# ARIEL

Enabling planetary science across light-years

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# PLANETS ARE UBIQUITOUS.

OUR GALAXY IS MADE OF GAS, STARS & PLANETS

There are at least as many planets as stars

# EXOPLANETS TODAY: HUGE DIVERSITY

3800+ PLANETS, 2700 PLANETARY SYSTEMS KNOWN IN OUR GALAXY



# HUGE DIVERSITY: WHY?

FORMATION & EVOLUTION PROCESSES? MIGRATION? INTERACTION WITH STAR?



### STAR & PLANET FORMATION/EVOLUTION

What we know: constraints from observations – Herschel, Alma, Solar System



#### Measured elements in Solar system

# **KEY EXOPLANET QUESTIONS**

• How diverse are exoplanets chemically?

- Does chemical diversity correlate with other parameters?
  - How do planets form?
  - How do planets evolve?



# THE SUN'S PLANETS ARE COLD

### Some key O, C, N, S molecules are **not** in GAS form





# WARM/HOT EXOPLANETS

O, C, N, S (TI, VO, SI) MOLECULES ARE IN GAS FORM



# **ISSUES WITH CURRENT DATA**

- WE ARE DEALING WITH LOW SNR & R OBSERVATIONS
- DATA ARE SPARSE, NOT ENOUGH WAVELENGTH COVERAGE
- BROAD WAVELENGTH COVERAGE IS NOT SIMULTANEOUS
- Absolute Calibration at the level of 10-4 is not guaranteed!
- INSTRUMENT SYSTEMATICS ARE DIFFICULT TO DISENTANGLE FROM THE SIGNAL
- Stellar activity is the largest source of astrophysical noise
- WE NEED OBSERVATIONS ON A POPULATION OF OBJECTS TO DRAW CONCLUSIONS

INAF – Sept. 2018

# ARIEL – ESA M4 mission

- 1-m telescope, spectroscopy from VIS to IR
- Satellite in orbit around L2
- ~1000 exoplanets observed (rocky + gaseous)
- Simultaneous coverage 0.5-7.8 micron
- Payload consortium: 16 ESA countries + NASA under study







# A CHEMICAL SURVEY OF A LARGE POPULATION

SCIENCE REQUIREMENTS: EXOPLANET RADIATION, MOLECULAR & CLOUD SIGNATURES, STAR ACTIVITY



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Aiming at 10 ppm stellar flux at multiple wavelengths



Through stable instrument, external calibration & proven postprocessing analysis







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COLOUR-MAGNITUDE DIAGRAMS, PRELIMINARY CLOUD-CHARACTERISATION

 Colour-colour diagrams and colour-magnitude diagrams in the IR and VIS will allow to identify families of planets



Triaud 2015; Mollière et al., 2016





(NON)-EQUILIBRIUM CHEMISTRY? ATMOSPHERIC CIRCULATION? CLOUD PATTERN?







CORRELATION WITH ANY OTHER KEY PARAMETERS?







ARIEL WILL CLARIFY CORRELATION WITH THE DENSITY



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![](_page_18_Picture_0.jpeg)

# **ERRESTRIAL-SUBNEPTUNES TRANSITION**

![](_page_18_Picture_2.jpeg)

ARE SUPER-EARTHS BIG TERRESTRIAL PLANETS, SMALL NEPTUNES? IS H/HE STILL THERE?

### Formation scenarios for small planets

### **ARIEL** observations for small planets

![](_page_18_Figure_6.jpeg)

Figure by M. Rocchetto,

![](_page_19_Picture_0.jpeg)

# IS ELEMENTAL COMPOSITION CORRELATED ...

![](_page_19_Picture_2.jpeg)

#### ... TO EXOPLANET PROVENANCE OR STELLAR METALLICITY?

![](_page_19_Figure_4.jpeg)

ARIEL retrieval WG., Turrini et al., 2018

![](_page_20_Figure_0.jpeg)

### LARGE POPULATION OF WARM/HOT PLANETS

![](_page_21_Figure_1.jpeg)

![](_page_22_Figure_0.jpeg)

![](_page_23_Picture_0.jpeg)

# DIVERSITY PROBED IN ARIEL CORE SAMPLE

PLANET SIZE, DENSITY, TEMPERATURE, STAR TYPE, METALLICITY

![](_page_23_Figure_3.jpeg)

![](_page_24_Picture_0.jpeg)

# DIVERSITY PROBED IN ARIEL CORE SAMPLE

PLANET SIZE, DENSITY, TEMPERATURE, STAR TYPE, METALLICITY

![](_page_24_Figure_3.jpeg)

![](_page_25_Picture_0.jpeg)

# DIVERSITY PROBED IN ARIEL CORE SAMPLE

#### PLANET SIZE, TEMPERATURE, STAR TYPE, METALLICITY

![](_page_25_Figure_3.jpeg)

# SYNERGIES/COMPLEMENTARITIES WITH JWST

![](_page_26_Picture_1.jpeg)

### JWST CANNOT OBSERVE 1000 PLANETS

![](_page_26_Figure_3.jpeg)

# ARIEL OPTIMAL DESIGN & PERFORMANCES

![](_page_27_Picture_1.jpeg)

![](_page_27_Figure_2.jpeg)

#### SYNERGIES/COMPLEMENTARITIES WITH ELT HIGHLY COMPLEMENTARY TO LARGE, GROUND-BASED FACILITIES **E-ELT** Simulations 0.0218 0.0008 Fitted model 0.0006 Observed Signal 0.0216 0.0004 0.0002 0.0214 0.0000 -0.0002 2.29 2.30 2.32 2.31 Wavelength $(\mu m)$ 0.0212 ARIEL spectra give the continuum 0.0210 at broad wavelength range 0.5 0.7 8 3 Wavelength (µm) INAF – Sept.2018

### PHASE B HAS STARTED...

### **150** SCIENTISTS ALREADY AT WORK!

![](_page_29_Figure_3.jpeg)

### CONCLUSIONS

![](_page_30_Picture_1.jpeg)

- Exoplanets appear to be ubiquitous in our Galaxy
- Current sample of discovered exoplanets is very diverse in terms of basic planetary/orbital parameters.
- Molecular & elemental composition can help to understand the nature and history of exoplanets
- Hubble, Spitzer, ground-based instruments have delivered pioneering observations of exoplanet atmospheres
- We need more accurate observations over a broader wavelength range (JWST) for a statistically large sample of planets (ARIEL) to understand the chemical diversity.
- ARIEL has been conceived to deliver the first chemical survey of ~ 1000 exoplanets, probing
  uniformly the gamut of planet and stellar parameters

![](_page_31_Picture_0.jpeg)

### Join the ARIEL team!

![](_page_31_Picture_2.jpeg)

![](_page_31_Picture_3.jpeg)