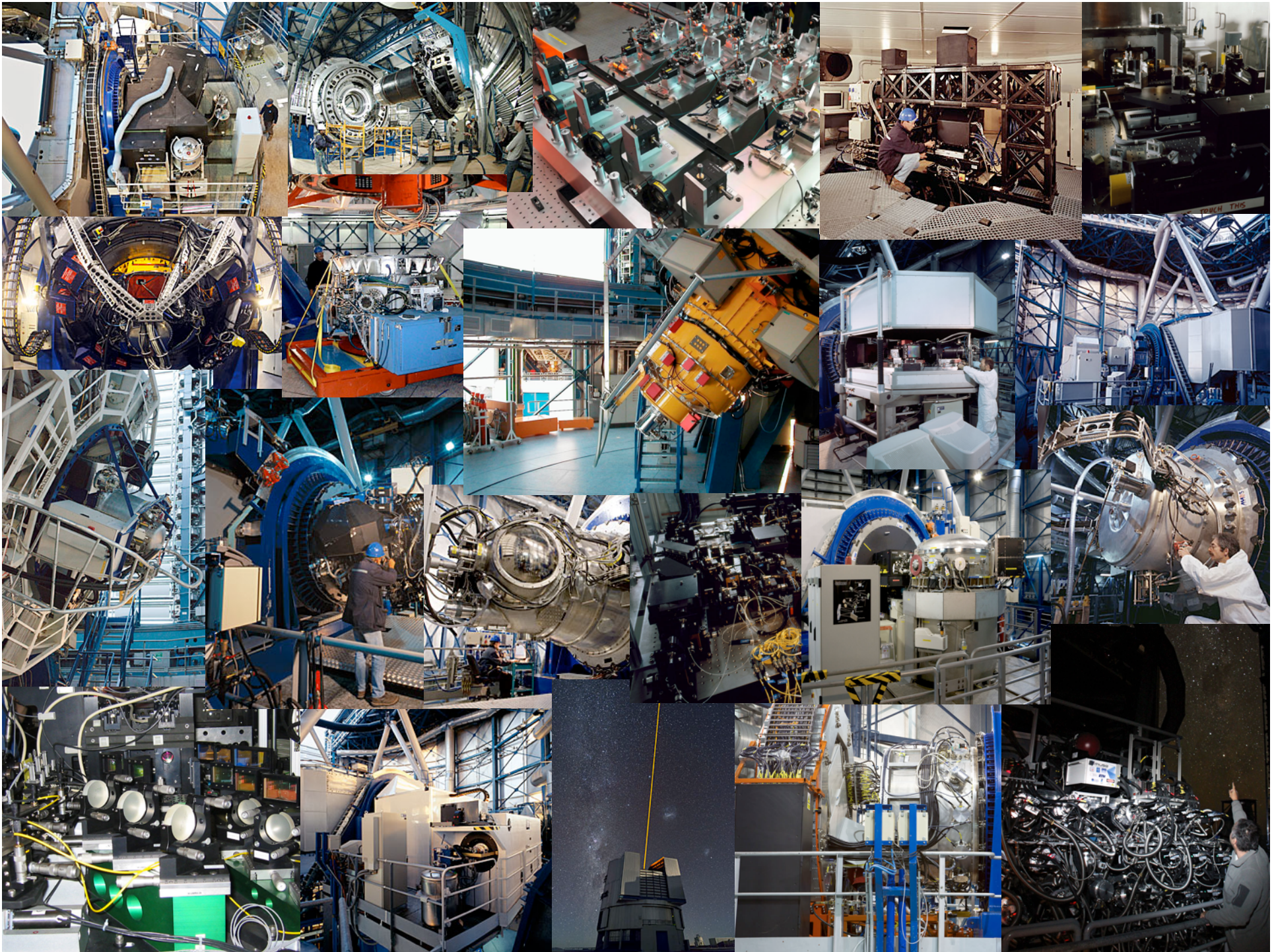


Paranal 2017



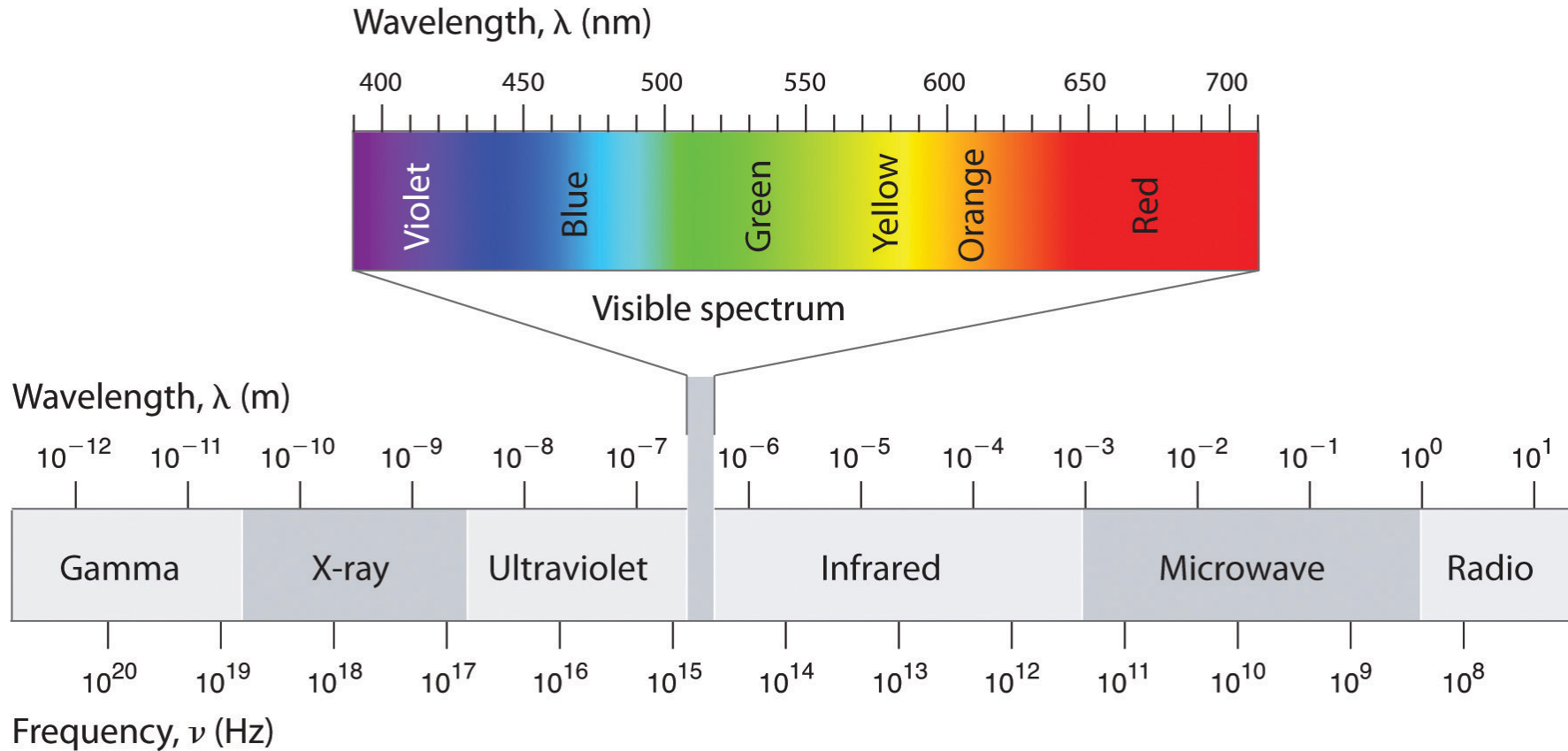
Status 2017







Wavelength range



Wien's law (black bodies)

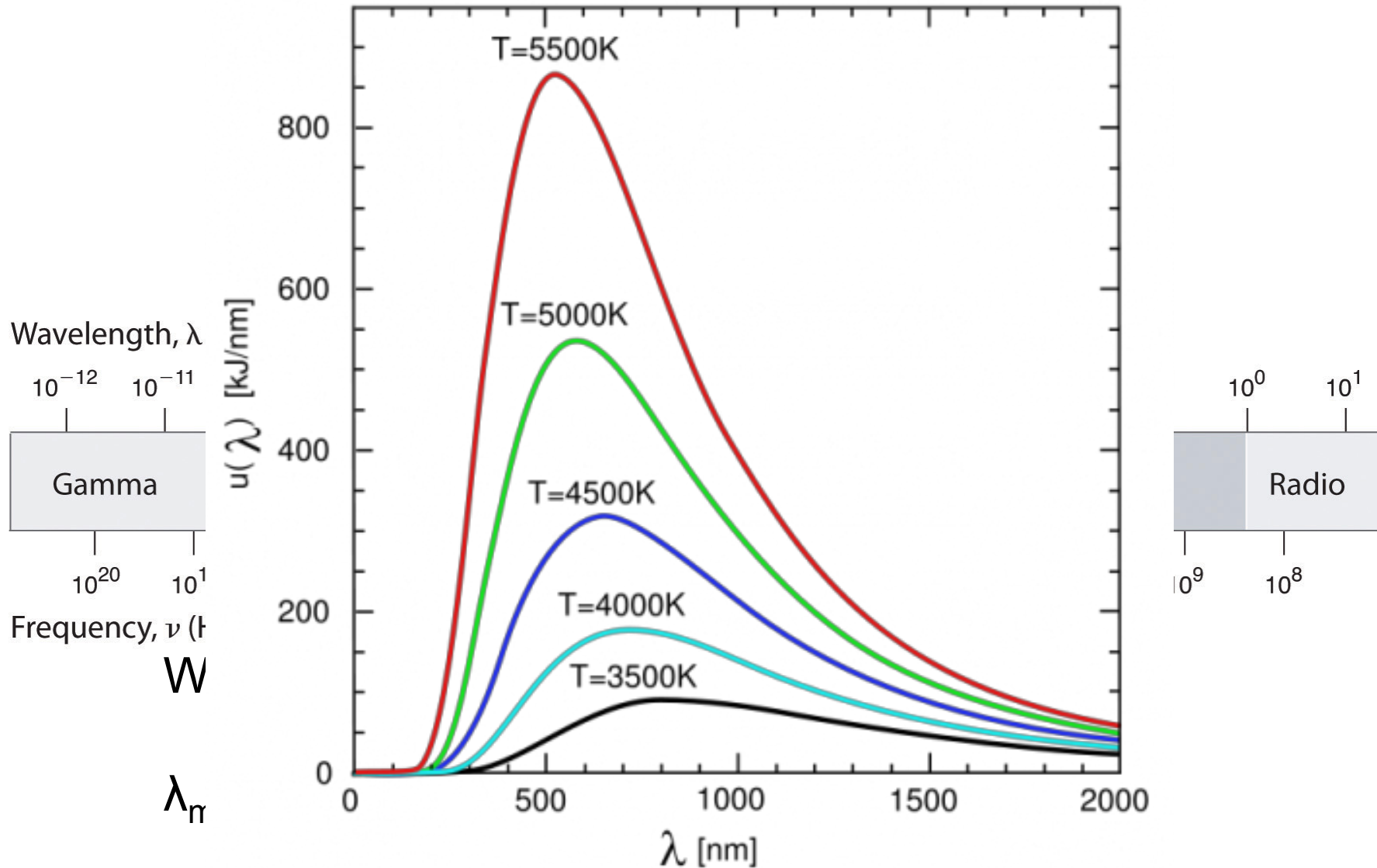
$$\lambda_{\max} = \frac{2.910^6 \text{ nm}}{T(\text{K})}$$

$$\rightarrow T = \frac{2.910^6 \text{ K}}{\lambda_{\max}(\text{nm})}$$

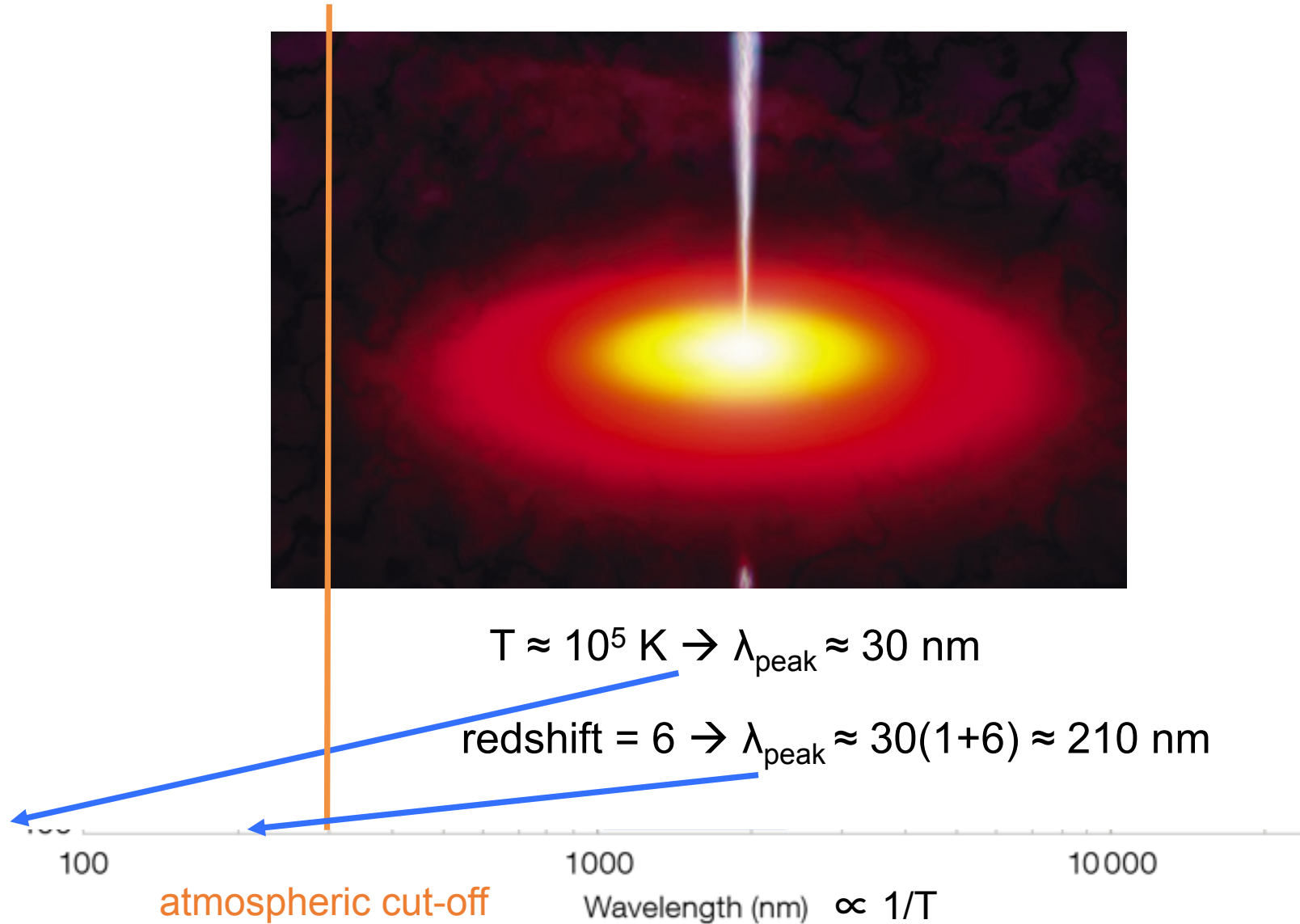




Wavelength range



Spectra and physics: quasars



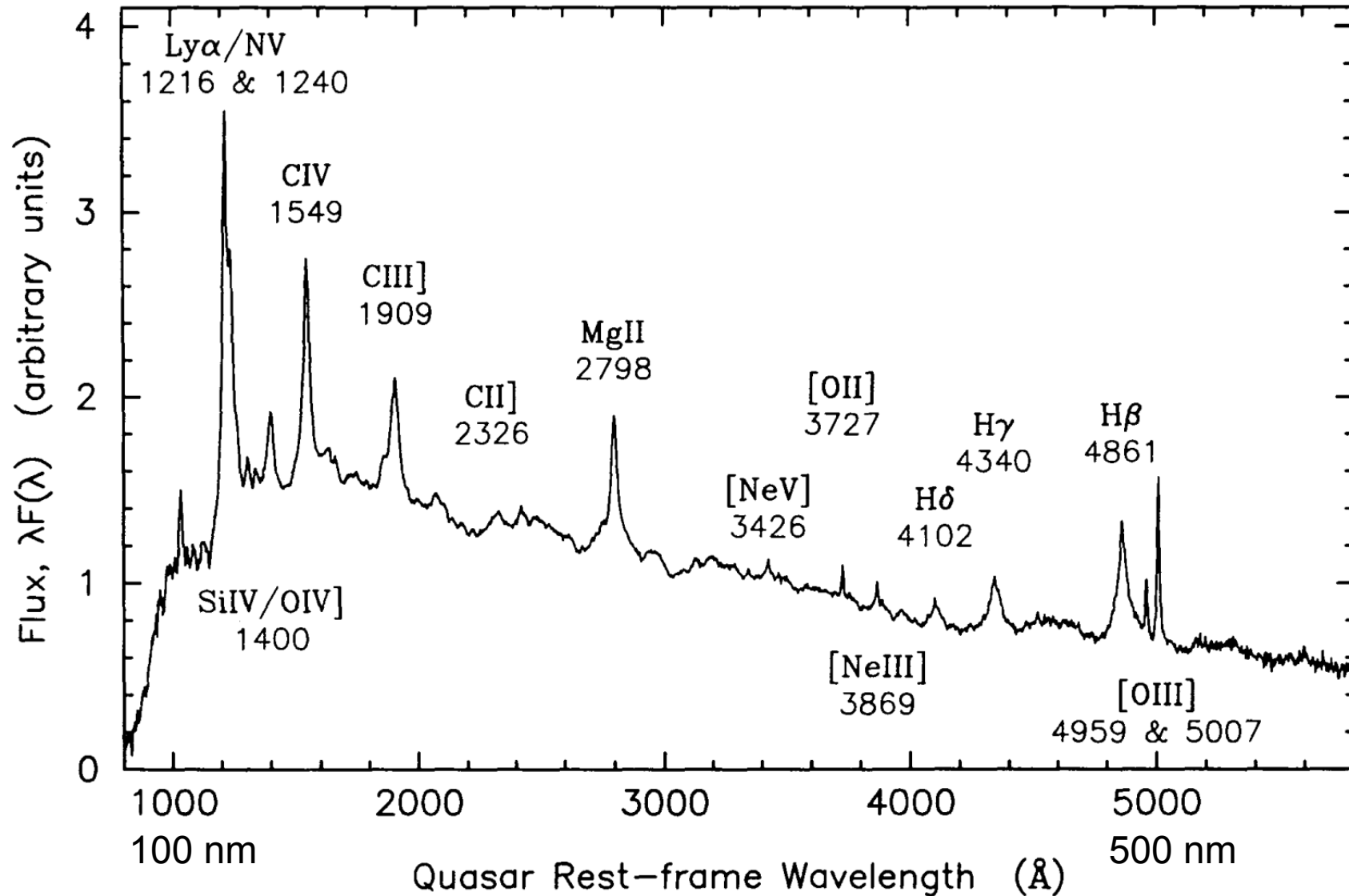
Spectra and physics: quasar dust



$$T \approx 100 - 1,000 \text{ K} \rightarrow \lambda_{\text{peak}} \approx 3,000 - 30,000 \text{ nm}$$

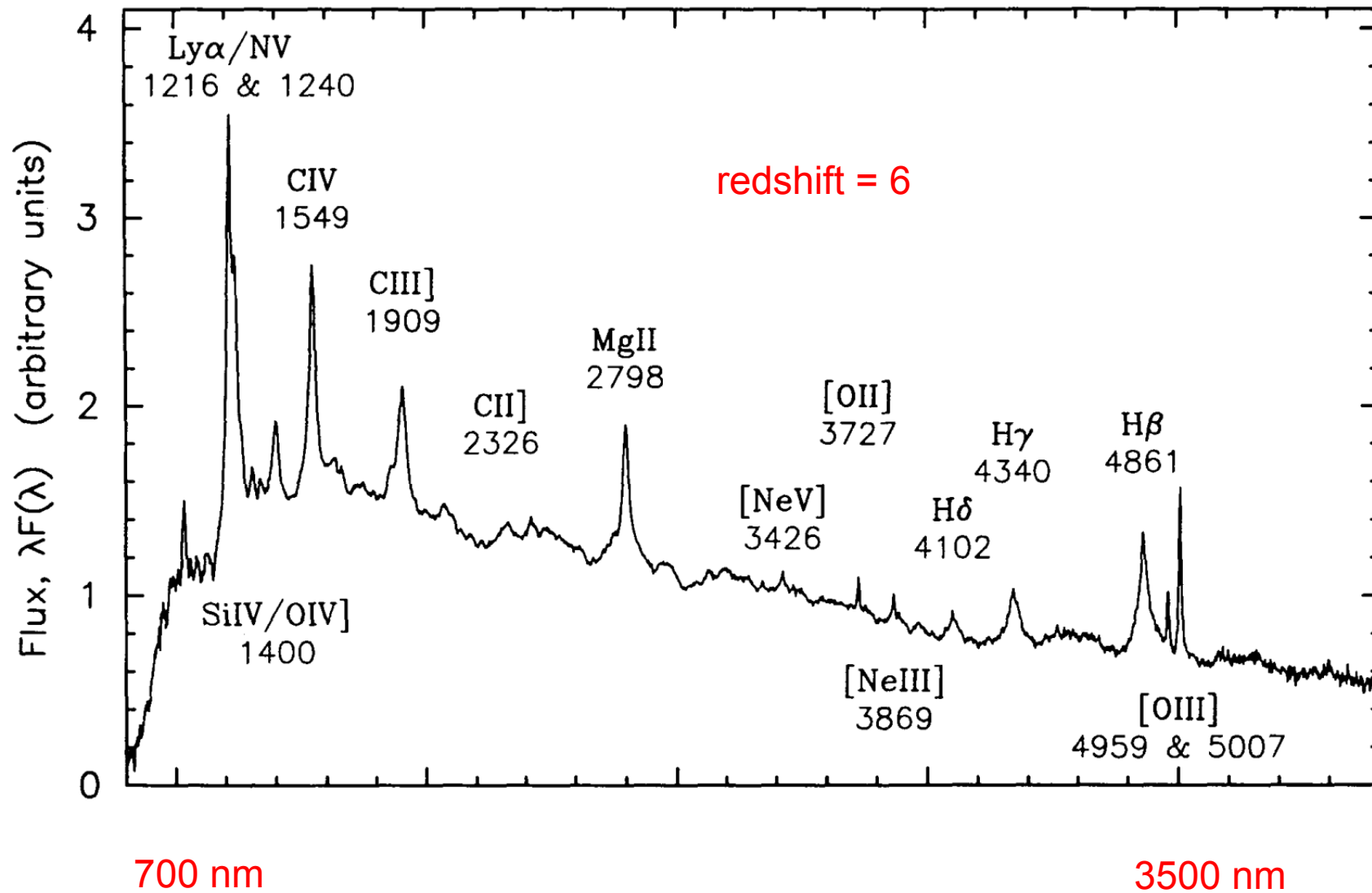


Spectra and physics: emission lines



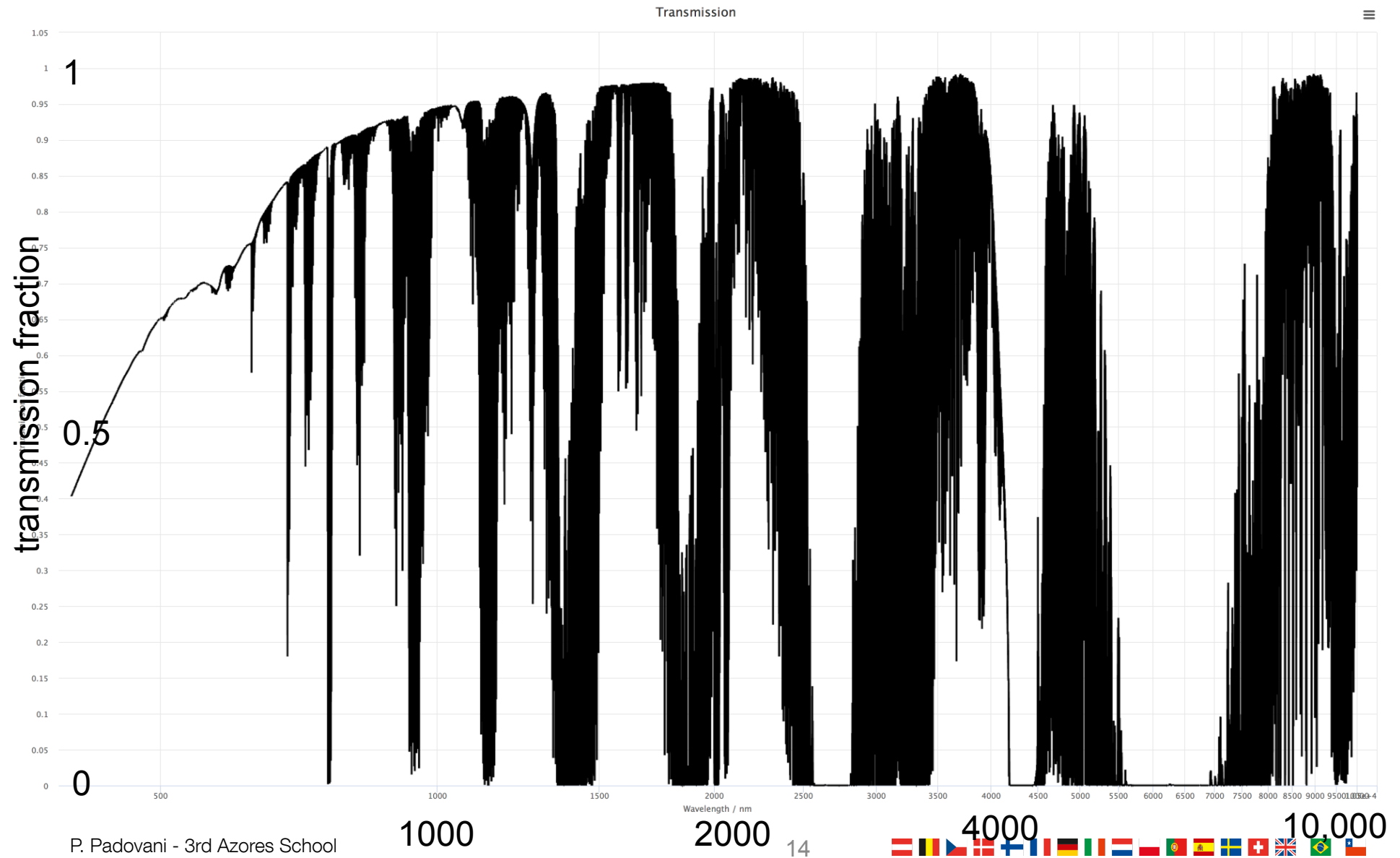


Spectra and physics: redshifted emission lines



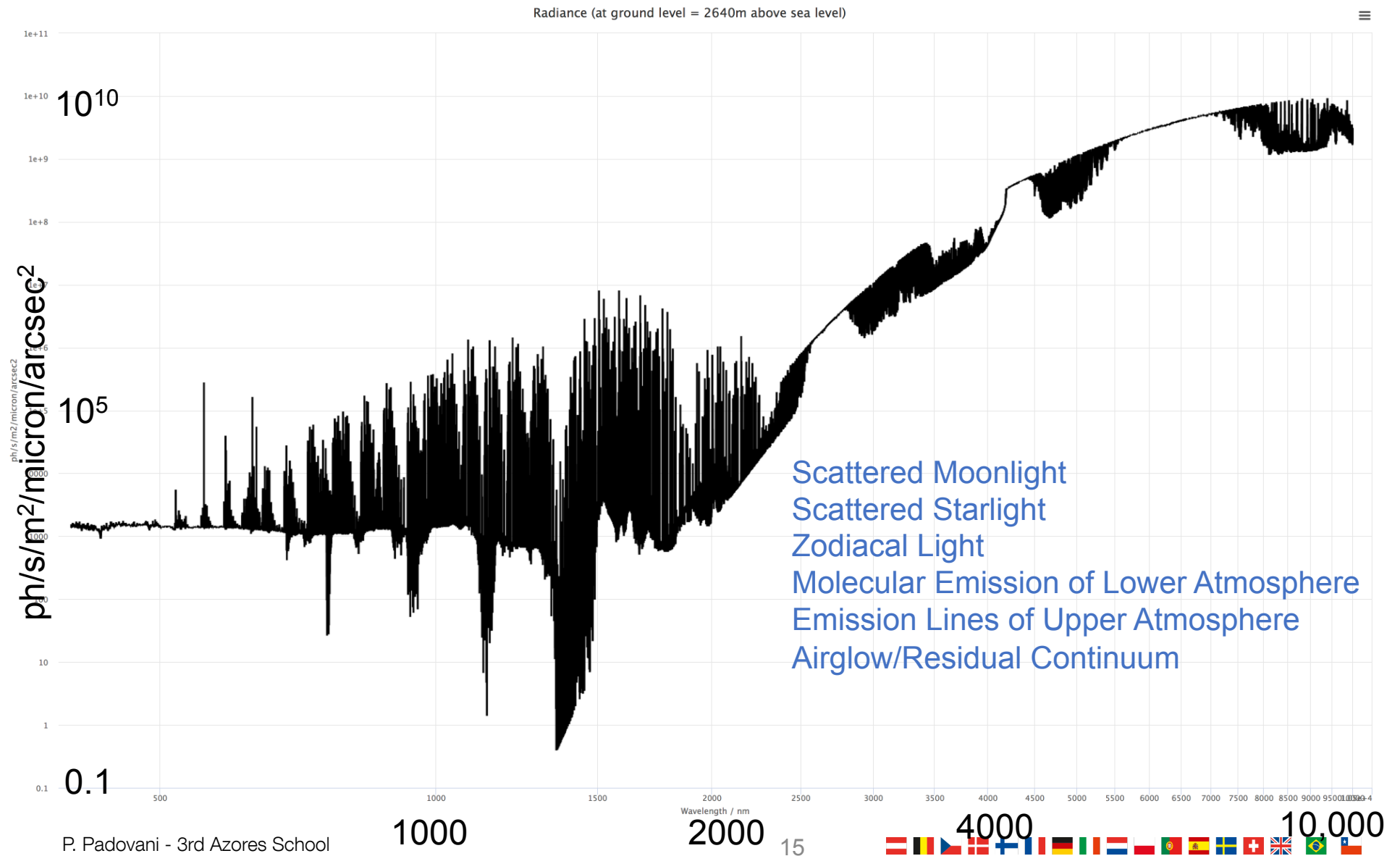


The effect of the atmosphere: transmission



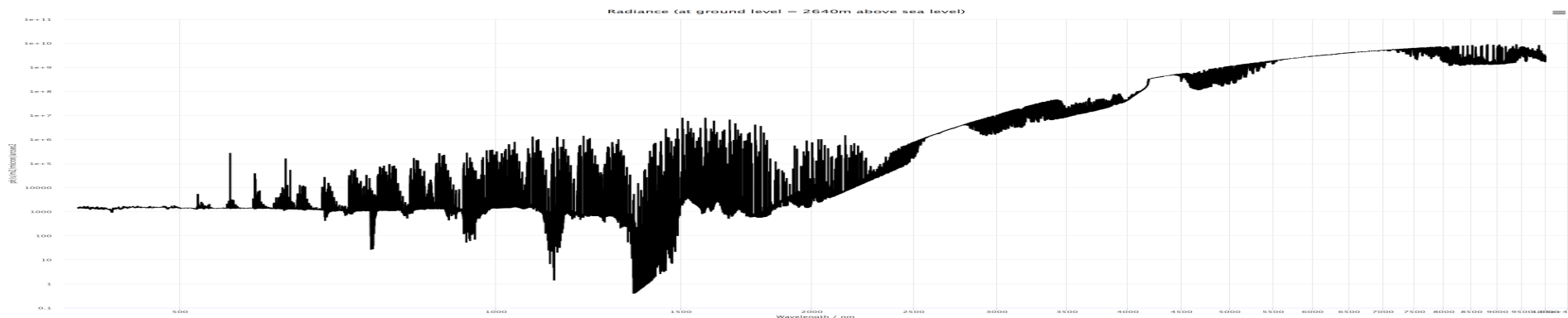
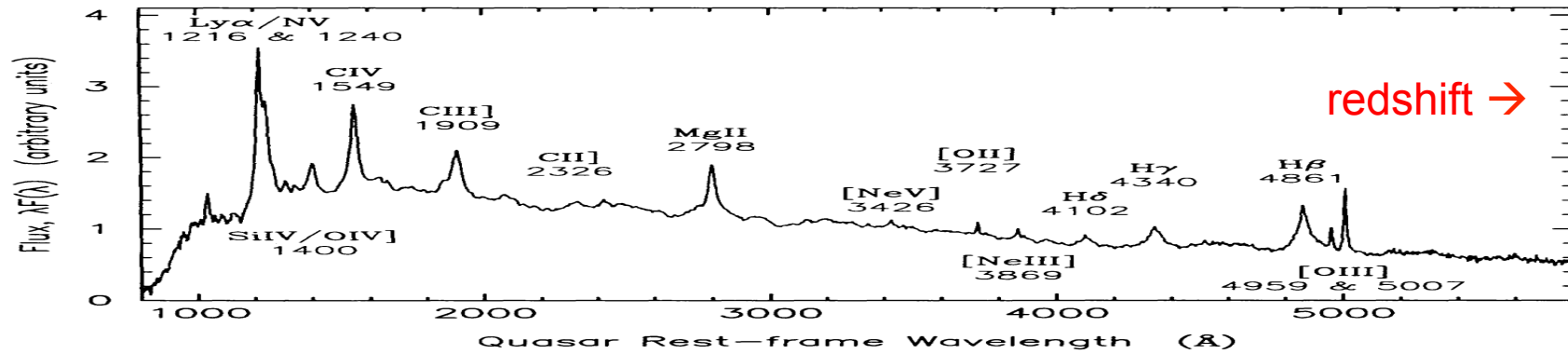


The effect of the atmosphere: emission





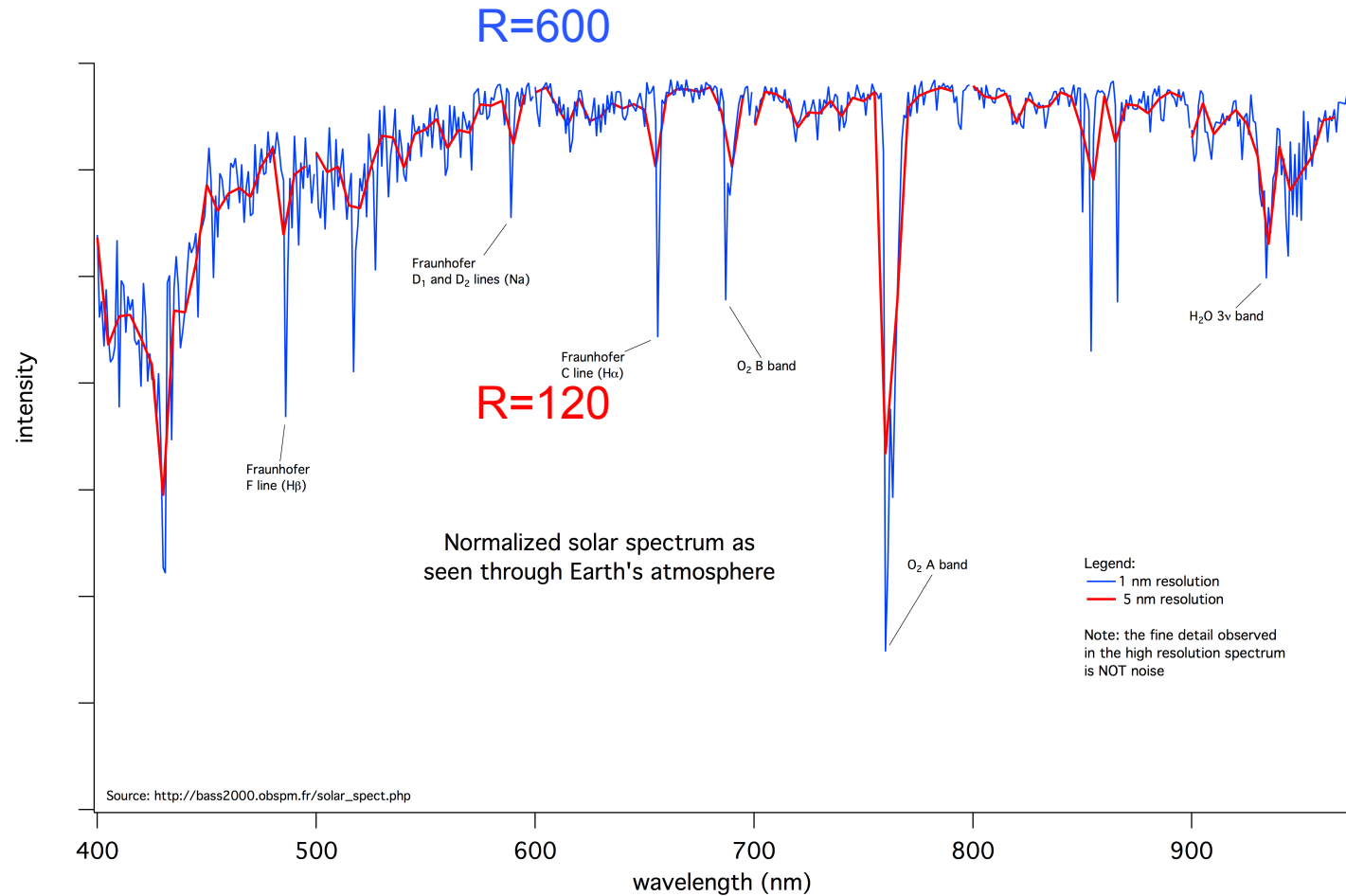
Physics and atmosphere





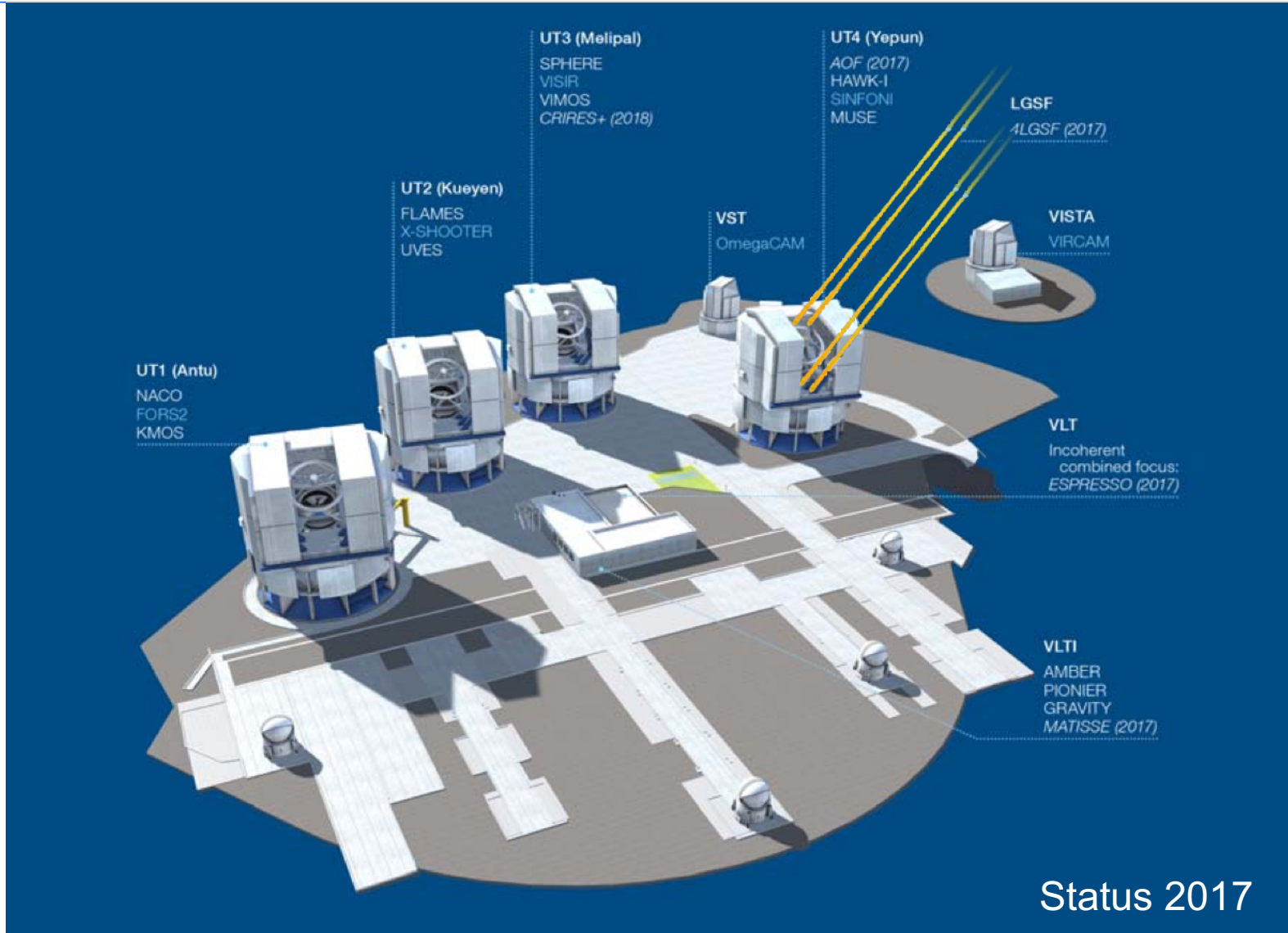
Spectra: resolving power

$$R = \lambda / \Delta\lambda$$





Paranal 2017

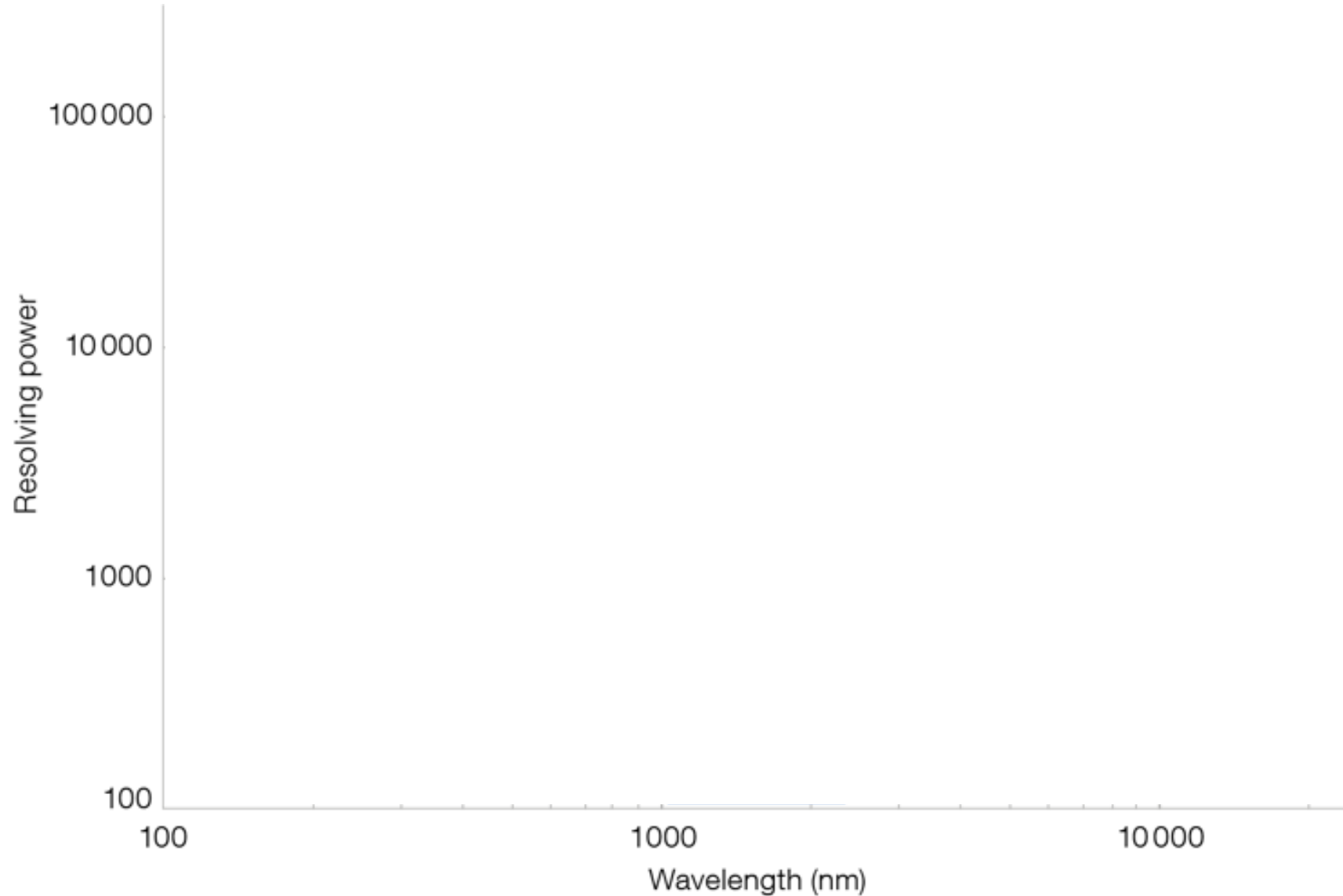


Status 2017





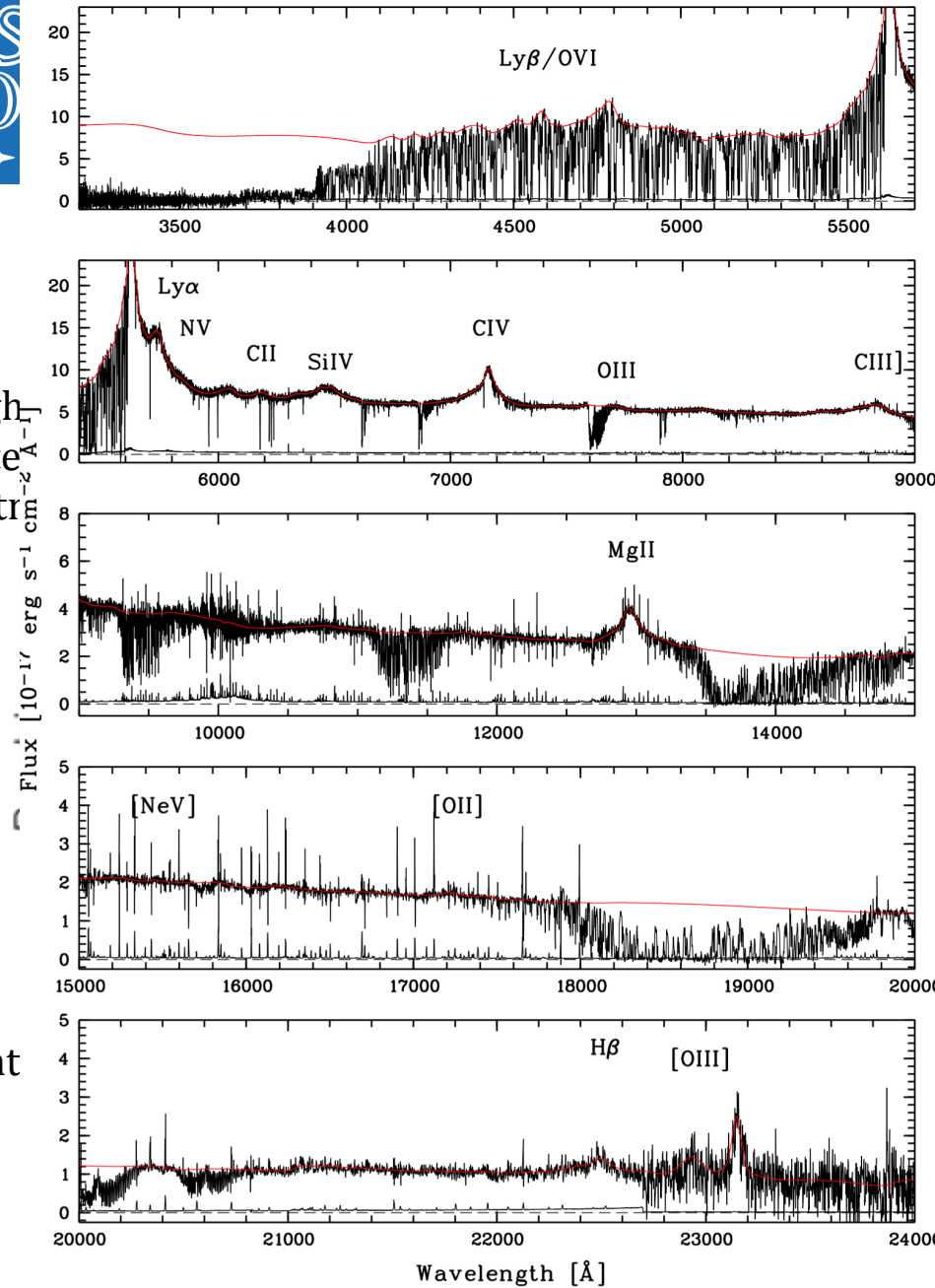
Resolving power and wavelength



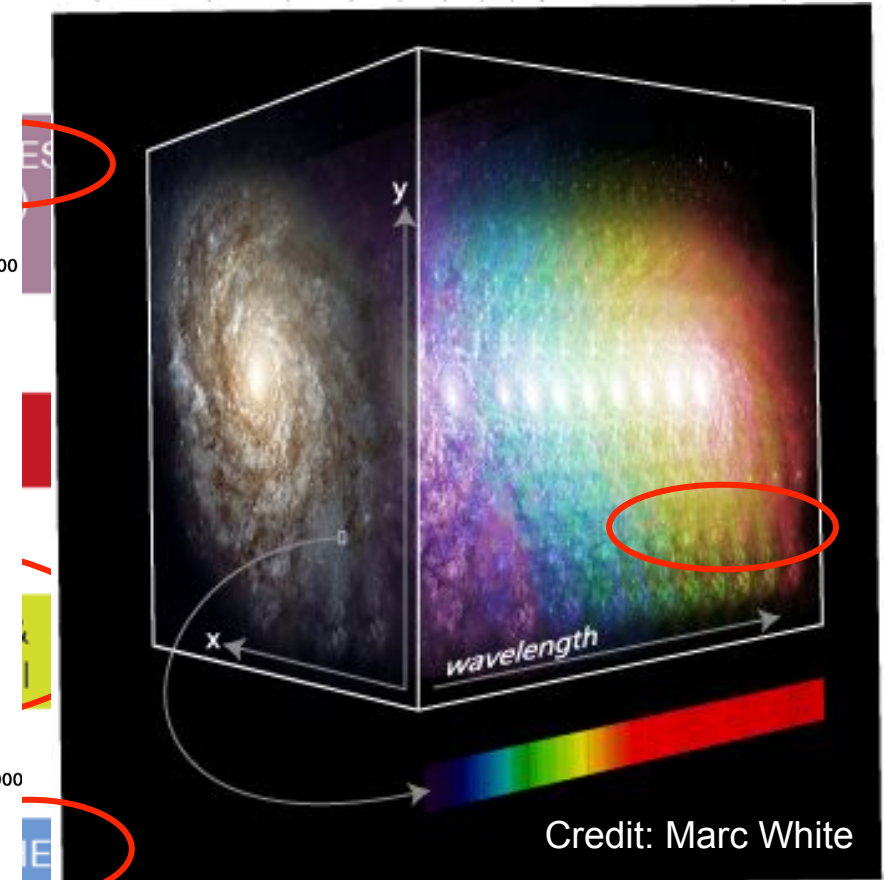


VL T spectrographs

bright
bette
subtr



faint



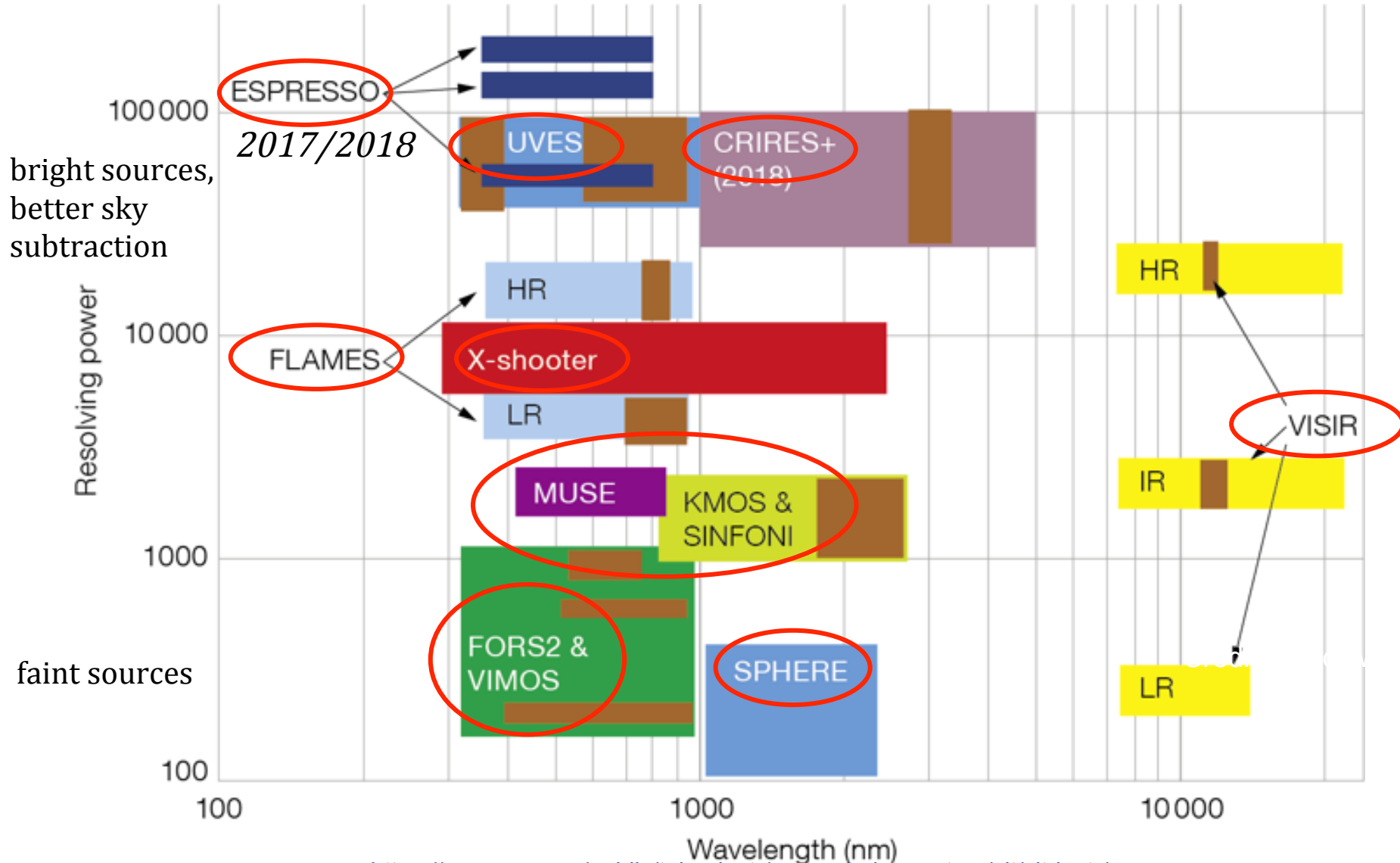
Wavelength (nm)
www.eso.org/observatory/vlt/vlt-instr/

P. Fig. 4. XQ-100 spectrum of QSO J1117+1311 at $z = 3.622$, a representative case of the whole sample





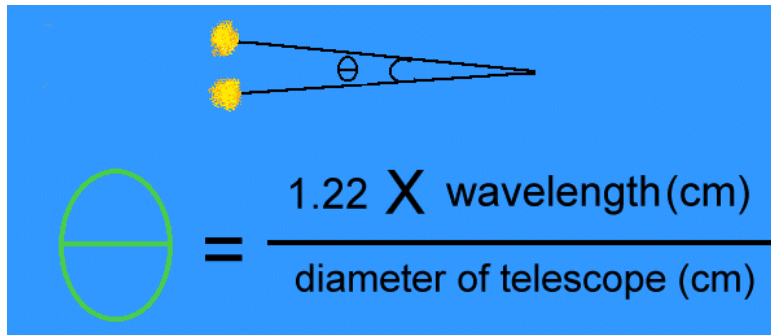
1st and 2nd generation VLT spectrographs





Imagers and physics: angular resolution

(a) 10'; (b) 1'; (c) 5"; (d) 1"



$\theta = \lambda / \text{diameter} \times 251643''$

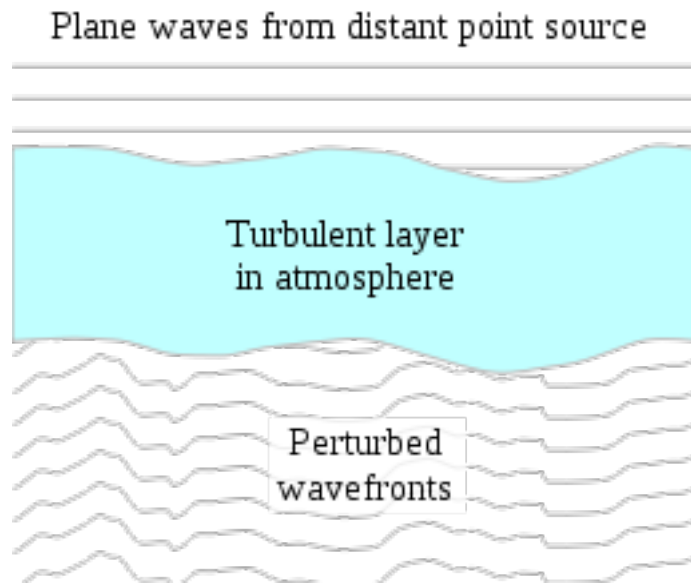


$\lambda = 1,000 \text{ nm}, \text{ diameter} = 8.2\text{m (VLT)} \rightarrow \theta = 0.03''$





Imagers and physics: atmospheric seeing



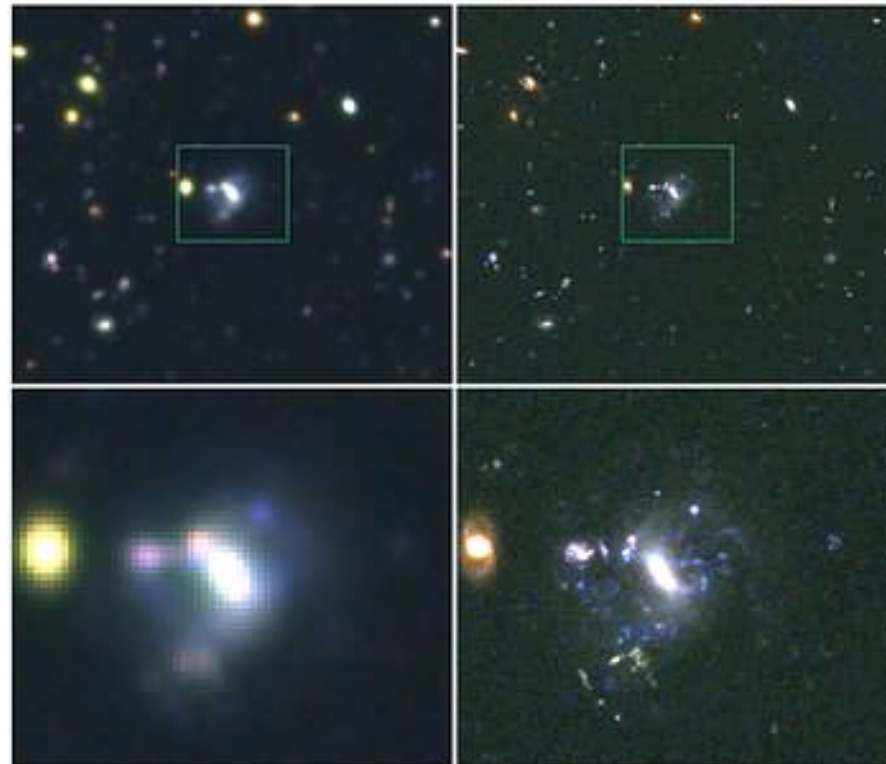
typical seeing $\sim 0.5 - 1''$



Ground: Subaru (8m)



Space: HST (2.4m)

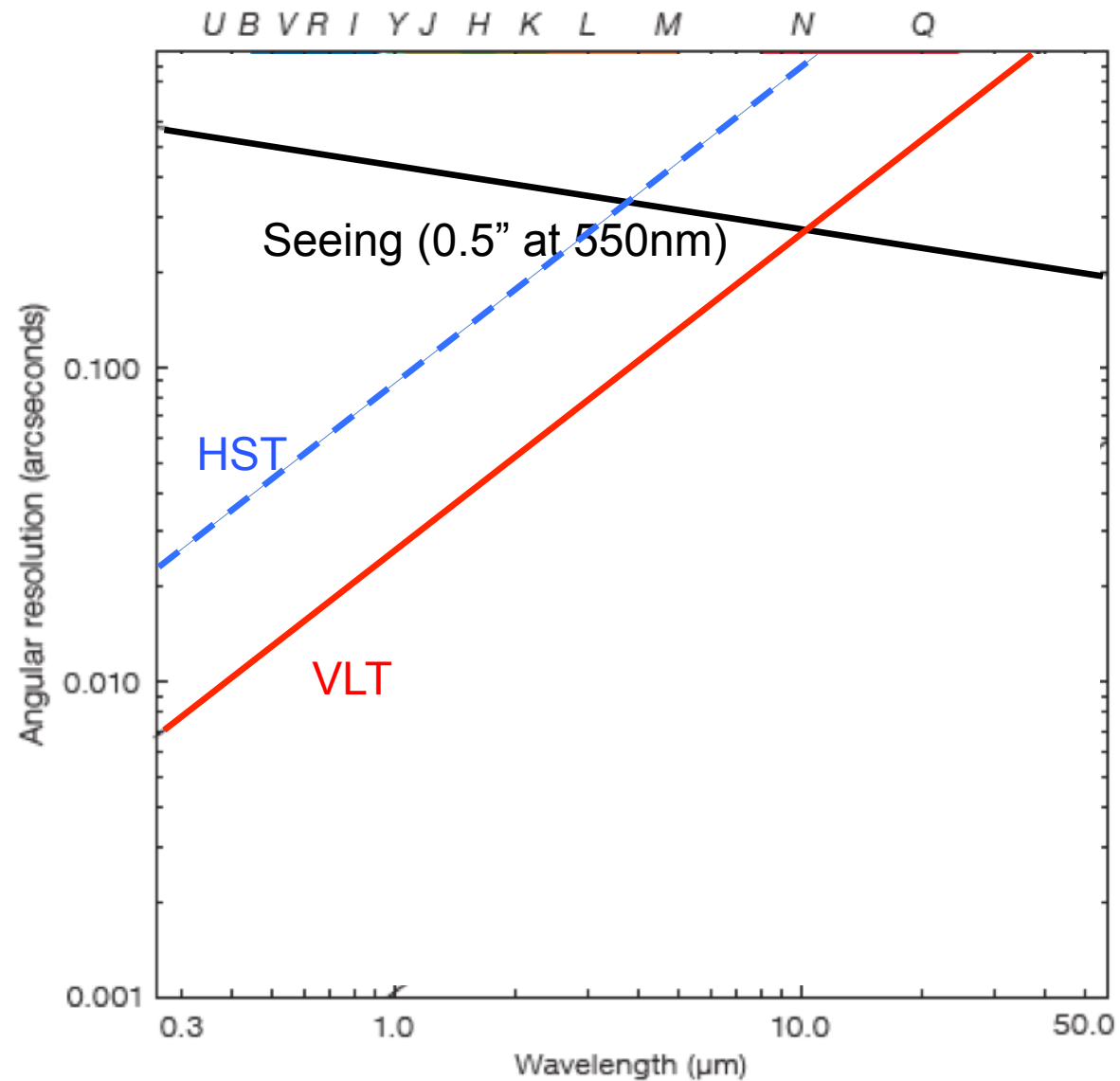


seeing $0.8''$

resolution $0.05''$

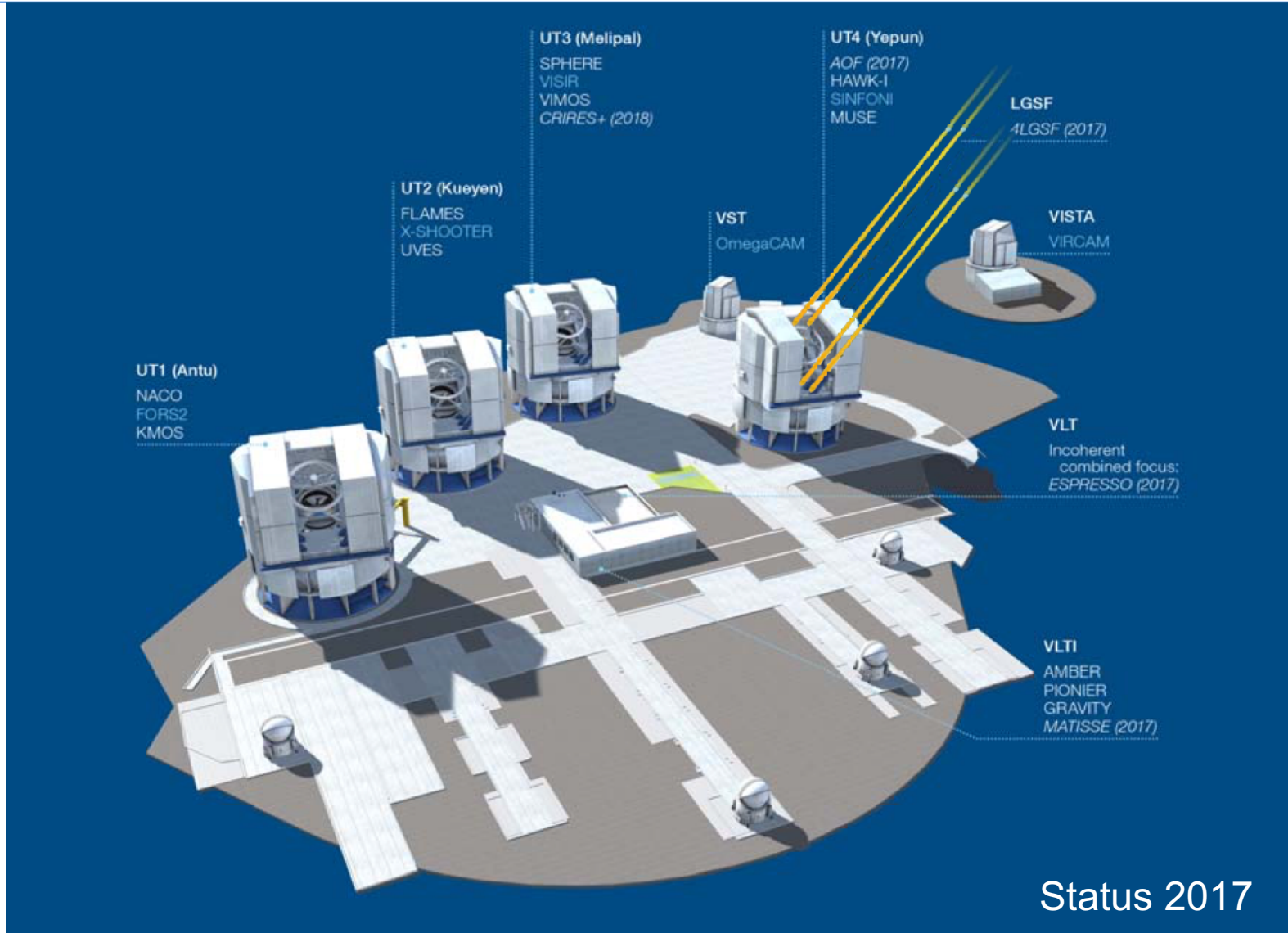


Resolution and seeing





Paranal 2017

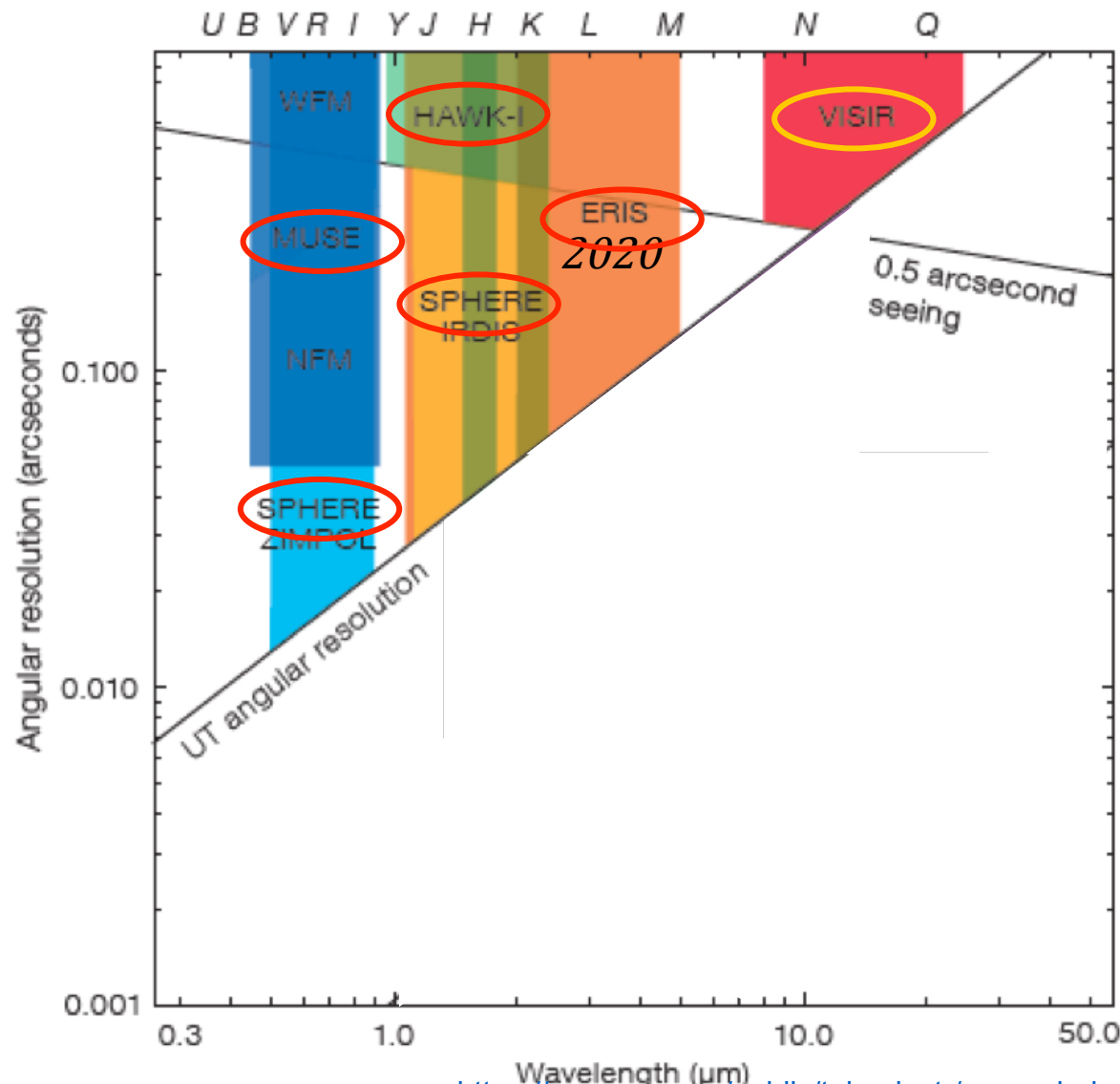


Status 2017





1st and 2nd generation VLT imagers



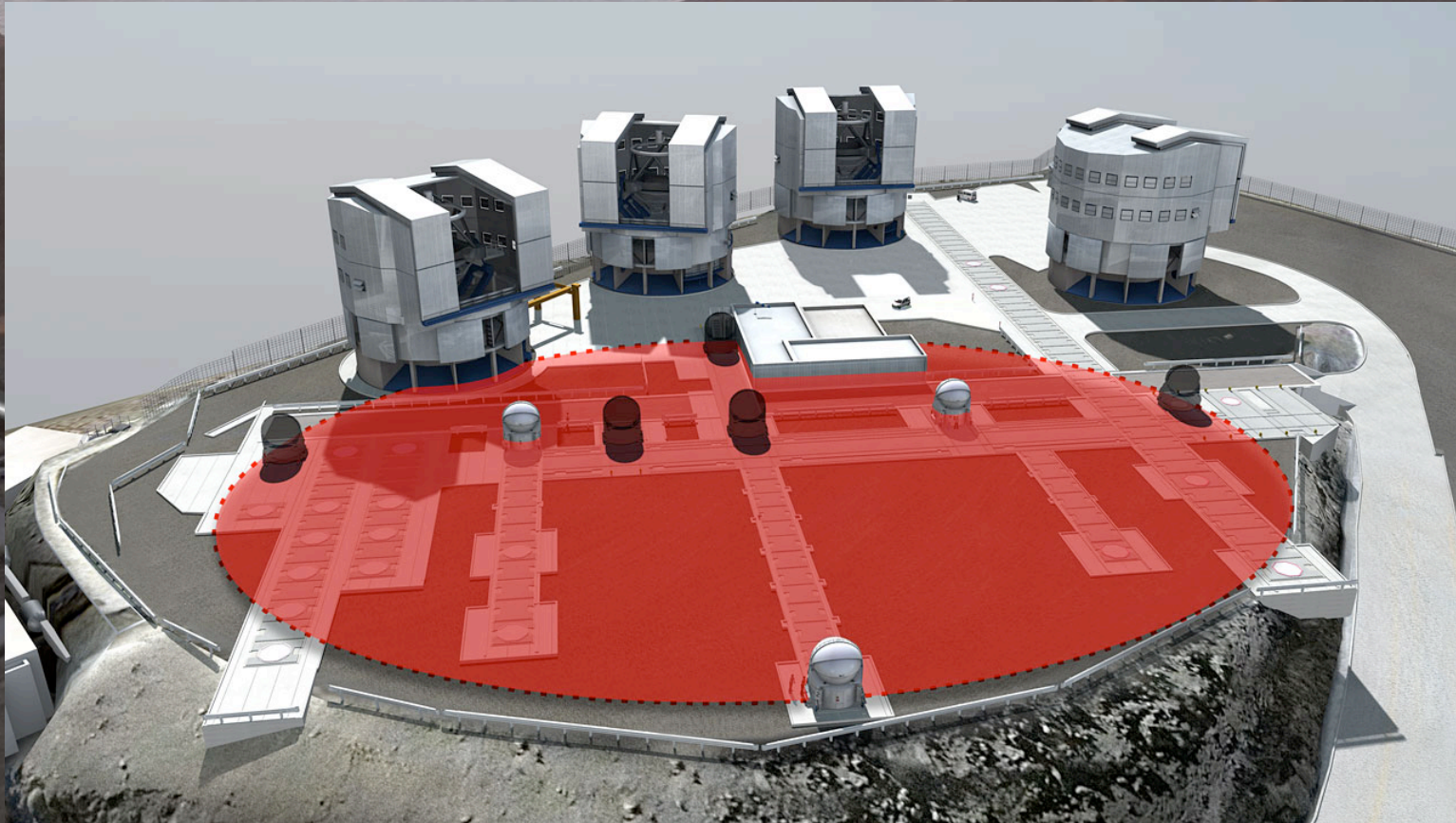
$$\theta = \lambda / \text{baseline} \times 251643''$$

(~ 12 x better than VLT)



VLTI - Very Large Telescope Interferometry

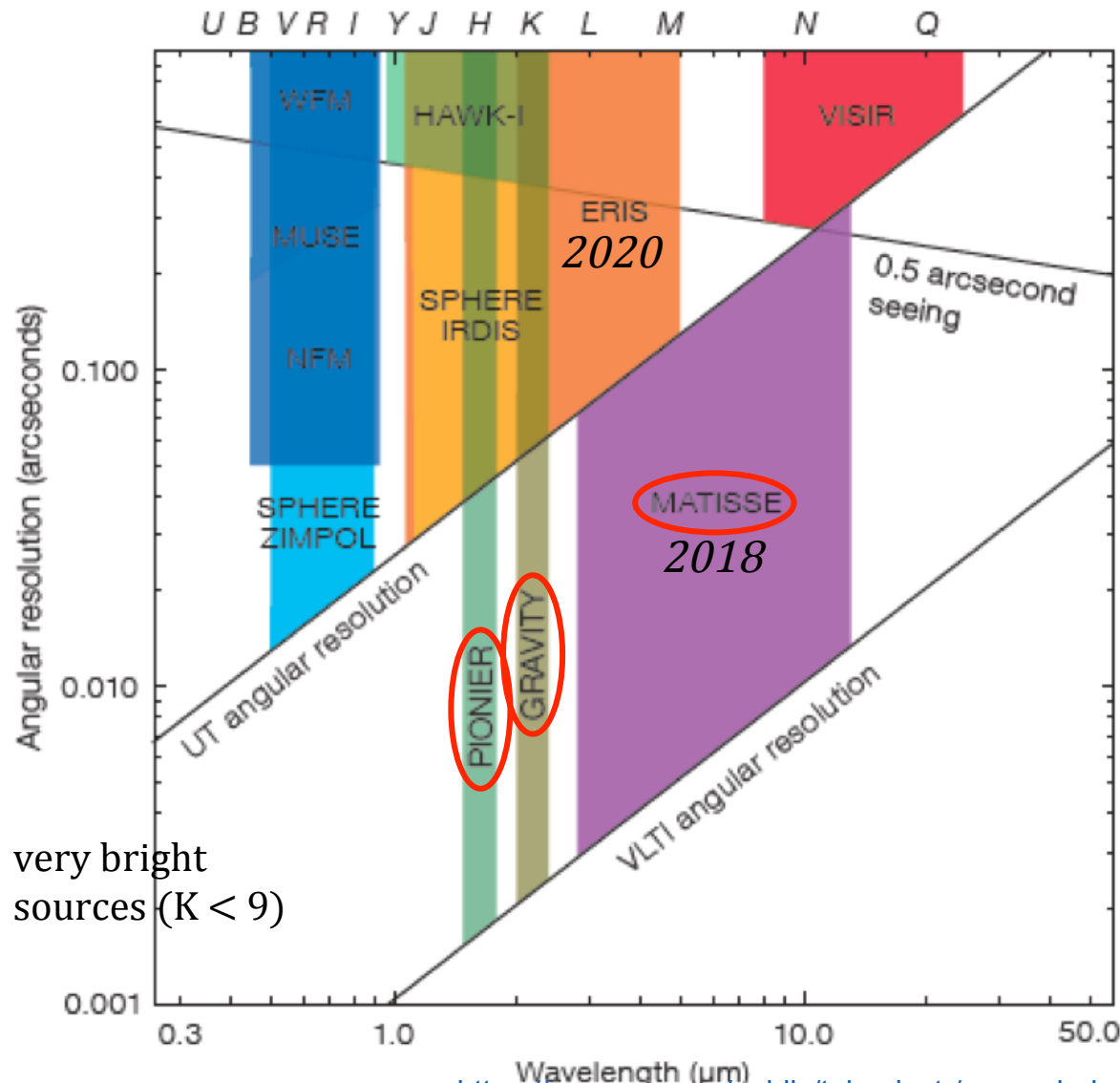
The VLTI is a virtual 100-Meter Telescope



Adapted from B. Leibundgut



1st and 2nd generation VLT/I imagers



$$\theta = \lambda / \text{baseline} \times 251643''$$

(~ 12 x better than VLT)

very bright sources ($K < 9$)





Current LaSilla instruments

■ New Technology Telescope (3.58m)

- **SofI** (Son of ISAAC): a large field of view IR (1,000 - 2,500 nm) spectro-imager
- **EFOSC2** (ESO Faint Object Spectrograph and Camera): low-R spectroscopy and imaging (305 – 1,100 nm)

■ ESO 3.6-metre telescope

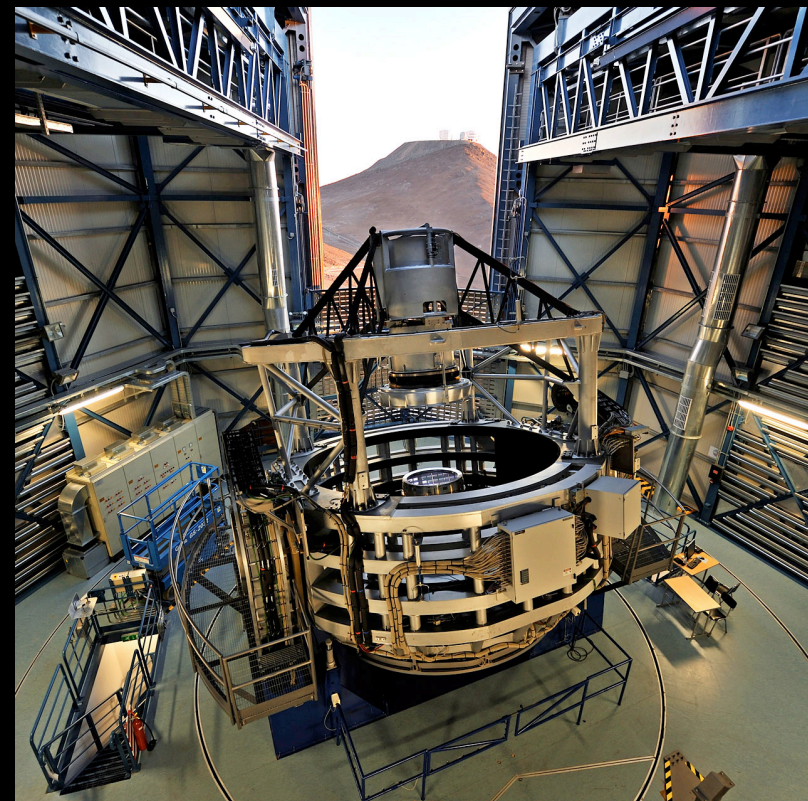
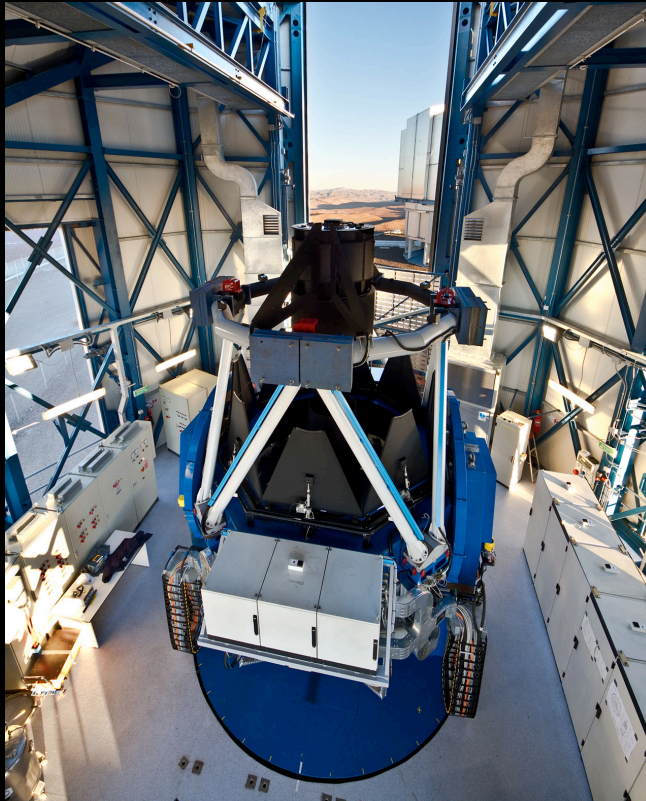
- **HARPS** (High Accuracy Radial velocity Planet Searcher): very high resolution ($R = 120,000$) spectrograph (378 - 691 nm)

<https://www.eso.org/public/teles-instr/lasilla/>

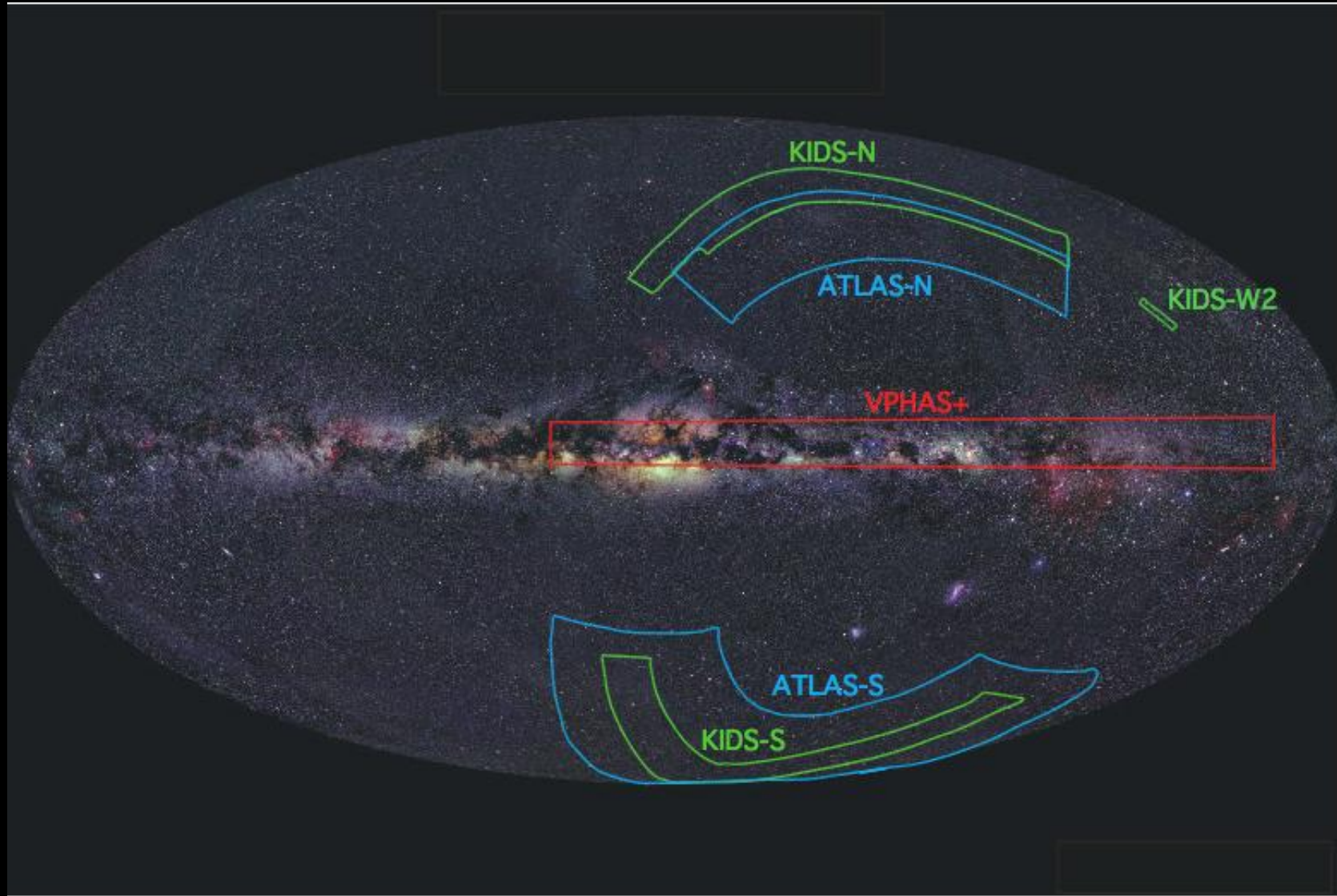


The Survey Telescopes

- VST (VLT Survey Telescope) 2.6m for optical and VISTA (Visible and Infrared Survey Telescope for Astronomy) 4.1m for infrared observations
- Coordinated sky surveys in 5-year projects



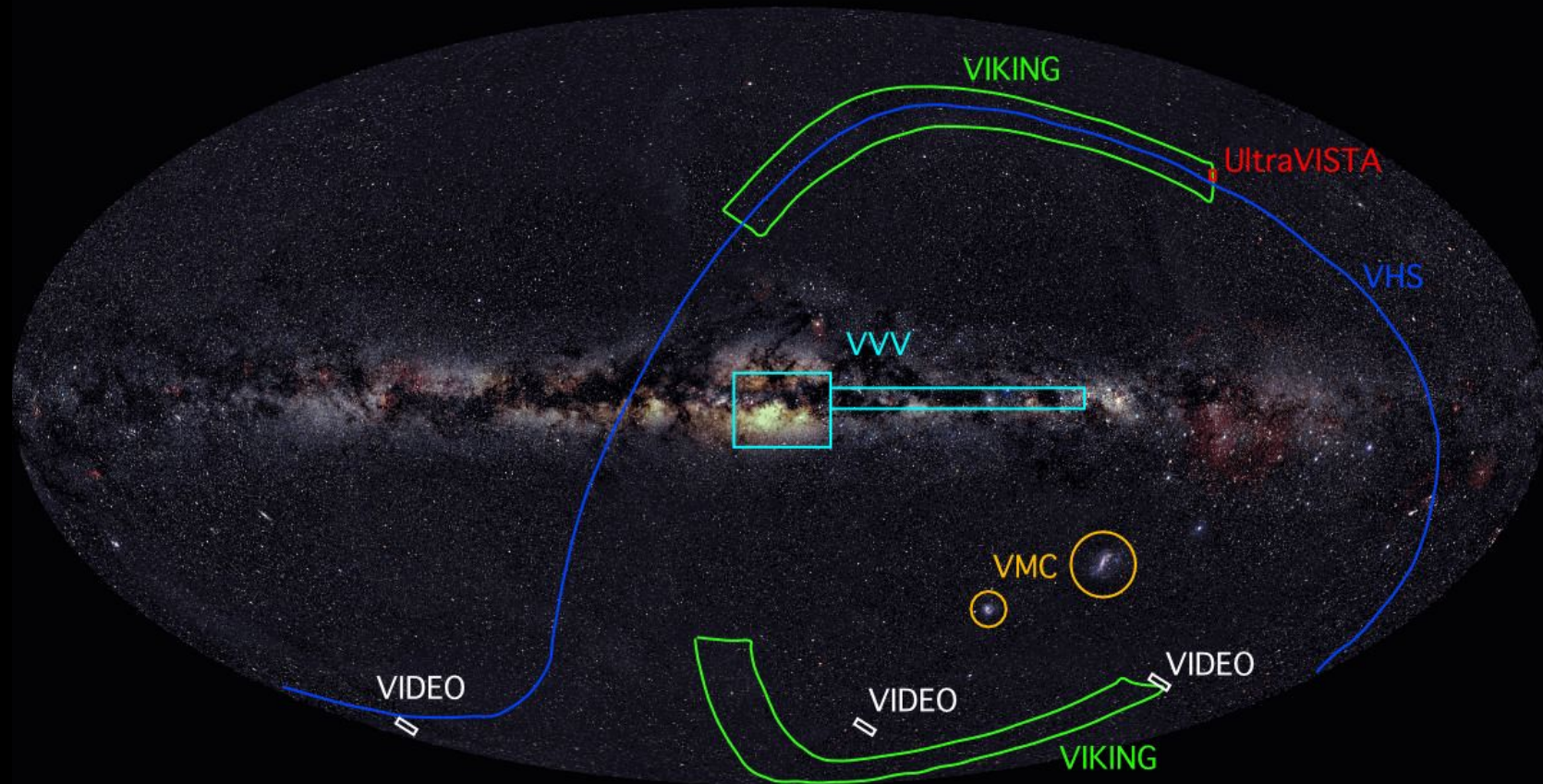
VST Public Surveys





VISTA Public Surveys (first cycle)

All public survey data are publicly available!





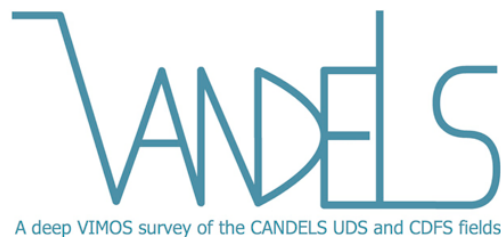
Spectroscopic Public Surveys



Milky Way, FLAMES



Transients, EFOSC2 and SOFI



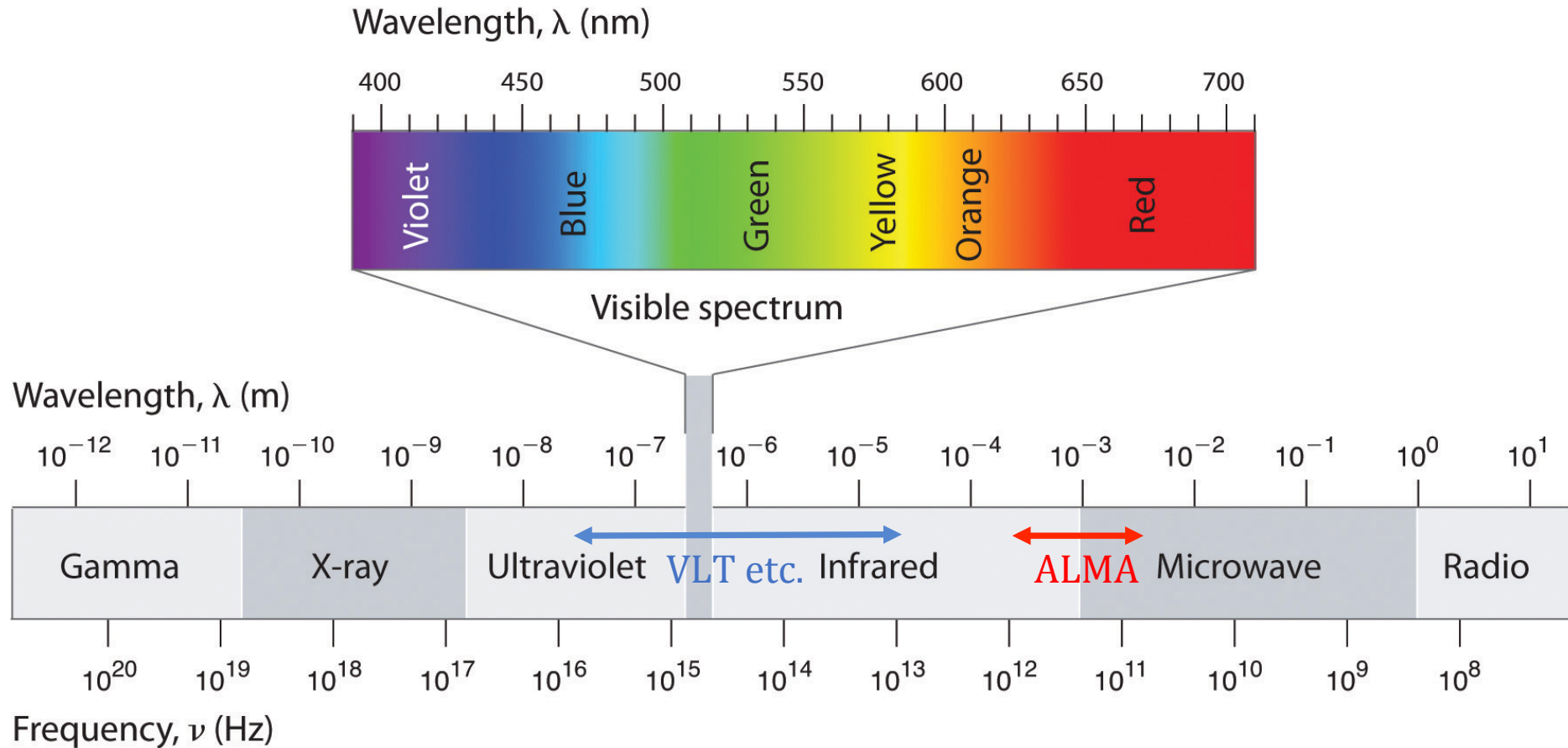
High-z galaxies, VIMOS



$z = 0.6 - 1$ galaxies, VIMOS



Atacama Large Millimeter/submillimeter Array (ALMA)



ALMA



- Some ALMA science topics
 - gas and dust in dense molecular clouds and proto-stellar discs
 - dust and molecular gas in nearby galaxies
 - dust and spectral line emission in high-redshift galaxies

- 66 antennas located at 5,000 m altitude
- Partnership
 - Europe (ESO), North America (USA and Canada), East Asia (Japan, Taiwan, South Korea)
- Wavelength range: 0.3 – 3.6 mm (84 – 950 GHz)
- Cold Universe: $T < 10$ K
- Spatial resolution:
 - 0.5 – 4.8" (compact configuration: ~ 160 m)
 - 20 – 43 mas (extended configuration: ~16 km)

$$\theta = \lambda / \text{baseline} \times 251643''$$



ESO Science Archive

- Science Archive Facility**
- Data Portal
- ESO Data
- Hubble Space Telescope Data
- Virtual Observatory Tools
- Catalogues, Plates and DSS
- Tools and Documentation
- Related External Services
- ESO & HST Image Galleries
- News and Updates
- FAQ
- ESO Data Access Policy

Warning!!
 Due to planned IT maintenance, there will be a disruption of some archive services between Saturday, 8 July 2017 at 08:00 CEST and Sunday, 9 July 2017 at 24:00 CEST. Full services won't be guaranteed before Monday, 10 July 2017.

We apologize for any inconvenience this may cause.

Welcome to the ESO Science Archive Facility

The ESO Science Archive Facility contains data from ESO telescopes at La Silla Paranal Observatory, including the APEX submillimeter telescope on Llano de Chajnantor. In addition, the raw UKIDSS/WFCAM data obtained at the UK Infrared Telescope facility in Hawaii are available.

The Principal Investigators of successful proposals for time on ESO telescopes have exclusive access to their scientific data for the duration of a proprietary period, normally of one year, after which the data becomes available to the community at large. Please read the [ESO Data Access Policy](#) statement for more information, along with the [relevant FAQs](#).

Browsing the archive does not require authentication, but to request and download data you have to log in to the [ESO User Portal](#). Please [acknowledge the use of archive data](#) in any publication.

Latest News and Updates

- Flux-calibration issue for the XSHOOTER UVB data products: SOLVED (19 May 2017)
- Release of CO(2-1) spectra from the APEX Low-redshift Legacy Survey for MOlecular Gas (ALLSMOG) (17 May 2017)
- New release of Gaia-ESO Spectroscopic Public Survey Data (12 May 2017)

[More news ...](#)

To browse the archive

Currently, **raw data** and various types of **data products** can be reached via different interfaces:

Category	Access Point	Data collection	Data Type	Instruments
LPO Raw Data	Raw data query form (all instruments) Instrument specific query forms Direct retrieval of raw data by file name	All ESO raw data	Various	Many La Silla Paranal instruments
LPO Data Products	Phase 3 main query form Phase 3 imaging query form Phase 3 spectral query form Phase 3 VIRCAM-specific query form Direct retrieval of reduced data by file name	Phase 3 Data Products (ESO public surveys; ESO pipeline-reduced products; Large programs: GOODS, zCOSMOS; etc.)	Imaging, Spectroscopy, Catalogs, etc.	Various
[Description of reduced data products types]	Catalogue Facility query interface	Phase 3 Catalogues [ESO User Portal authentication required also when browsing]	Catalogues	Various
	HARPS-Polarimetry pipeline processed data query form	HARPS-Polarimetry pipeline processed data	Spectroscopy	HARPS-Polarimetry, HARPS reduced calibrations (other HARPS see Phase3 above), FEROS is now available via the Phase 3 interfaces.
	Other Advanced Data Products (available only as downloadable packages, no query form)	Various (30 Doradus, Corot, GaBoDs, etc.)	Spectroscopy Imaging	FEROS WFI
	Science Verification, Commissioning, EIS, etc. (no query form)	Full list of available data packages	Various	Many
APEX Quick Look Products	APEX query form	APEX	Heterodyne, Bolometer	APEX-2A, LABOCA, SABOCA, SHeFI
LPO Schedule	Scheduling query form	ESO Observing Programme Information and Scheduling		All La Silla Paranal instruments, including APEX
ALMA Data	ALMA Science Archive	All ALMA data	Cube	ALMA

Size

500 Tb

100 Tb

350 Tb





ESO Science Archive Form (raw data)

Target, Program, and Scheduling Information

Target Name Resolved by SIMBAD

RA **DEC** **J2000**

Search Box 00 10 00 **Input** RA(h) DEC(deg)

Output Sexagesimal (h, deg)

List of Targets Choose File no file selected

Night (YYYY MM(M) DD)

Otherwise give a query range using the following start/end dates:

Start 12 hrs [UT] **End** 12 hrs [UT]

Program ID **Program Type** Any

PI CoI **SV** Any

Title

Observing Information

Imaging	Spectroscopy	Interferometry	Other
ALL NONE	ALL NONE	ALL NONE	ALL NONE
<input type="checkbox"/> EFOSC2/LaSilla	<input type="checkbox"/> CES/LaSilla	<input type="checkbox"/> AMBER/VLTI	<input type="checkbox"/> BOL/APEX
<input type="checkbox"/> EMMI/LaSilla	<input type="checkbox"/> CRIRES/VLT	<input type="checkbox"/> GRAVITY/VLTI	<input type="checkbox"/> HET/APEX
<input type="checkbox"/> FORS1/VLT	<input type="checkbox"/> EFOSC2/LaSilla	<input type="checkbox"/> MIDI/VLTI	<input type="checkbox"/> LGSF/VLT
<input type="checkbox"/> FORS2/VLT	<input type="checkbox"/> EMMI/LaSilla	<input type="checkbox"/> PIONIER/VLTI	<input type="checkbox"/> MAD/VLT
<input type="checkbox"/> HAWKI/VLT	<input type="checkbox"/> FEROS/LaSilla	<input type="checkbox"/> VINCI/VLTI	<input type="checkbox"/> MASCOT/Paranal
<input type="checkbox"/> GROND/LaSilla	<input type="checkbox"/> FORS1/VLT		<input type="checkbox"/> WFCAM/UKIRT
<input type="checkbox"/> ISAAC/VLT	<input type="checkbox"/> FORS2/VLT	Polarimetry	
<input type="checkbox"/> NACO/VLT	<input type="checkbox"/> GIRAFFE/VLT	ALL NONE	Sparse Aperture Mask
<input type="checkbox"/> OMEGACAM/VST	<input type="checkbox"/> HARPS/LaSilla	<input type="checkbox"/> EFOSC2/LaSilla	ALL NONE
<input type="checkbox"/> SOFI/LaSilla	<input type="checkbox"/> ISAAC/VLT	<input type="checkbox"/> FORS1/VLT	<input type="checkbox"/> NACO/VLT
<input type="checkbox"/> SPHERE/VLT	<input type="checkbox"/> KMOS/VLT	<input type="checkbox"/> FORS2/VLT	<input type="checkbox"/> VISIR/VLT
<input type="checkbox"/> SUSI2/LaSilla	<input type="checkbox"/> MUSE/VLT	<input type="checkbox"/> ISAAC/VLT	
<input type="checkbox"/> TIMMI2/LaSilla	<input type="checkbox"/> NACO/VLT	<input type="checkbox"/> NACO/VLT	
<input type="checkbox"/> VIMOS/VLT	<input type="checkbox"/> SINFONI/VLT	<input type="checkbox"/> SOFI/LaSilla	
<input type="checkbox"/> VIRCAM/VISTA	<input type="checkbox"/> SOFI/LaSilla	<input type="checkbox"/> SPHERE/VLT	
<input type="checkbox"/> VISIR/VLT	<input type="checkbox"/> SPHERE/VLT		
<input type="checkbox"/> WFI/LaSilla	<input type="checkbox"/> TIMMI2/LaSilla	Coronagraphy	
	<input type="checkbox"/> UVES/VLT	ALL NONE	
	<input type="checkbox"/> VIMOS/VLT	<input type="checkbox"/> EFOSC2/LaSilla	
	<input type="checkbox"/> VISIR/VLT	<input type="checkbox"/> NACO/VLT	
	<input type="checkbox"/> XSHOOTER/VLT	<input type="checkbox"/> SPHERE/VLT	
	<input type="checkbox"/> VISIR/VLT		

Category

SCIENCE
 CALIB
 ACQUISITION

Data Product Info

Type Any

User defined input:

Mode Any

User defined input:

Dataset ID

Orig Name

Release Date

OB Name

OB ID

TPL START

Instrumental Setup

TPL ID

Exptime

Filter

Grism

Grating

Slit

Instrument & Mode





ESO Science Archive Form (data products)



PHASE3 ARCHIVE INTERFACES

This form provides access to **reduced or fully calibrated data sets**, and **derived catalogs**, that were contributed by PIs of ESO programmes or produced by ESO (using ESO calibration pipelines with submillimetre) data products. Each available data set is fully described; please see the [list of contributed data releases](#) and [pipeline-processed data streams](#) including their corresponding descriptions. This form [Read more...](#)

Output preferences: Return max rows.

Target/Position Information

Target name SIMBAD name Query by Target List: no file selected
 Input Coord. Sys.
 Position RA DEC RA: sexagesimal hours, decimal degrees
 Search Box Output Display: RA DEC Gal long Gal lat

Bandpass/Wavelength and Product Category

Filter OR Wavelength [nm] E.g.: 656, 393 AND 656, 393..656
 Product category Any catalog cube image source_table spectrum visibility

Observation/Temporal Parameters

Telescope Instrument OBSTECH
 Date Obs UT time (Place the mouse here to see examples)
 MJD Obs Modified Julian Date
 Exptime Total integration time per pixel [s]
 Multi OB

Collections and Observing Programmes

Collection
 Run/Program ID PI Name Certified by

Submission, Proprietary Period & Bibliographic Information

ORIGFILE ARCFILE
 Release Date REFERENC bibcode or doi
 Batch Id Publication Date





ALMA Science Archive Form

ALMA Science Archive Query

Query Form Results Table

Search Reset

[Query Help](#)

Position

Source name (Resolver)
Source name (ALMA)
RA Dec
Galactic
Target list
Angular resolution
Largest angular scale
Field of view

Energy

Frequency
Bandwidth
Spectral resolution
Band

Time

Observation date
Integration time

Polarisation

Polarisation type

Observation

Line sensitivity (10 km/s)
Continuum sensitivity
Water vapour

Project

Project code
Project title
PI name
Proposal authors
Project abstract
Publication count
Science keyword

Publication

Bibcode
Title
First author
Authors
Abstract
Year

Options

View:
 observation
 project
 publication
 public data only
 science observations only





(Some) ESO Science Results

- Supermassive black hole at the centre of the Milky Way
- Exo-planets
- *Accelerating Universe and supernovae (lecture by B. Leibundgut)*
- *Stability of fundamental constants (lecture by J. Webb)*
- See <http://www.eso.org/public/science/top10/> for more

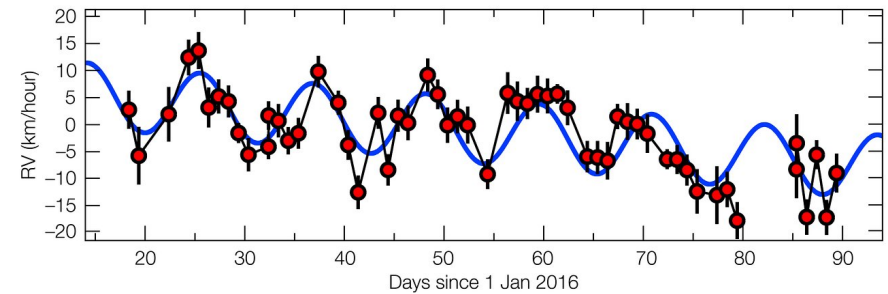
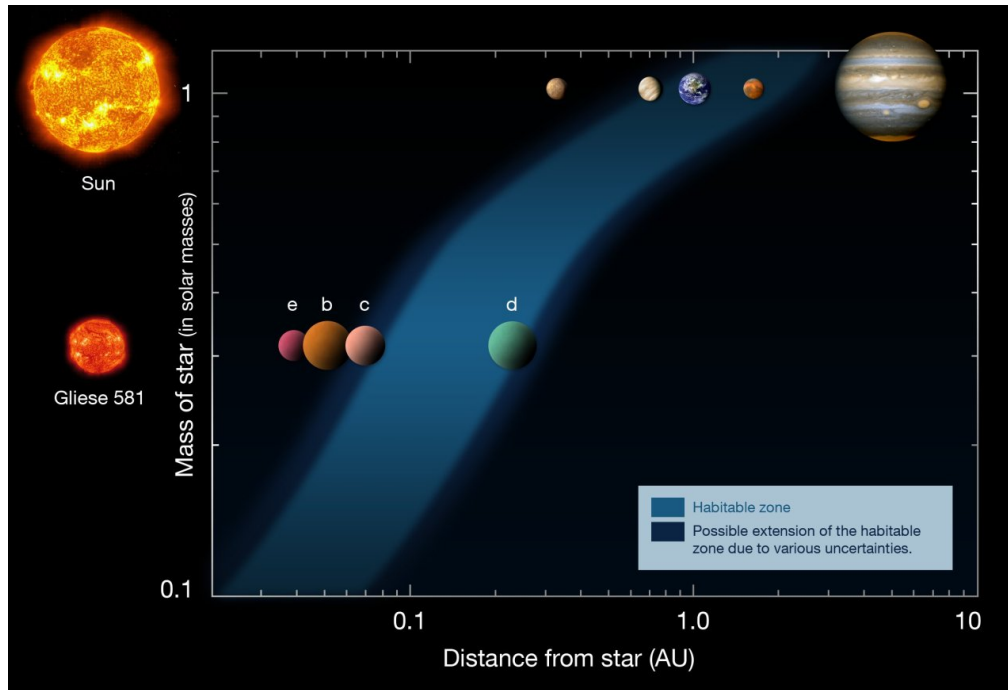


Supermassive black hole at the centre of the Milky Way

- Precise mass determination from 17 stars (Gillessen et al. 2017)
 - $M = (4.28 \pm 0.10)_{\text{stat}} \pm 0.21_{\text{Ro}} \times 10^6 M_{\odot}$
- No relativistic effects detected so far: e.g.,
the first general relativistic correction to the Newtonian potential as given by the Schwarzschild metric:
 $V(r) = -GM_{\text{MBH}}/r + GM_{\text{MBH}}l^2/c^2r^3$ where l is the orbital angular momentum of the star.
 - GRAVITY should (might?) do that

Exo-planets (1): Proxima b

■ Planet in habitable zone around nearest star (Proxima Centauri)

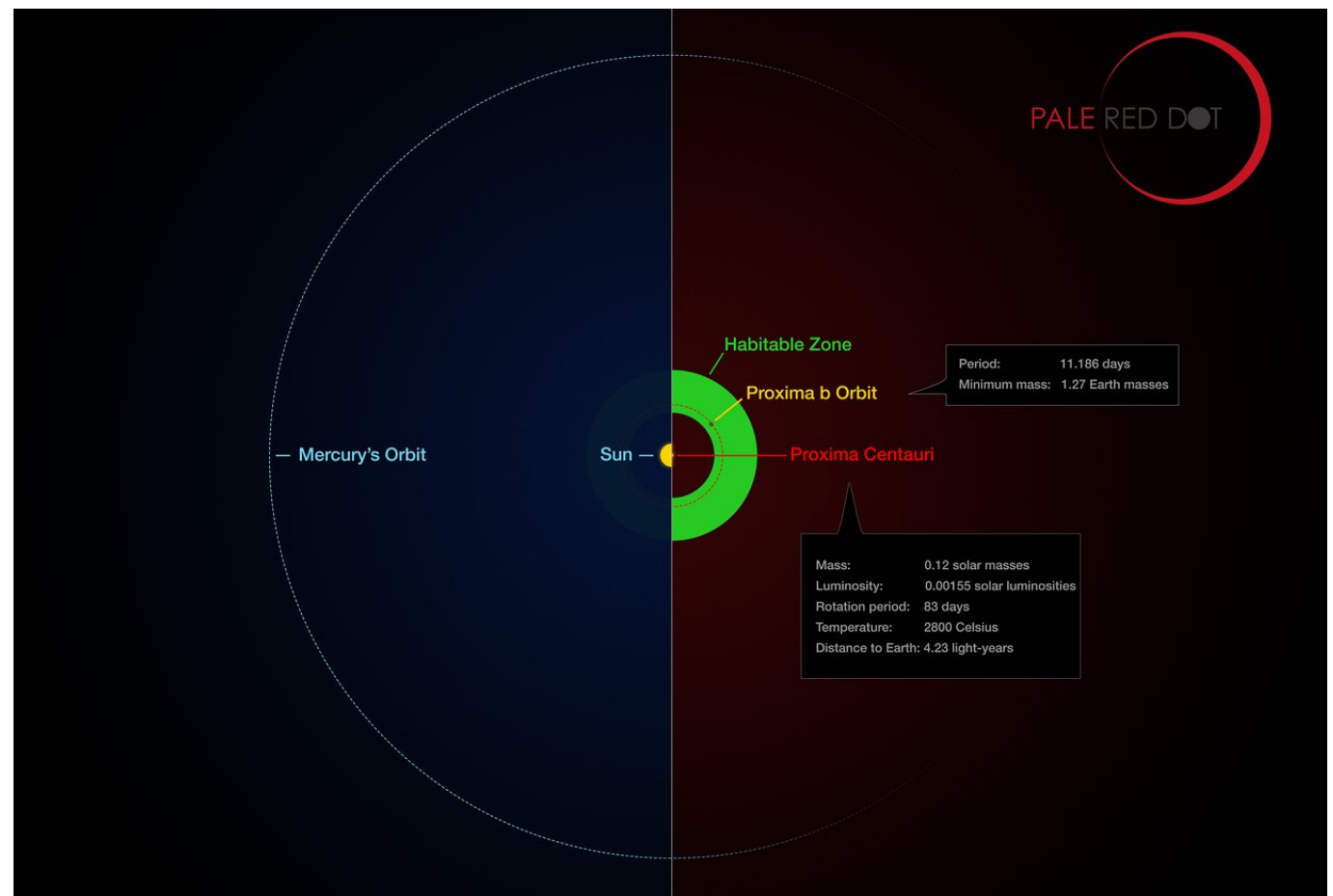


HARPS data (Anglada-Escudé et al. 2017)



Exo-planets (1): Proxima b

- Planet in habitable zone around nearest star (Proxima Centauri)

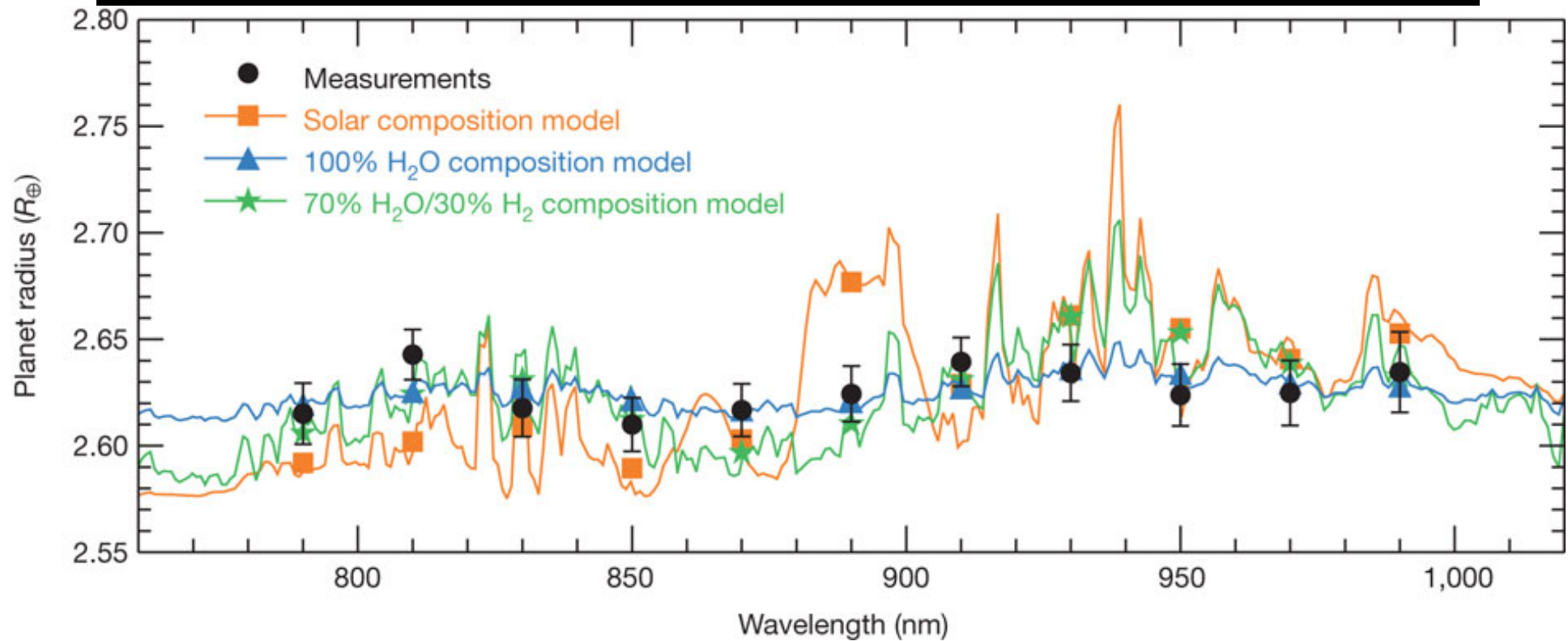




Exo-planets (2): GJ 1214b

- First Super-Earth atmosphere analysed

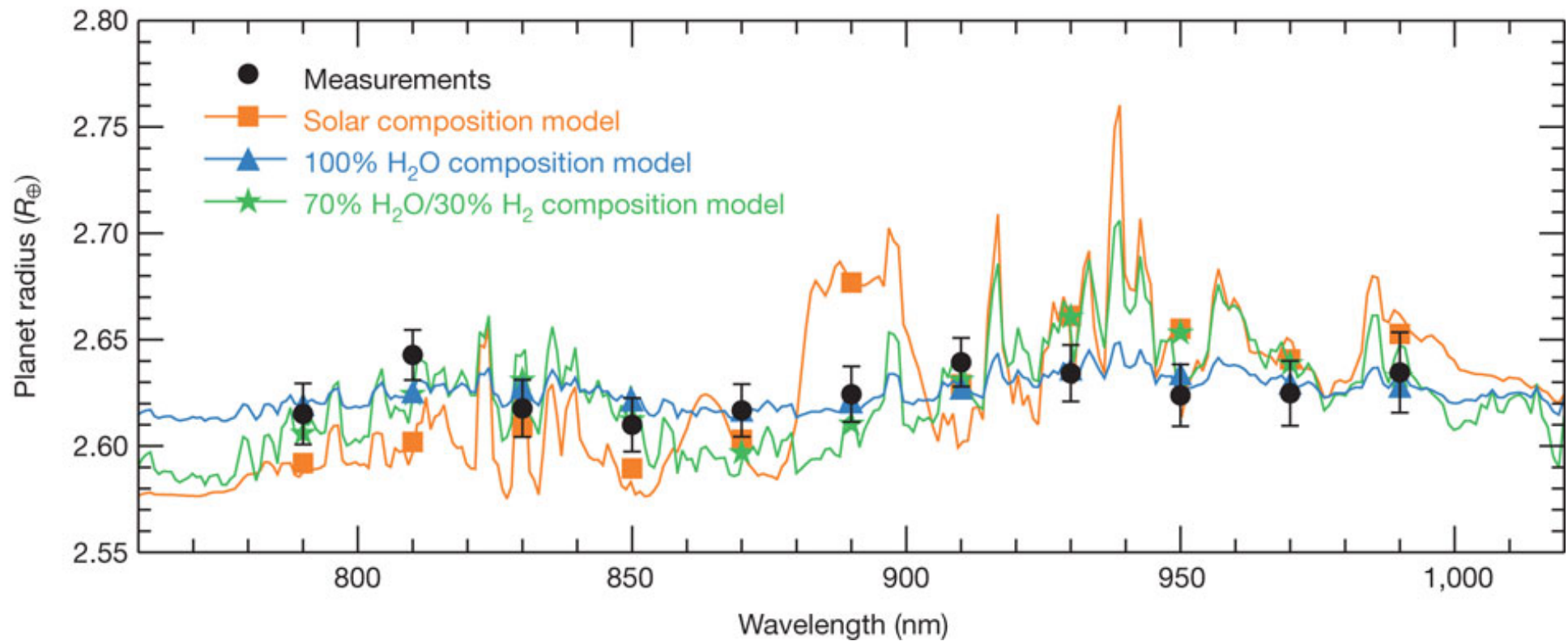
- (



FORS2 data (Bean et al. 2010)

Exo-planets (2): GJ 1214b

- First Super-Earth atmosphere analysed
- GJ 1214b: $R = 2.6 \oplus$ and $M = 6.5 M_{\oplus}$



FORS2 data (Bean et al. 2010)



Summary

- ESO is an intergovernmental treaty-level organization
- ESO instruments cover a very large range of parameter space and wavelengths
- The ESO archive is a free resource, there to be used
- ESO is producing exciting science