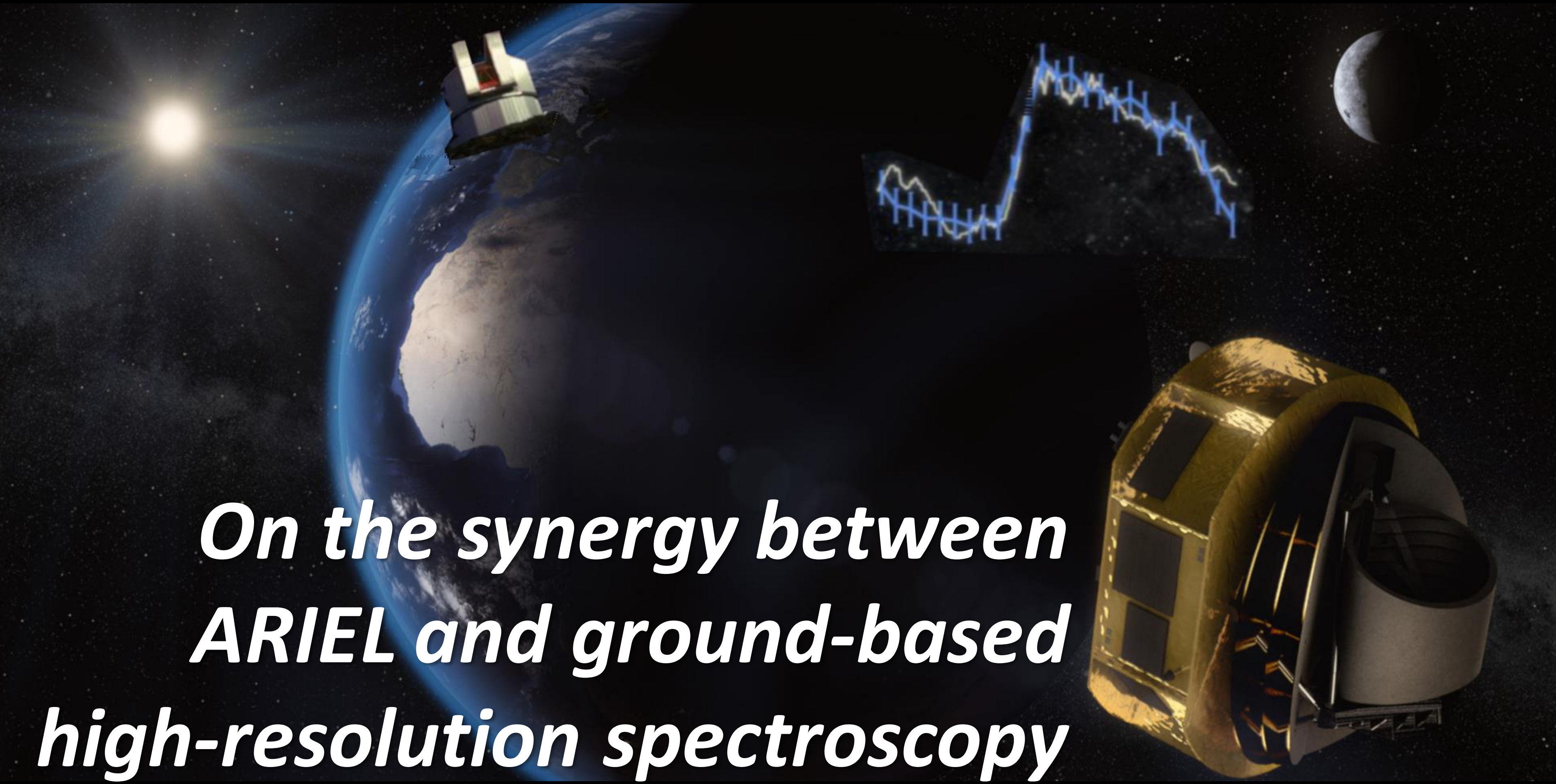


On the synergy between ARIEL and ground-based high-resolution spectroscopy

G. Guilluy, A. Sozzetti, P. Giacobbe, A.S. Bonomo, G. Micela

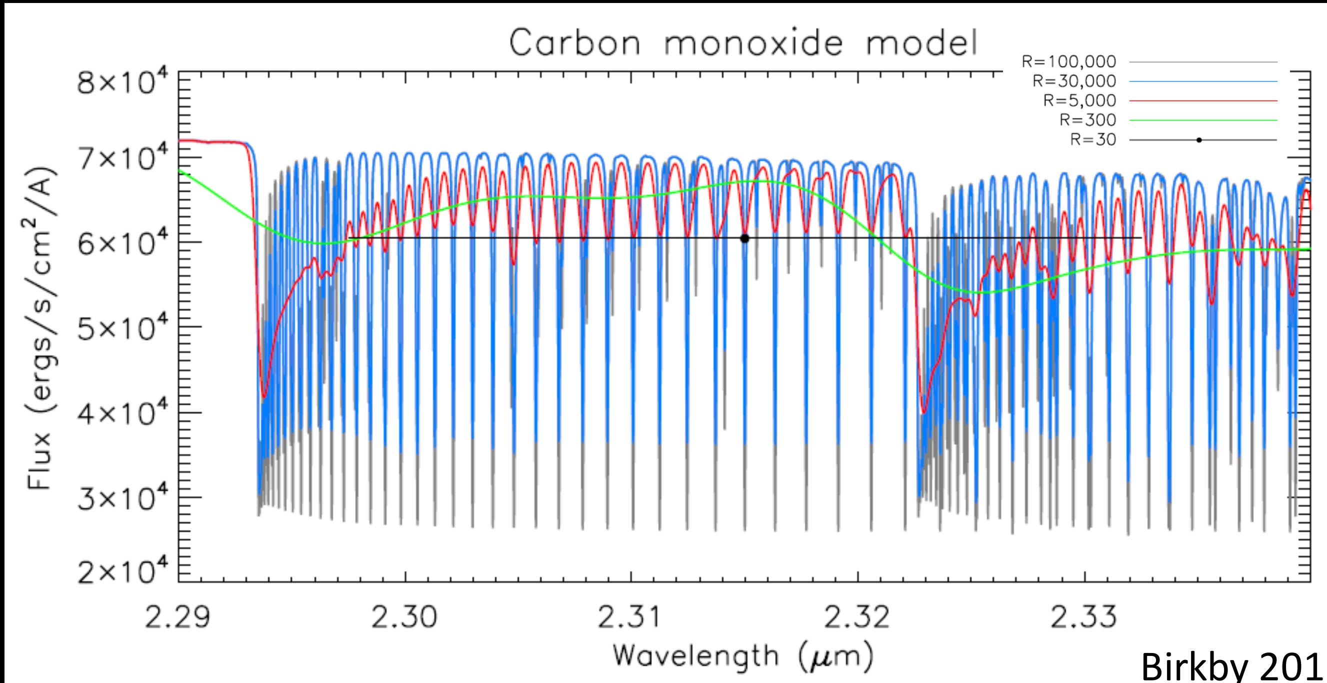
Exoplanet Atmospheres: LRS vs. HRS

LRS

- multiple species overlapping → ambiguities in molecular identification
- Space-based observation → no telluric contamination
- at LRS atmospheric retrieval starting from the observation is more readily performed

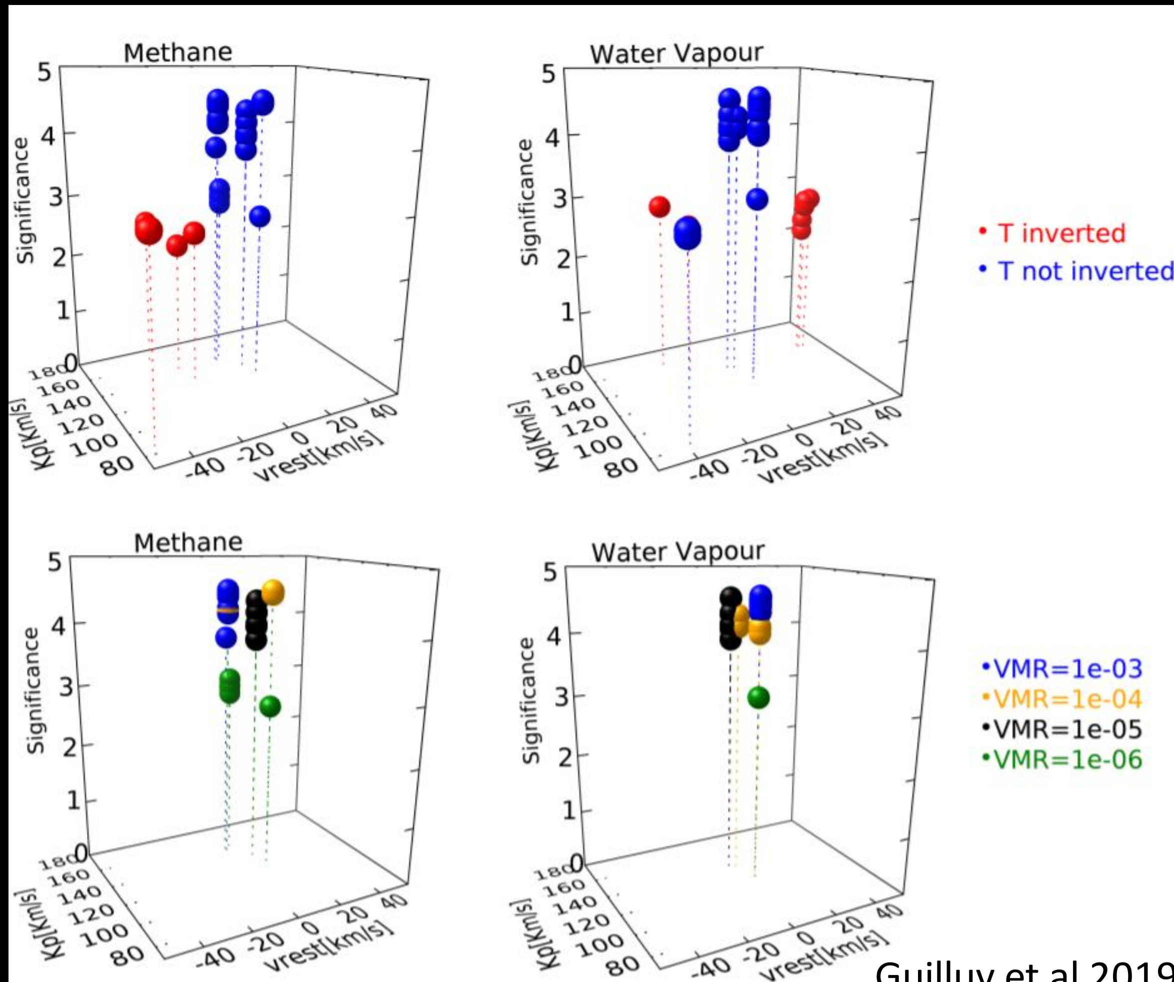
HRS

- molecular lines are resolved → no ambiguities in molecular identification
- ground-based observations → there are traces of our atmosphere
- retrieving atmospheric properties from HRS data is challenging



Birkby 2018

HRS: Abundance determination?



In some case it's difficult to set detection significances in a fully principled way, or derive temperatures and abundances as required to extract physical information on the planet's atmosphere

Combining HRS & LRS

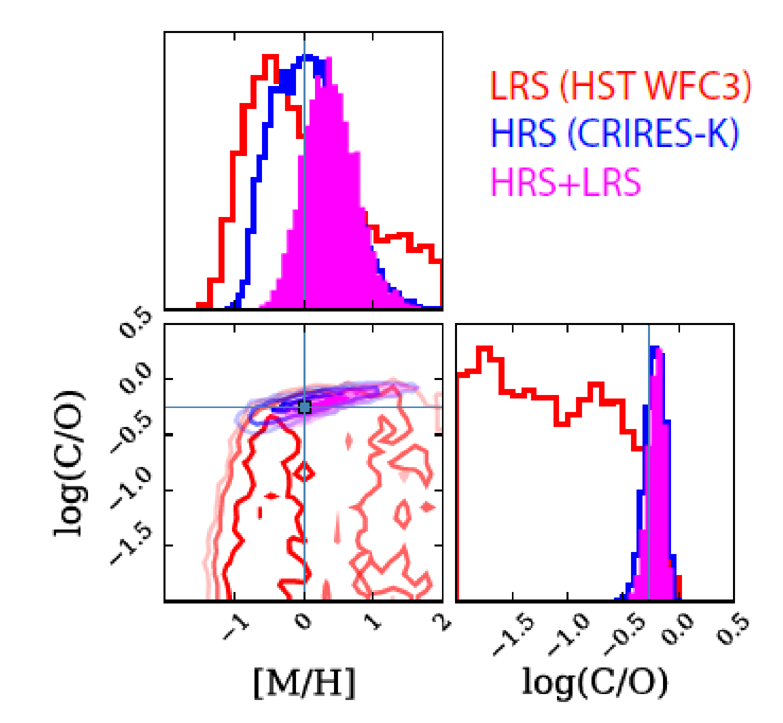
The potential for improved characterization applies to the combination of HRS from the ground with HST, JWST, and naturally ARIEL LRS

- Brogi&Line2019 introduce a robust unbiased framework to combine HRS and LSR

→ they analysed a narrow spectral range: the VLT CRIRES K-band

- Now spectrographs like GIANO-B, CARMENES, SPIROU are available and soon NIRPS and CRIRES+

→ we have to apply this framework on a bigger spectral coverage



Brogi & Line 2019

A study case

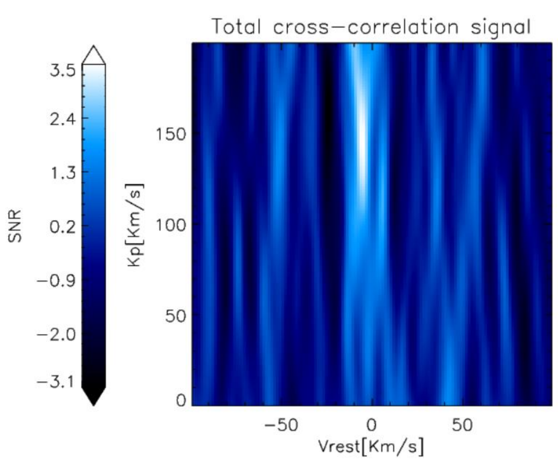
- A representative Hot Jupiter
- Separate LRS & HRS analysis (multiple molecules) – real data
- Adding ARIEL simulated data
- First qualitative statements and work in progress

GIANO-B analysis

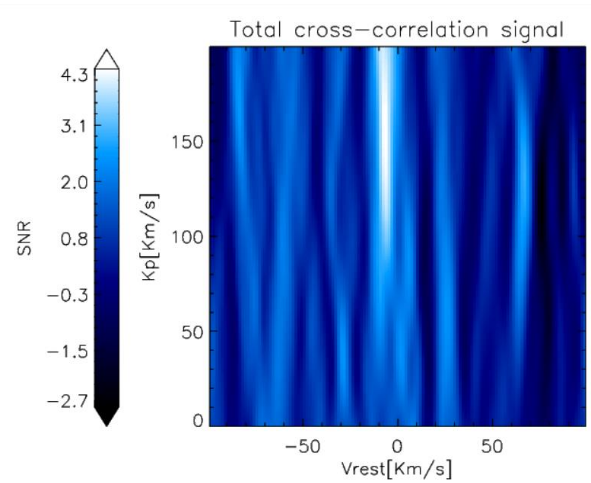
- 4 transit nigths gathered with GIANO-B.
- Spectra extraction and wavelength calibration performed with the GOFIO tool (M. Rainer)
- PCA analysis to separate the planetary signal from the stellar and telluric contamination
- Cross-correlation with model templates (Guillot T/P profile)
- Shift in the planetary rest frame.

Instrument	GIANO-B
Location	TNG, La Palma (Spain)
Spectral coverage	(0,95-2,45) µm
Resolution	50 000

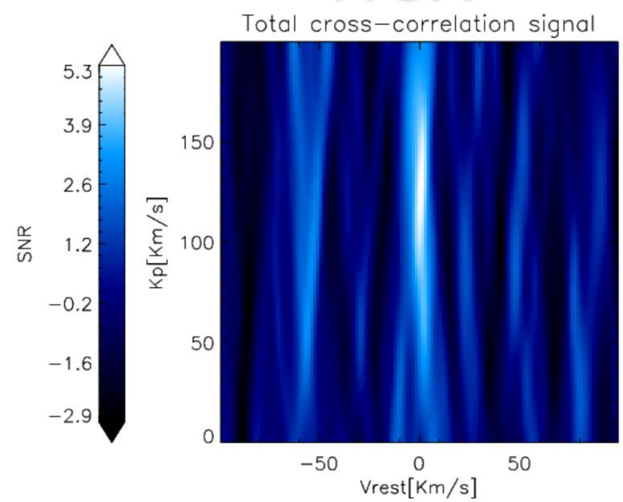
CO



H_2O

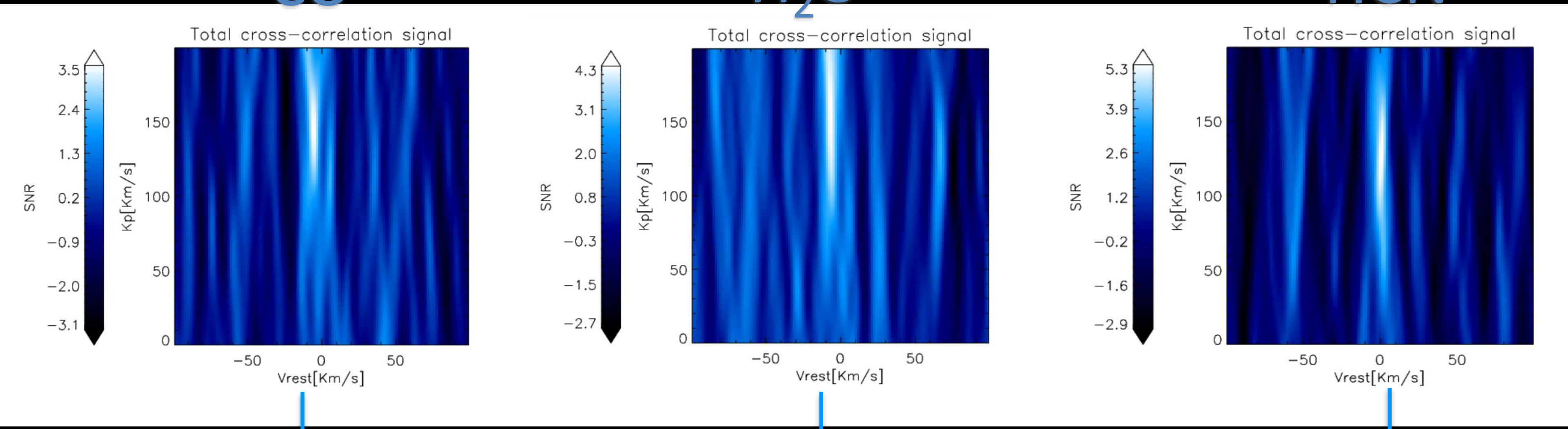


HCN



Giacobbe et al. in Prep

CO H_2O HCN



$\log_{10}(CO)$=-3,920 $\log_{10}(H_2O)$= -5,097 $\log_{10}(HCN)$=-4,398

- If we decrease of 1 order of magnitude the $\log_{10}(H_2O)$ the SNR decreases, of 2 orders the detection becomes very weak

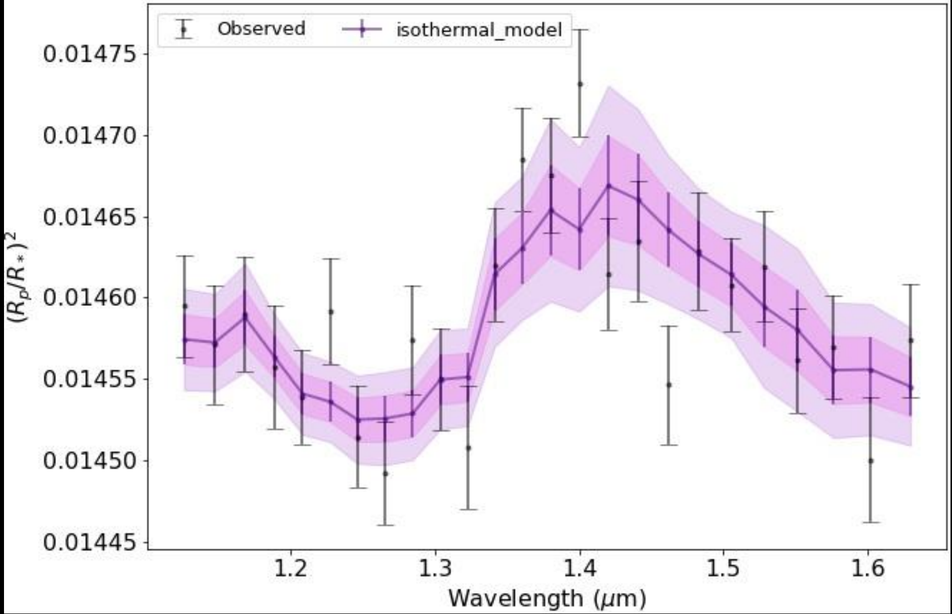
- It is analogous for CO, and HCN.

Giacobbe et al. in Prep

HST/WFC3 analysis

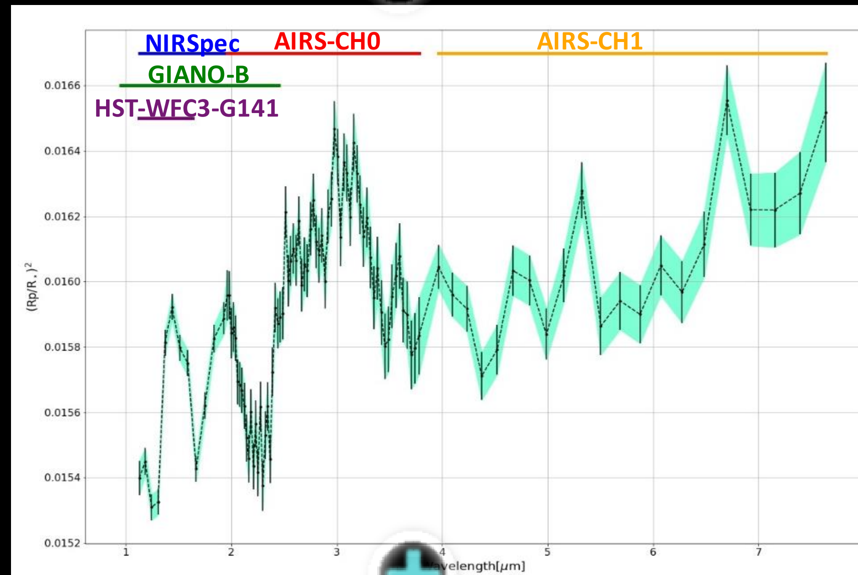
-1 HST/WFC3 visit analysed with the public avaiable **Iraclis pipeline** (Tsiaras et al. 2018a) **TauREx** atmospheric retrieval code (Waldmann et al. 2015a,b)

	H2O+HCN+CO Isothermal T/P profile	H2O+HCN+CO Guillot T/P profile
σ	6	6
Log10(H2O)	$-4{,}38^{+0{,}33}_{-0{,}32}$	$-4{,}59^{+0{,}20}_{-0{,}25}$
Log10(HCN)	$-6{,}19^{+0{,}90}_{-1{,}17}$	$-6{,}42^{+0{,}82}_{-0{,}95}$
Log10(CO)	$-5{,}37^{+2{,}23}_{-1{,}81}$	$-5{,}53^{+1{,}76}_{-1{,}56}$



ARIEL Simulation

Forward model with [TauREx logo], scaled to the Ariel res + **Noise** from **ArielRad** (Mugnai2020 sub)



Retrieval with [TauREx logo]

Instrument	Range[µm]	log(H2O)	log(CO)	log(HCN)
Input		-3.920	-5.097	-4.398
NIRSpec	1,12-1,93	$-3.31^{+0,30}_{-0,56}$	$-4.97^{+1,95}_{-2,02}$	$-4.22^{+0,39}_{-0,67}$
AIRS-CH0	1,95-3,78	$-3{,}92^{+0,17}_{-0,20}$	$-6{,}17^{+1,58}_{-1,27}$	$-4{,}50^{+0,22}_{-0,22}$
AIRS-CH1	3,96-7,63	$-4.57^{+0,56}_{-0,83}$	$-6.81^{+1,06}_{-0,79}$	$-4.93^{+0,48}_{-0,59}$
HST-WFC3-G141	1,125 – 1,650	$-4.17^{+0,99}_{-0,67}$	$-4.87^{+2.12}_{-2.16}$	$-4.59^{+0,84}_{-0,77}$
GIANO	0,95-2,45	$-3{,}59^{+0,25}_{-0,24}$	$-5{,}74^{+1,82}_{-1,54}$	$-4{,}16^{+0,27}_{-0,27}$

Preliminary Inferences

- We need a comparison between the LSR and the HSR results before combining them
- Where we note differences, we have to combine HSR and LSR
- Following Brogi&Line2019 (or similar approaches) we can combine LSR and HSR on a range as wide as the GIANO-B one

To do next…

- Complete the development of a framework to:

a) directly compute the likelihood of the model fit to the data, and explore the posterior distribution of parameterised model atmospheres

b) explore how to break degeneracies, detect additional molecules, adopt more sophisticated atmospheric models

A true synergy between space observatories and ground-based high-resolution observations lies ahead!