CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

JOHN TEMPLETON FOUNDATION

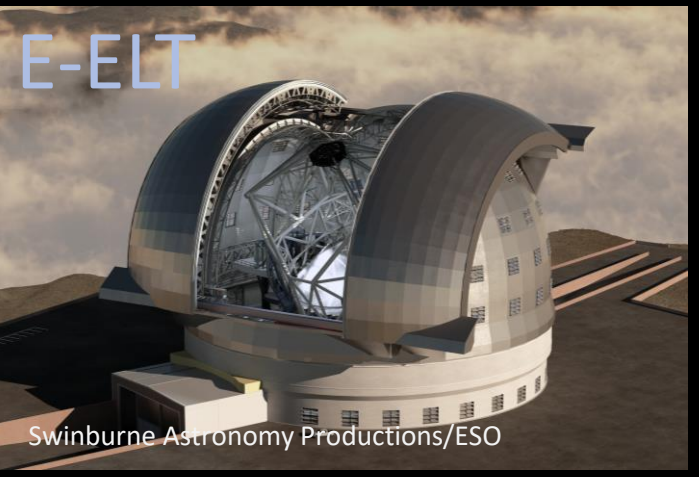
A Fabry Perot Instrument for Oxygen Searches in Exoplanet Atmospheres

S. Rukdee | Max Planck Institute for Extraterrestrial Physics

ESO Atmo 2021

FUTURE INSTRUMENTS FOR CHARACTERIZATION OF EXOPLANET ATMOSPHERES

G-CLEF
GMTNIRS



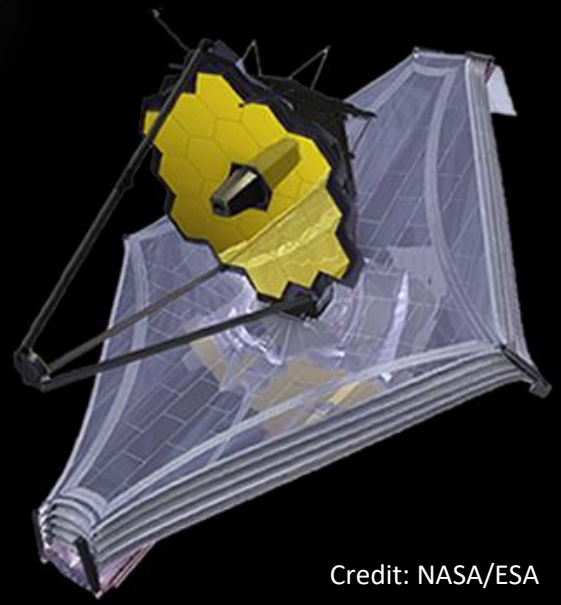
HIRES
METIS

HROS
NIRES

Ground based

Credit: ARIEL/Science Office

ARIEL

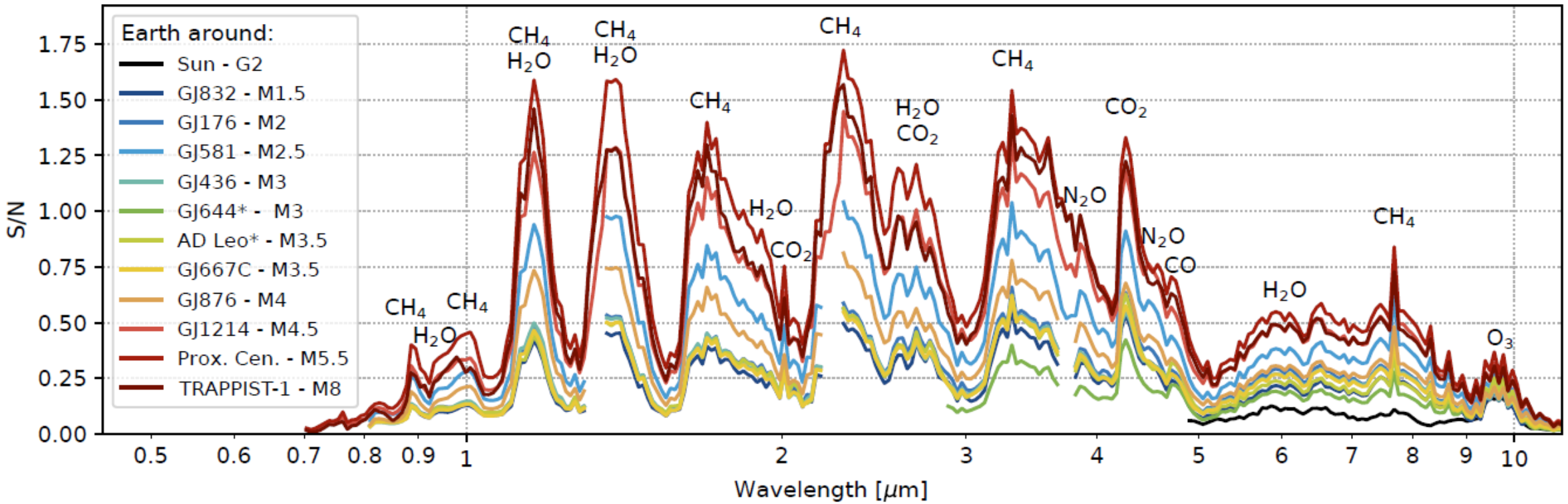


JWST

Credit: NASA/ESA

Space based

M-dwarf planets at 10 parsecs | single transit | R =100



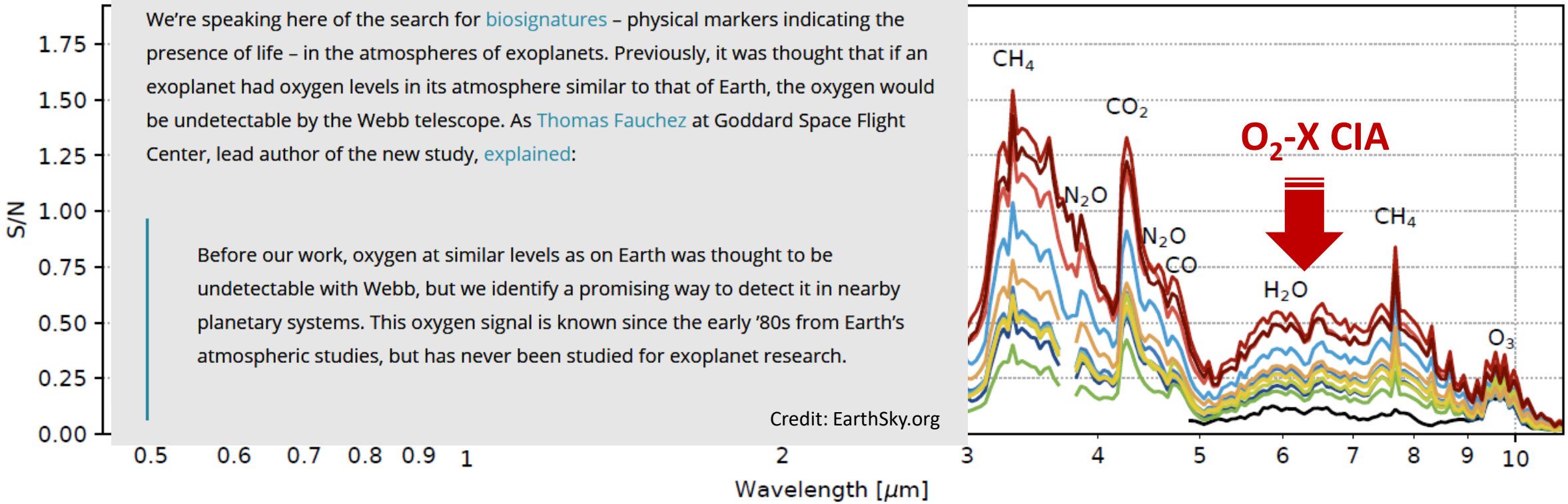
TRANSMISSION SPECTROSCOPY WITH JWST

Wunderlich+ 2019

We're speaking here of the search for biosignatures – physical markers indicating the presence of life – in the atmospheres of exoplanets. Previously, it was thought that if an exoplanet had oxygen levels in its atmosphere similar to that of Earth, the oxygen would be undetectable by the Webb telescope. As Thomas Fauchez at Goddard Space Flight Center, lead author of the new study, explained:

> Before our work, oxygen at similar levels as on Earth was thought to be undetectable with Webb, but we identify a promising way to detect it in nearby planetary systems. This oxygen signal is known since the early '80s from Earth's atmospheric studies, but has never been studied for exoplanet research.

Credit: EarthSky.org

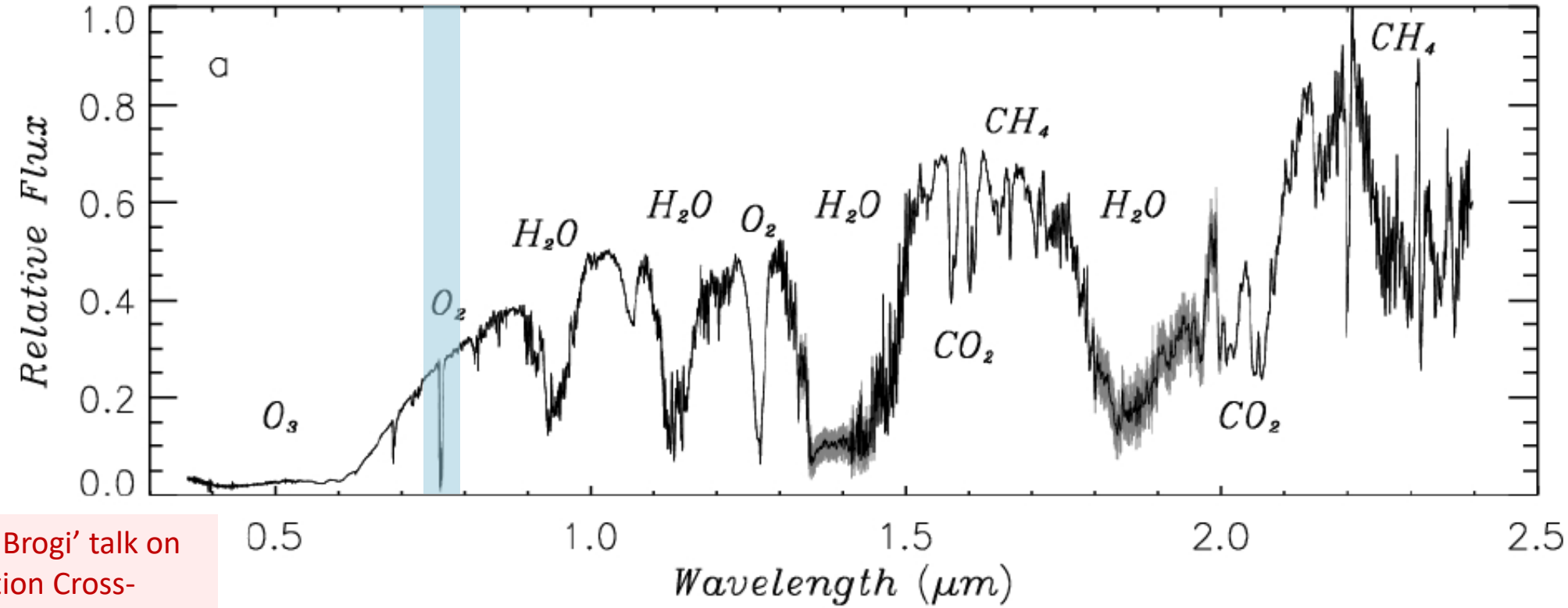


TRANSMISSION SPECTROSCOPY WITH JWST

Wunderlich+ 2019

Fauchez+ 2020

HIGH RESOLUTION
GROUND-BASED OBSERVATION

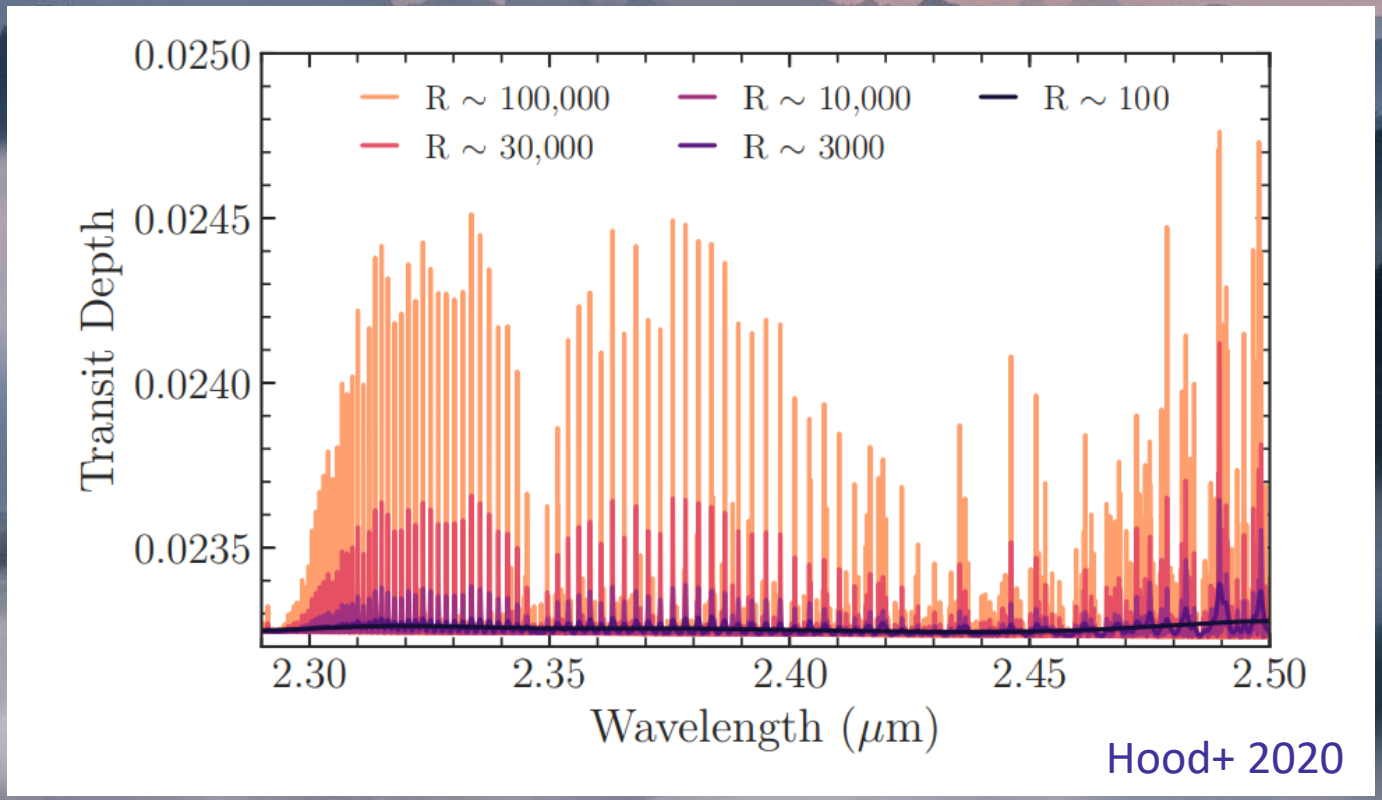


See Matteo Brogi' talk on High resolution Cross-correlation Spectroscopy

Palle+ 2009

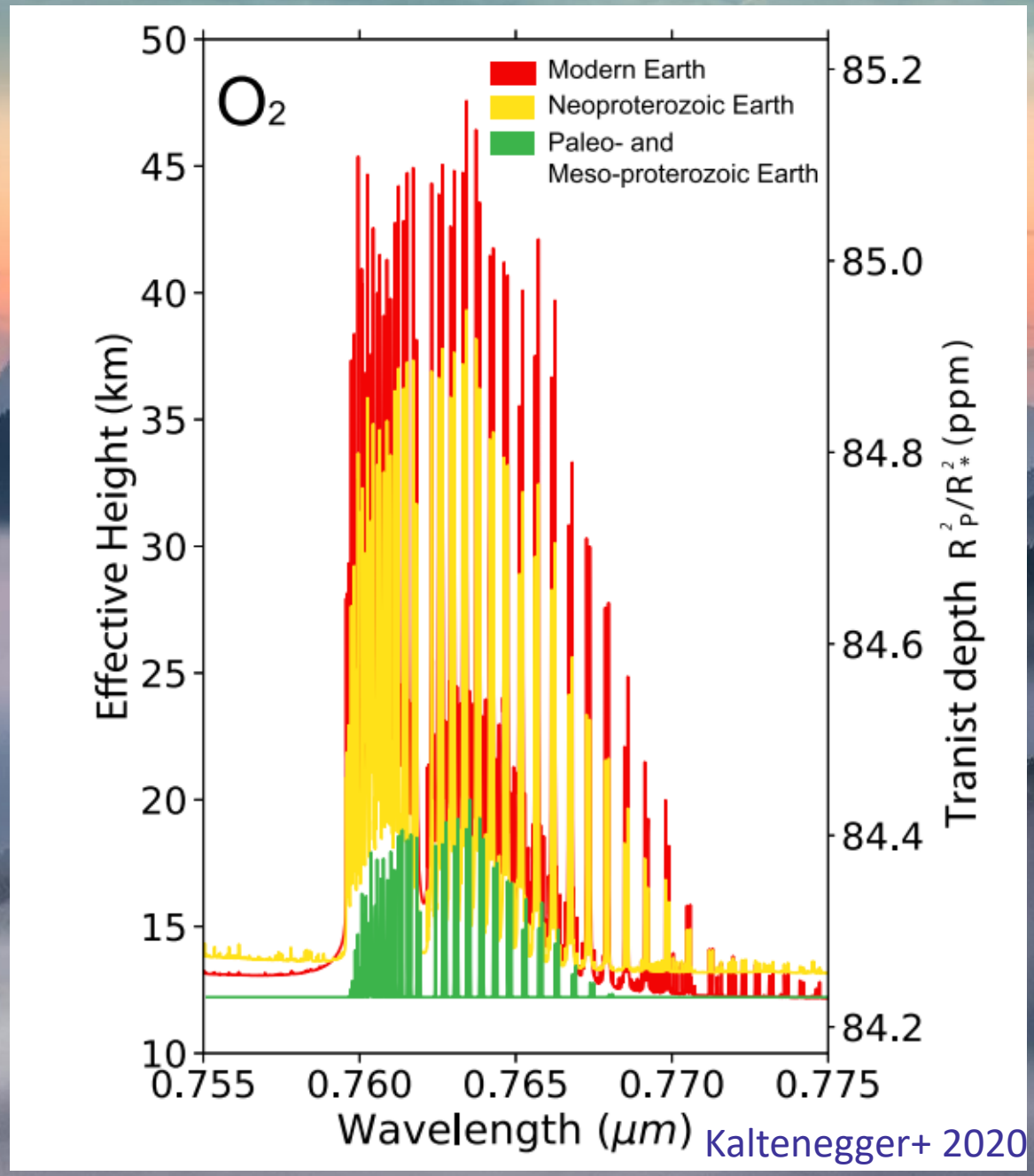
CLOUD - a visible aggregation of minute water droplets and/or ice particles in the atmosphere above the earth's surface – AMS

HAZE - Particles suspended in air, reducing visibility by scattering light; often a mixture of aerosols and photochemical smog – AMS



Hood+ 2020

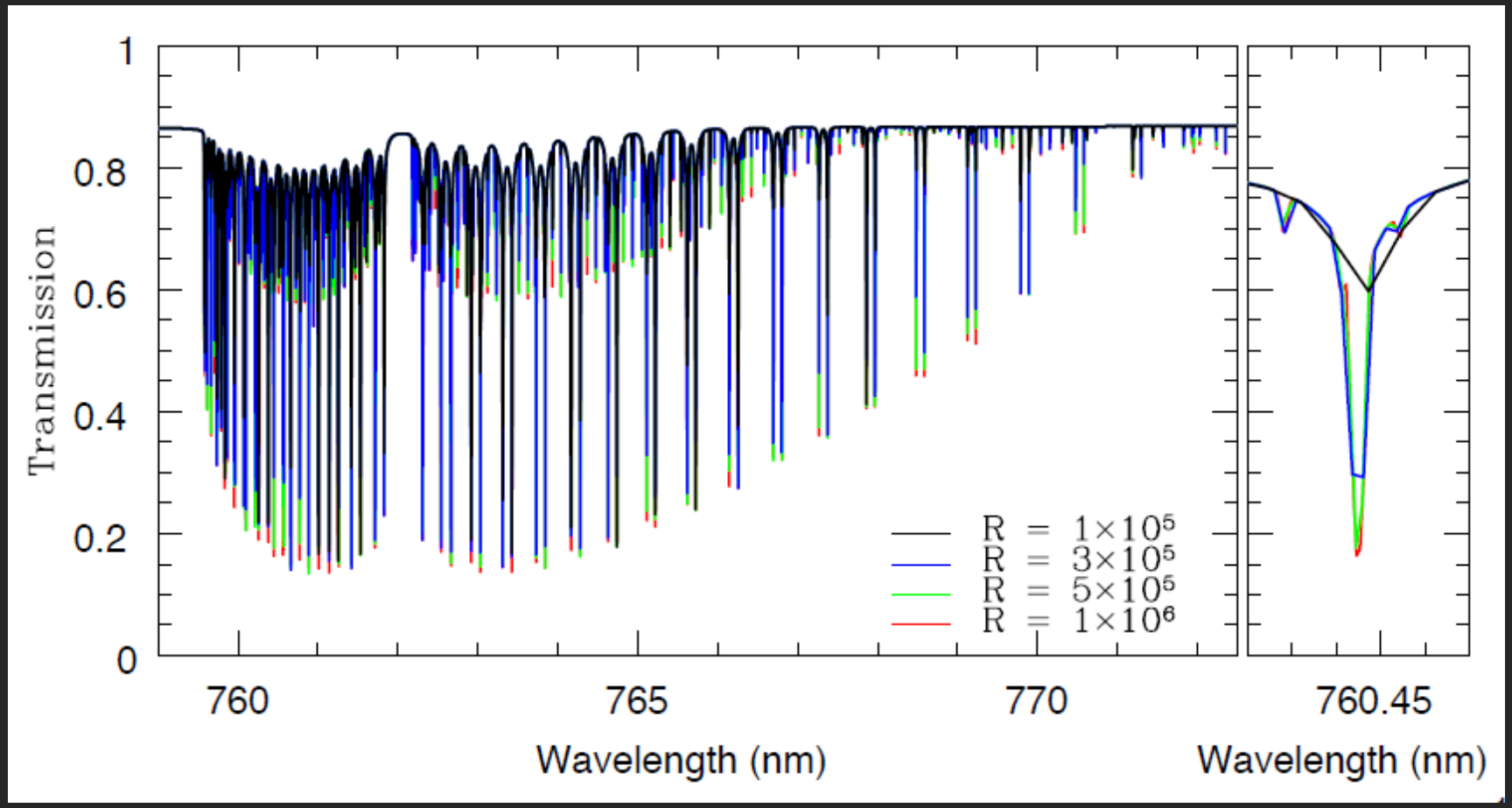
Why High Resolution ?



Kaltenegger+ 2020

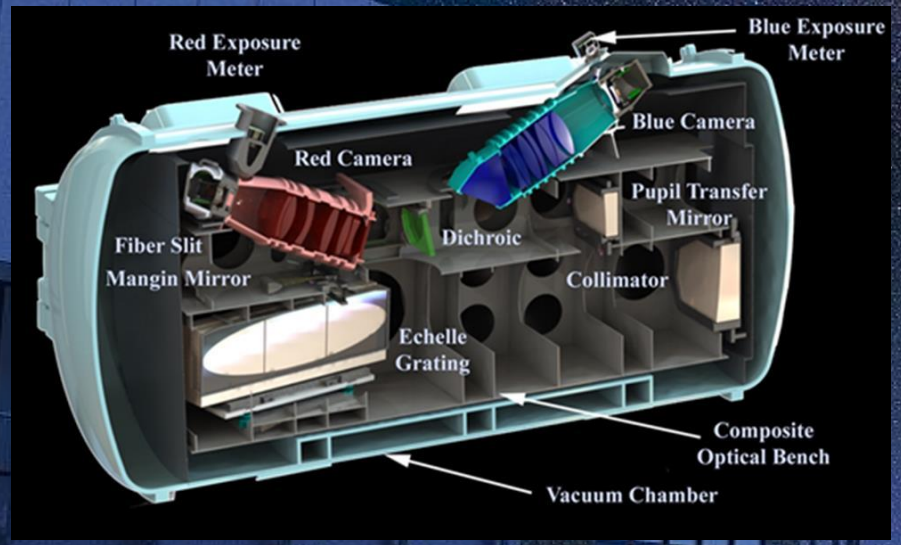
Why High Resolution ?

How High ?



Lopez-Morales+ 2019

Searching for Oxygen with



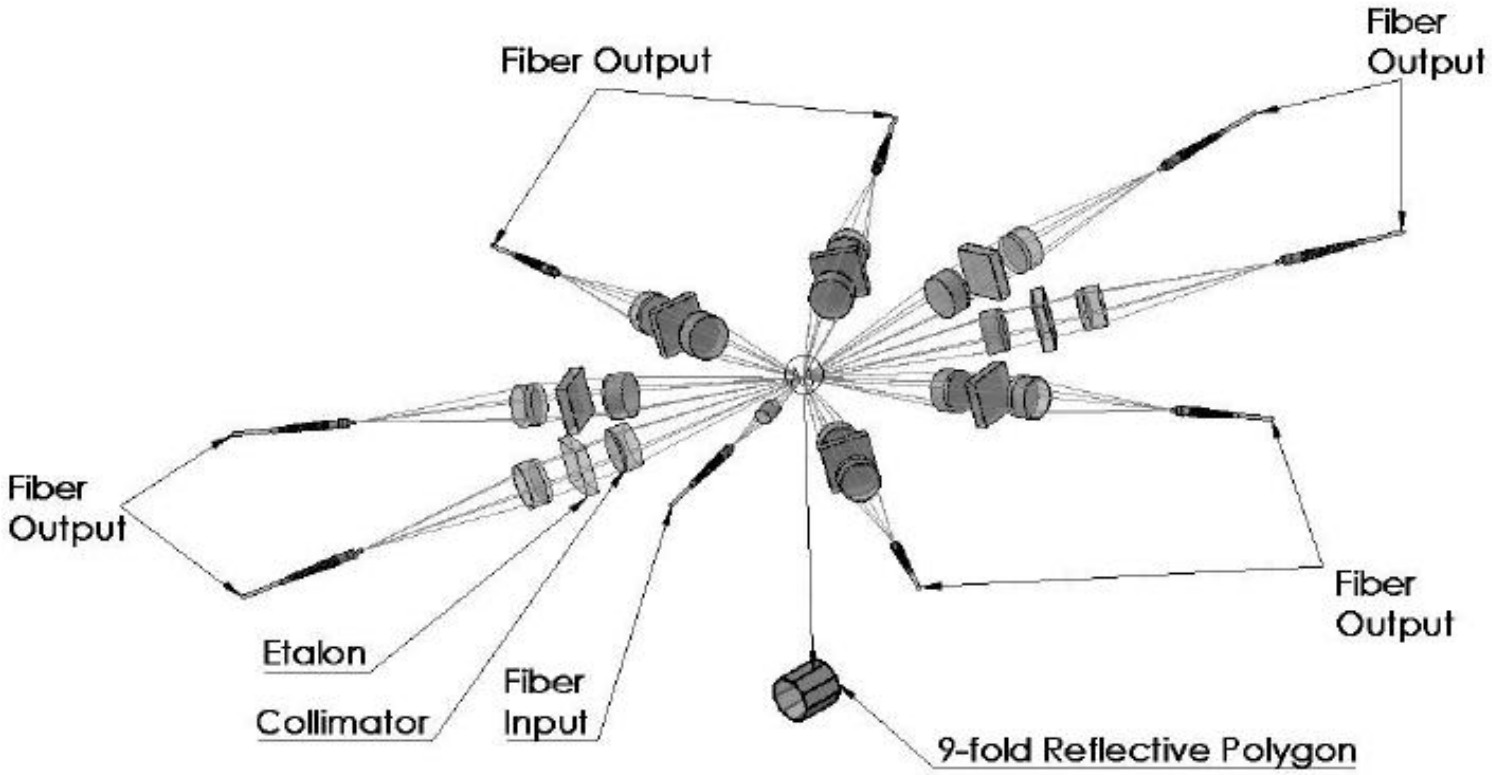
Stellar Type	P(days)	Transit Duration (h)	Number of Transits	Hours
M1V	43	4.0	33	133
M2V	33	3.4	40	133
M3V	27	3.0	44	130
M4V	16	2.1	34	70
M5V	10	1.5	53	79
M6V	6	1.1	68	75

G-CLEF spectrograph
Szentgyorgyi+ 2014, 2016

Distance 5 pc from host stars & 20 % red noise
Rodler & Lopez-Morales 2014

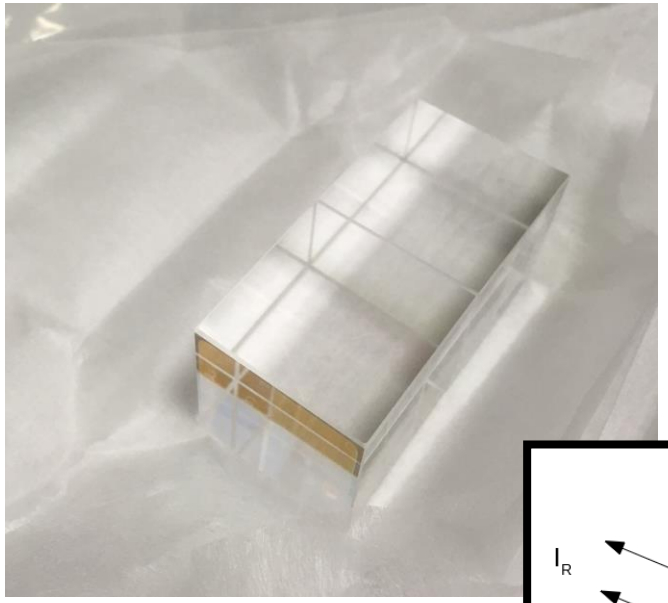
CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

Fabry Perot Instrument for Oxygen Searches

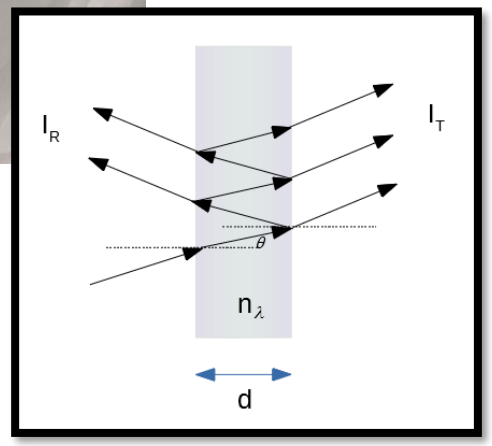


Ben-Ami+ 2018

Fabry Perot Interferometer



Etalon | Dualon



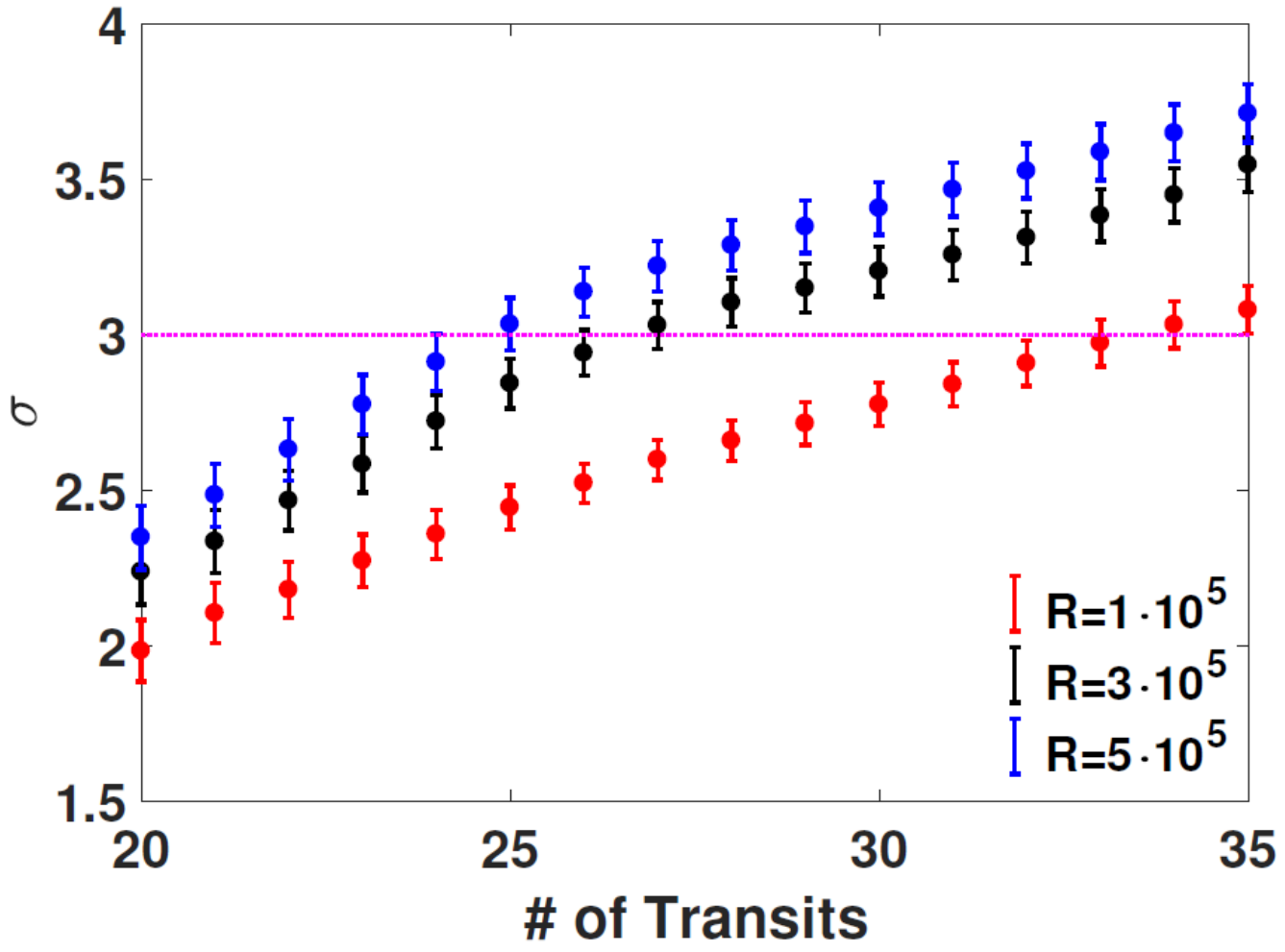
ISO OBSERVATIONS OF PLANETARY ATMOSPHERES

Th. Encrenaz[1]

[1] *DESPA, Observatoire de Paris, 92195 Meudon, FRANCE*

ABSTRACT

The Infrared Space Observatory (ISO) satellite, operated by ESA in 1995-1998, has provided a very significant contribution to our knowledge of planetary atmospheres. The main results of ISO observations of the giant planets and Titan can be summarized as follows: (1) a new determination of the D/H ratio; (2) the discovery of an external source of water, and the detection of CO_2 in the stratospheres of Saturn, Neptune and Jupiter; (3) the detection of new hydrocarbons in the stratospheres of Saturn (CH_3C_2H, C_4H_2, C_6H_6, CH_3), Jupiter (CH_3C_2H, C_6H_6) and Neptune (CH_3, C_2H_4); (4) the study of NH_3 and PH_3 in Jupiter and Saturn, and the determination of $^{14}N/^{15}N$ in Jupiter; (5) the detection of H_2O in the deep troposphere of Saturn; (6) the observation of H_3^+ in Uranus. ISO spectra of Mars have provided information about the water vapor content and the composition of aerosols.



Observing with FPI

The number of transits needed for a 3σ detection drops by 25%-35% when observing with FPI array.

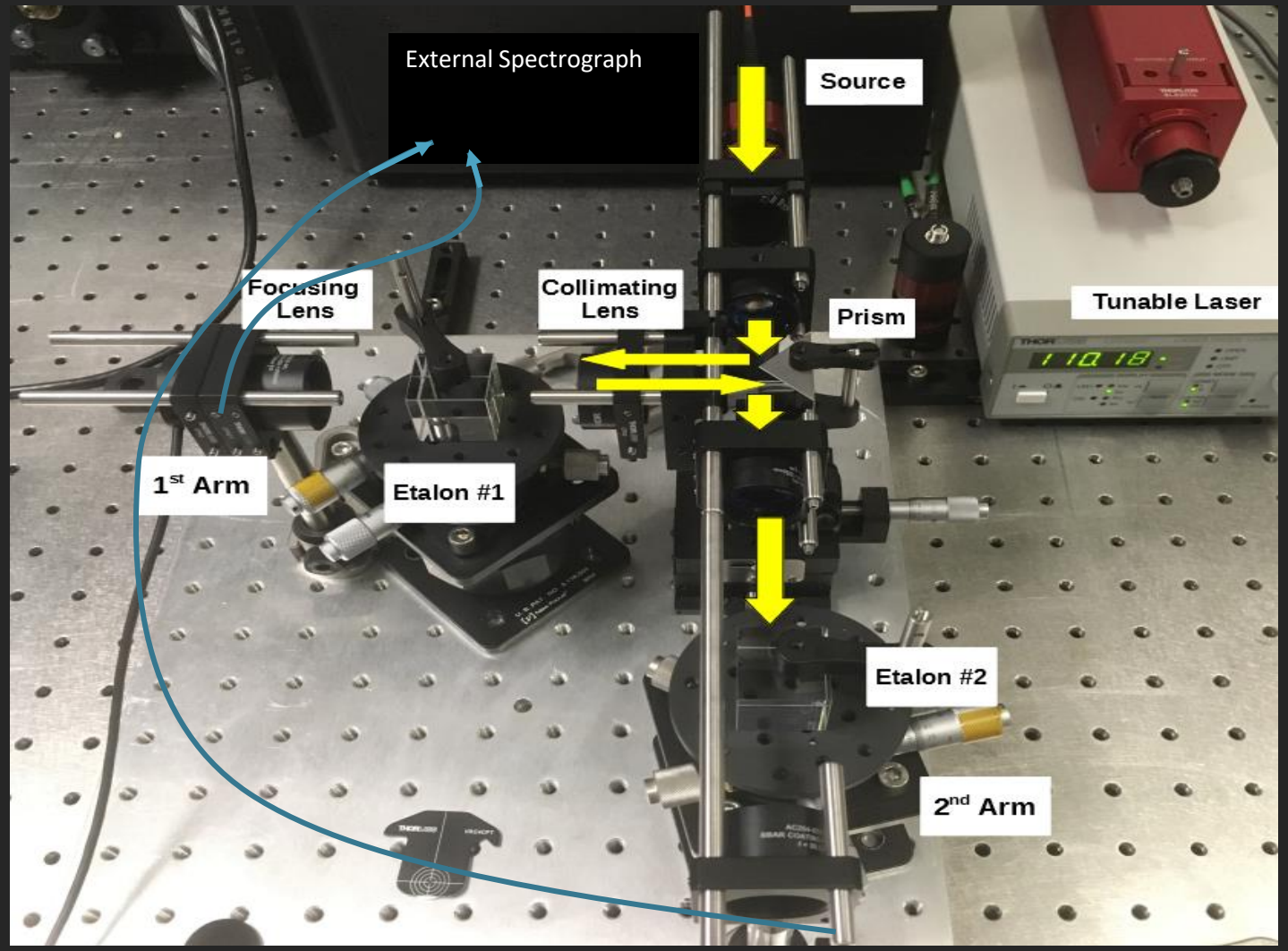
Rodler & Lopez-Morales 2014

Ben-Ami+ 2018

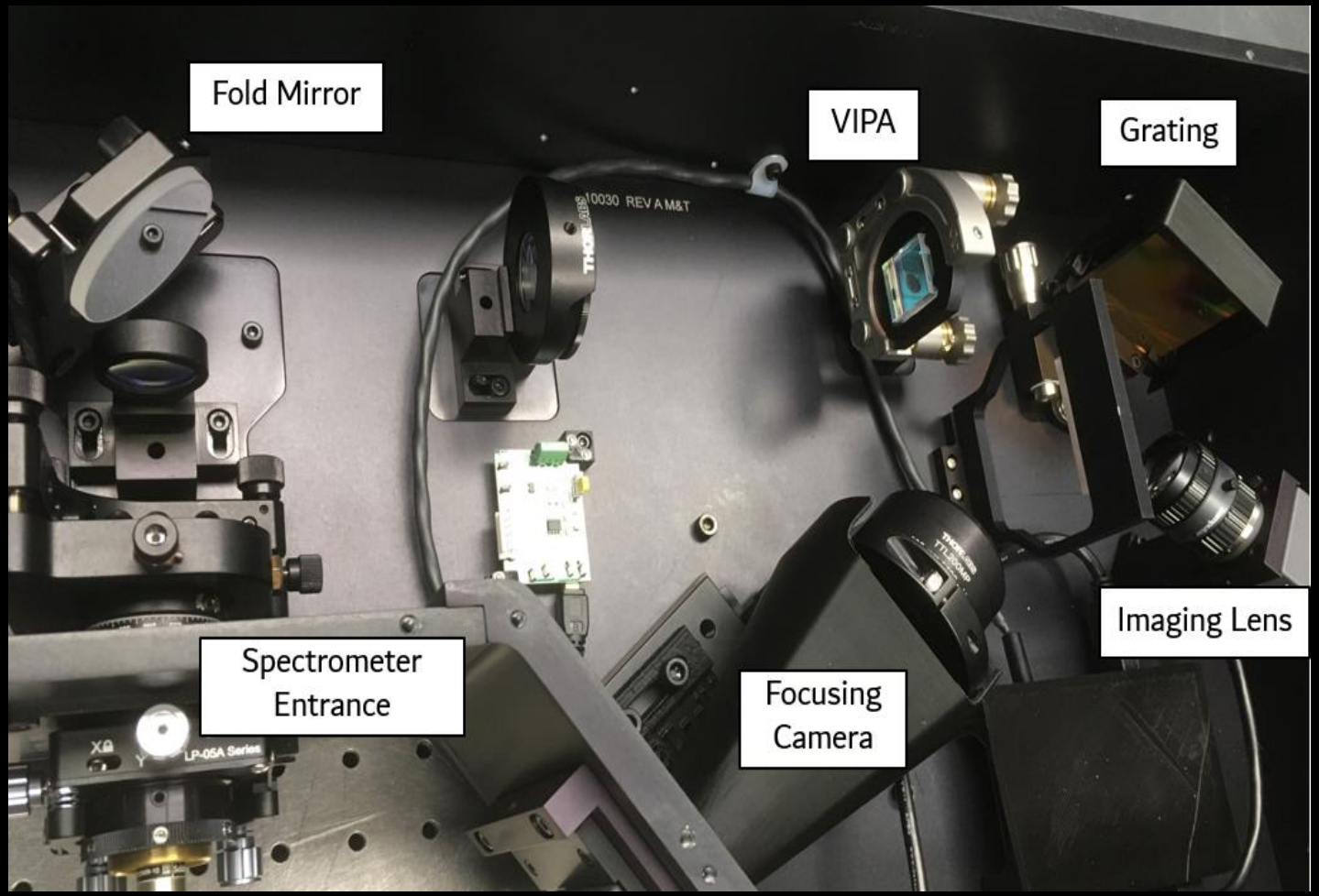
FIOS Prototype

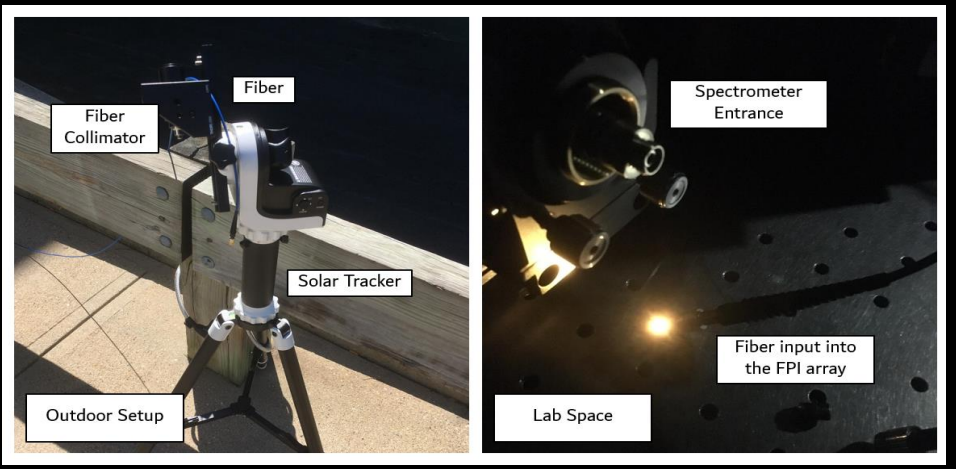
[Fabry Perot Instrument for Oxygen Searches]

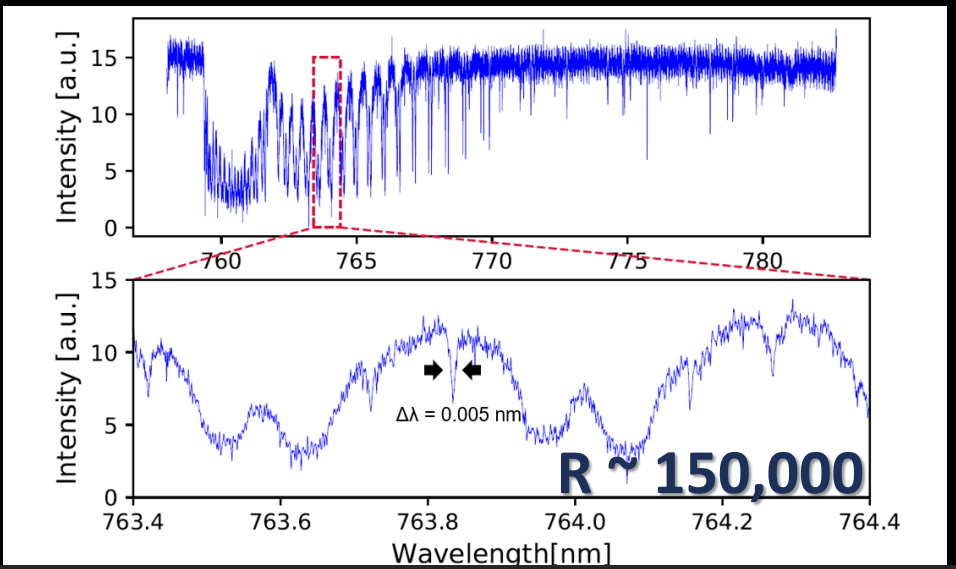
S. Rukdee, S. Ben-Ami, M. López-Morales,
J. Garcia-Mejia, D. Charbonneau, A. Szentgyorgyi



Rukdee+ 2020 SPIE



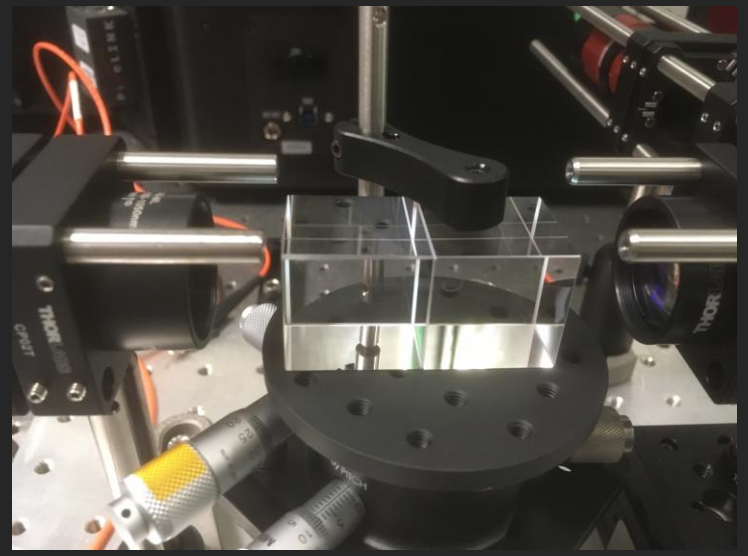




VIPA : Virtually Imaged Phased Array > Interferometry based disperser [Light-machinery]

VIPA Spectrometer

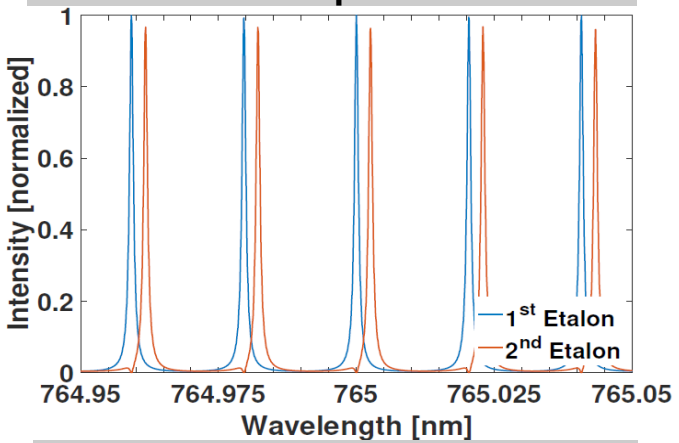
Lesson Learned from LAB DEMO



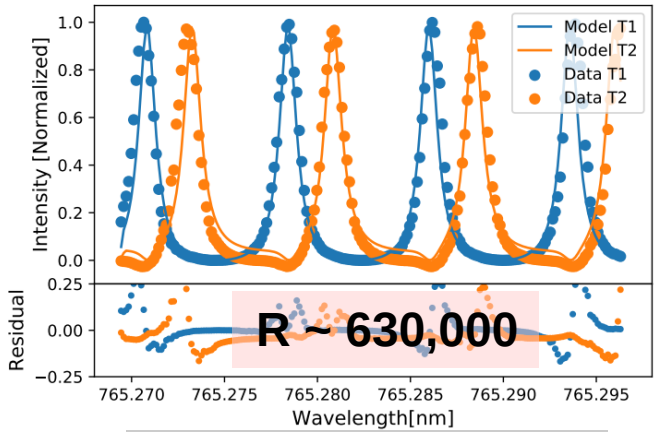
Ben-Ami+ 2018

Rukdee+ 2020 SPIE

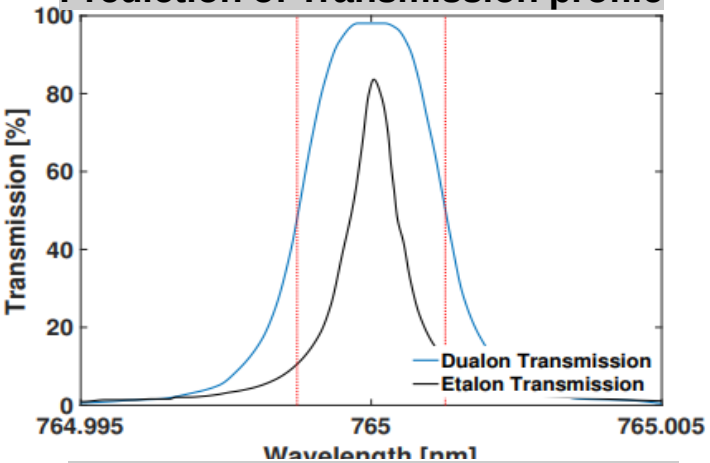
Prediction under perfect condition



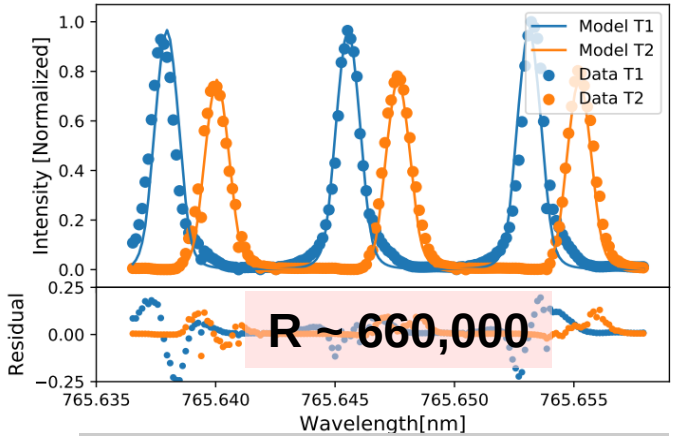
Prototype Result (Etalons)



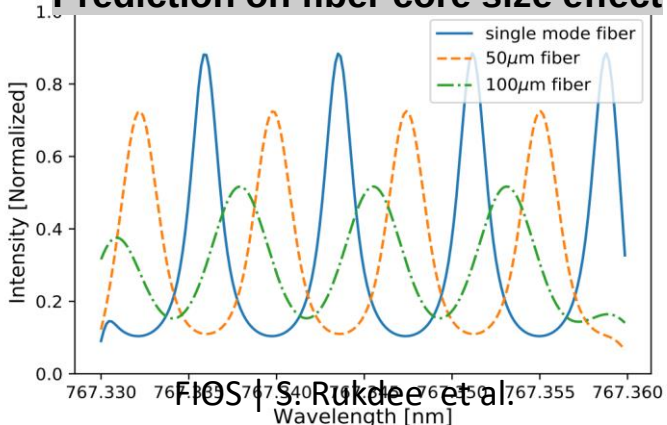
Prediction of Transmission profile



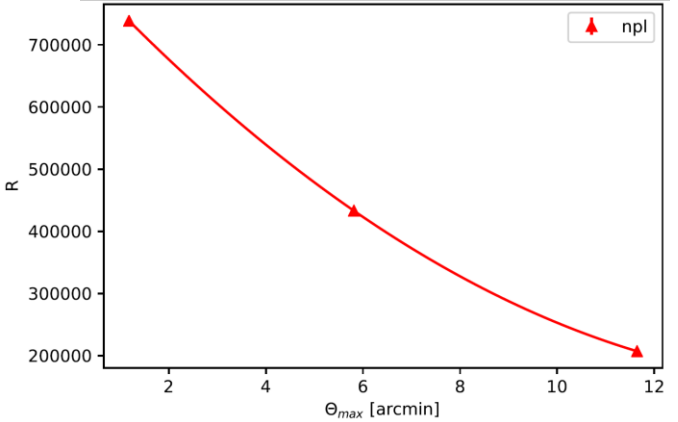
Prototype Result (Dualons)



Prediction on fiber core size effect

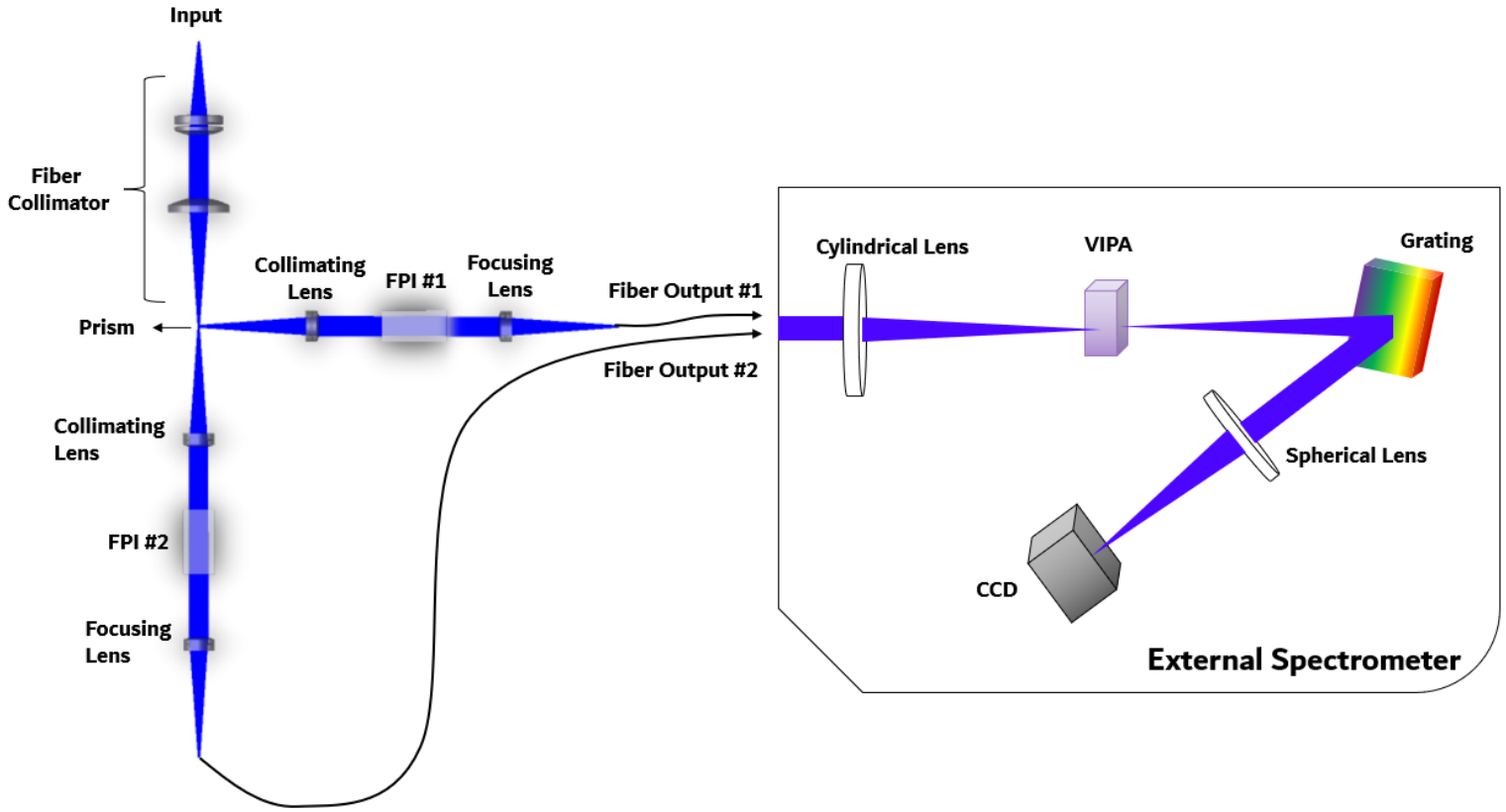


Observation fiber core size effect



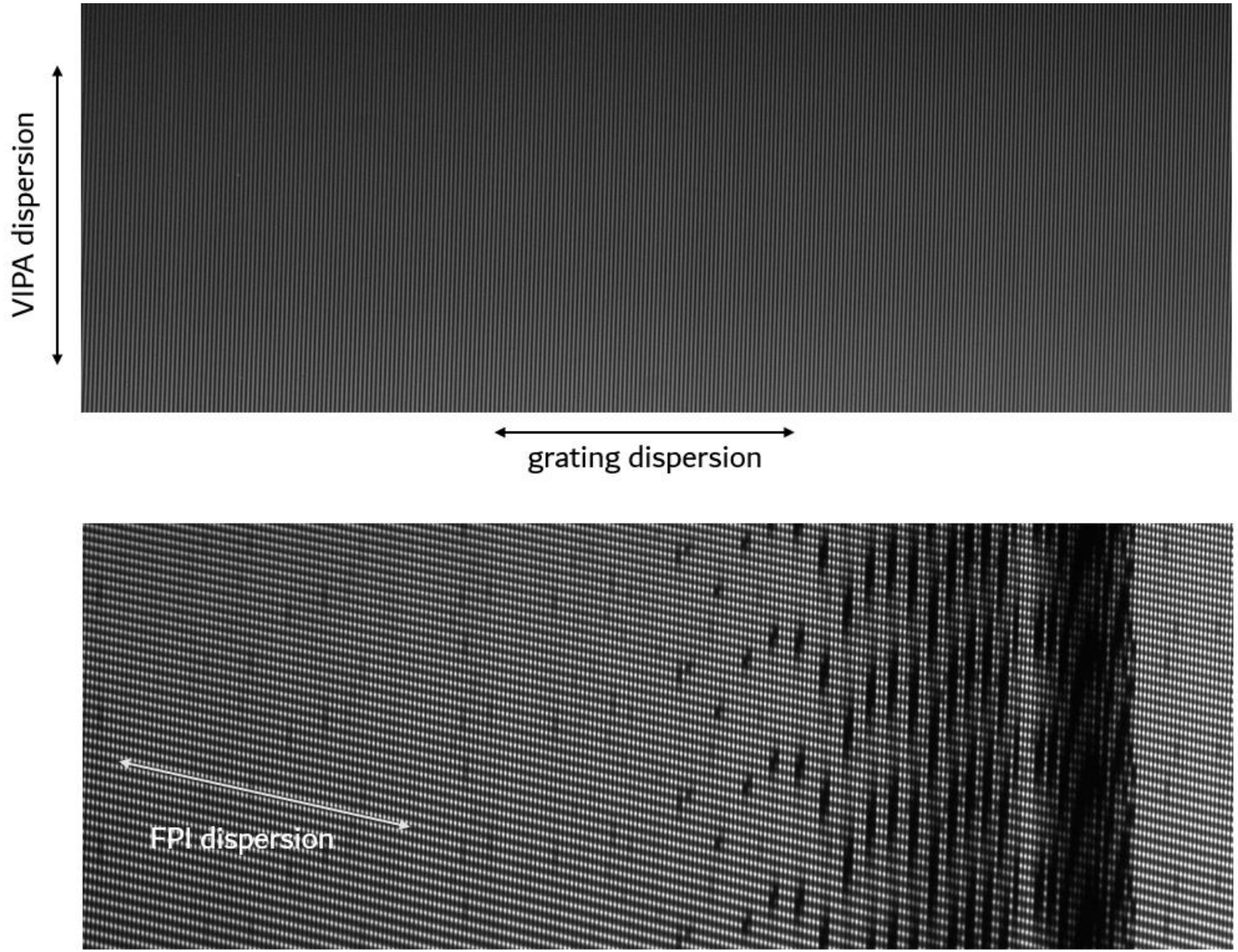
APPLICATION

RUKDEE+ 2021 (in prep.)

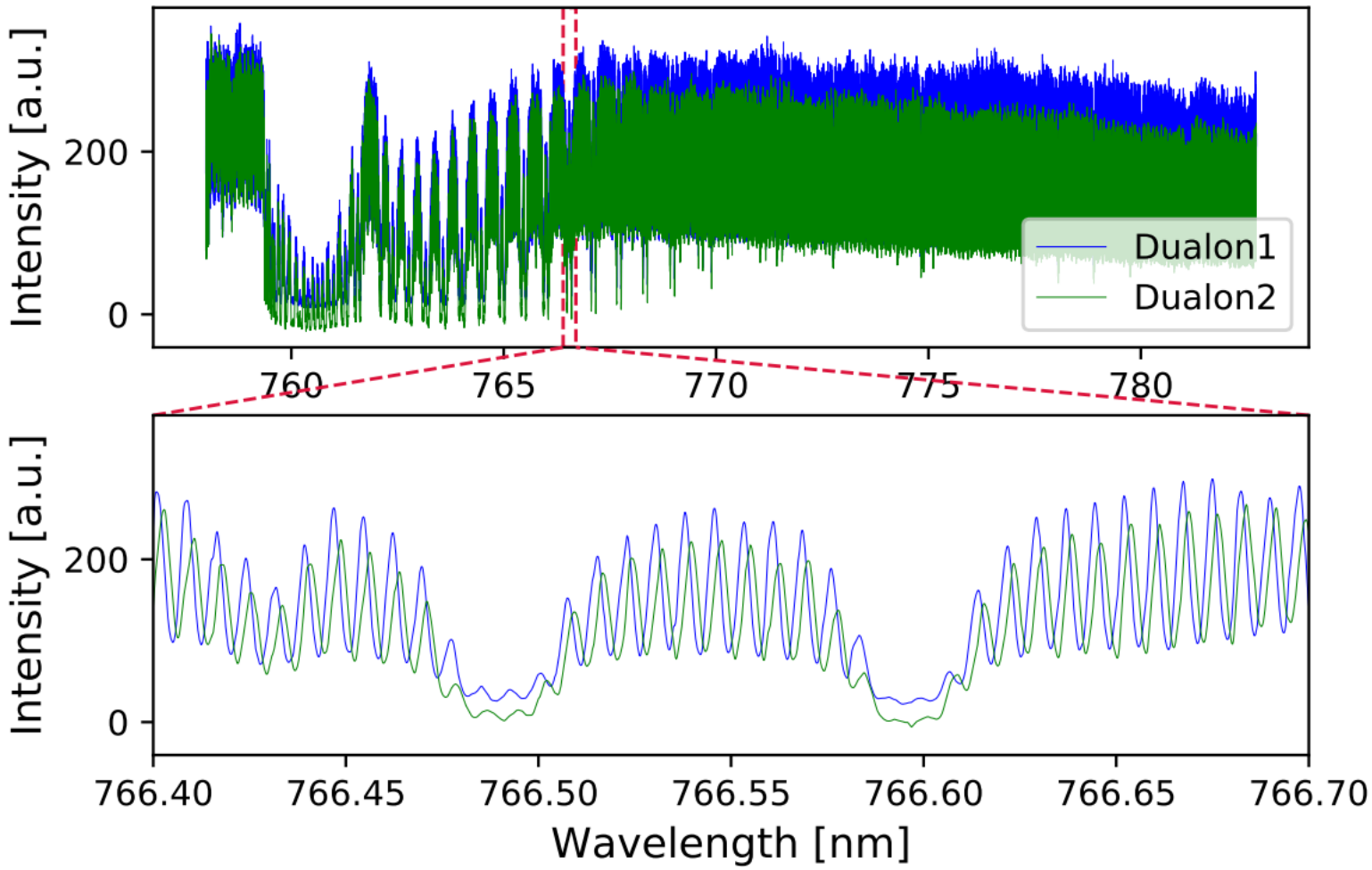


APPLICATION

RUKDEE+ 2021 (in prep.)



RESULTS
FIOS on sky

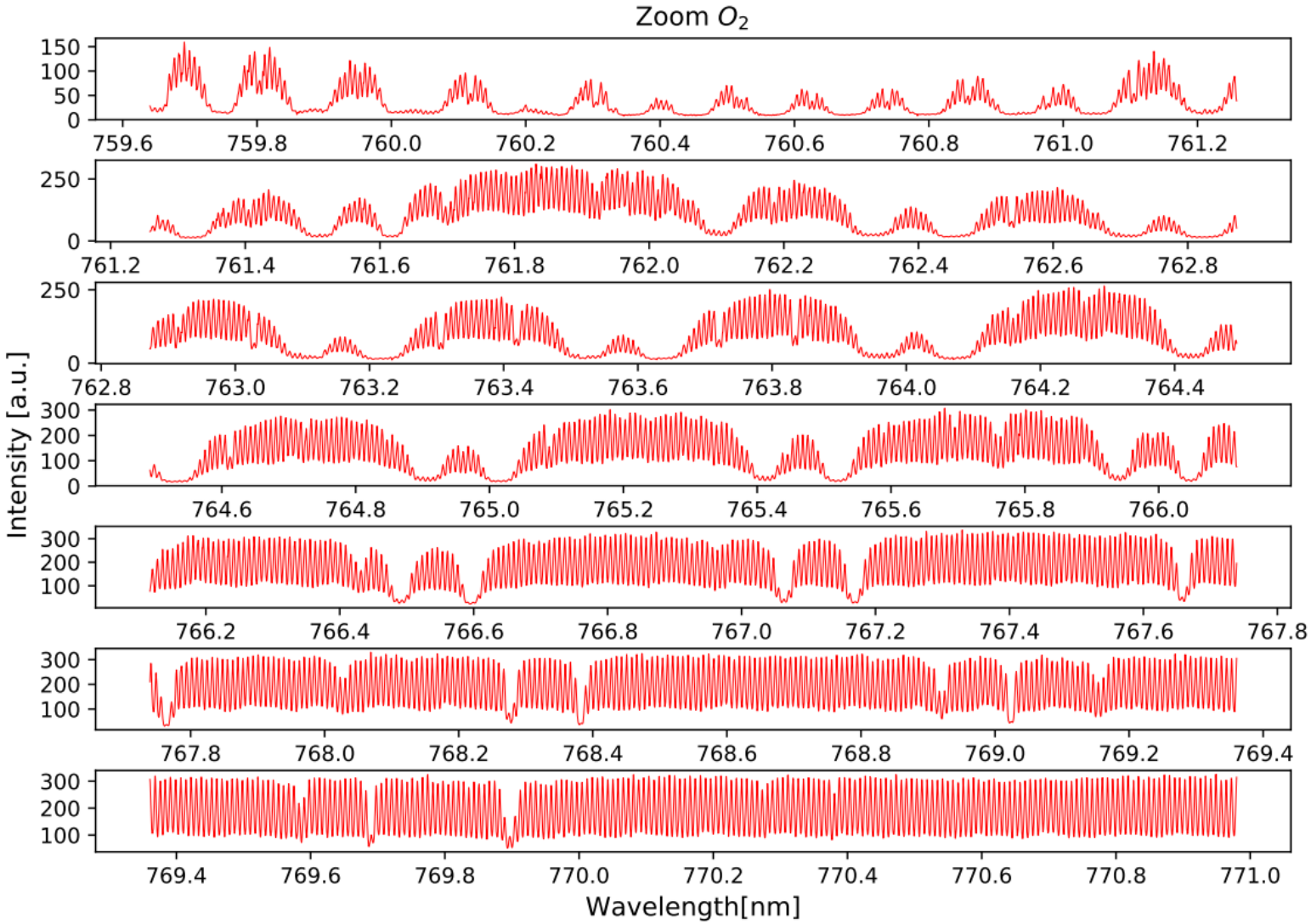


RUKDEE+ 2021 (in prep.)

RESULTS
FIOS on sky

[Boost with One FPI]

RUKDEE+ 2021 (in prep.)



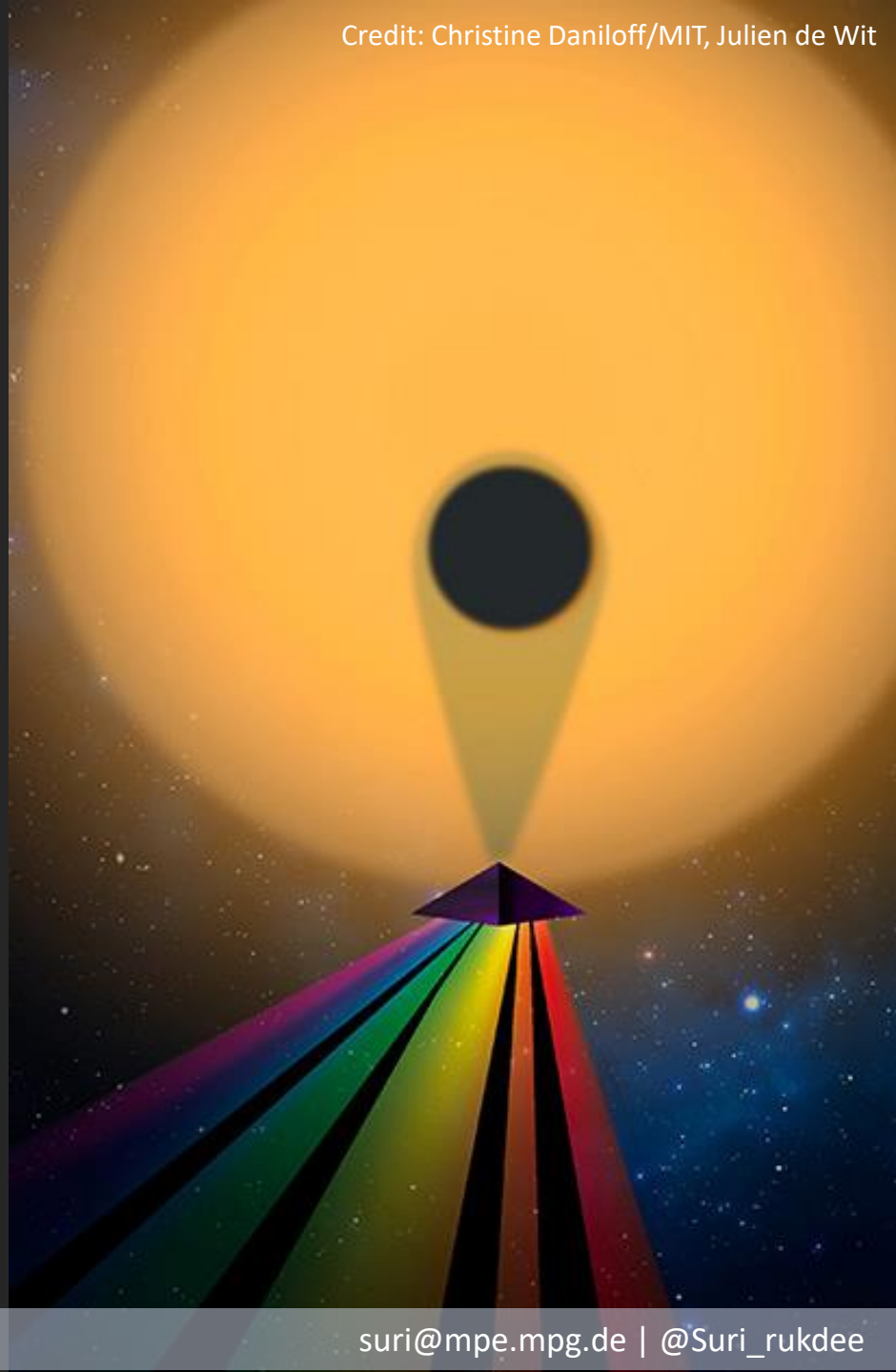
SUMMARY

FIOS is a new ultra-high resolution FPI-based instrument.

- **FPI arrays create chained spectra over the O_2 A-band.**
- **Lab prototype achieves up to R = 600,000.**
- **Dualons improve throughput and resolution.**

FIOS-like instrument should be enabled for all ELTs.

- **E-ELT HIRES + FIOS in O_2 and CH_4 channel = biotic Oxygen!**



Credit: Christine Daniloff/MIT, Julien de Wit