



# Determination of ages for planet hosting stars

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# Why are the ages of planet hosting stars so important?



1. The only way to determine the age of the planets

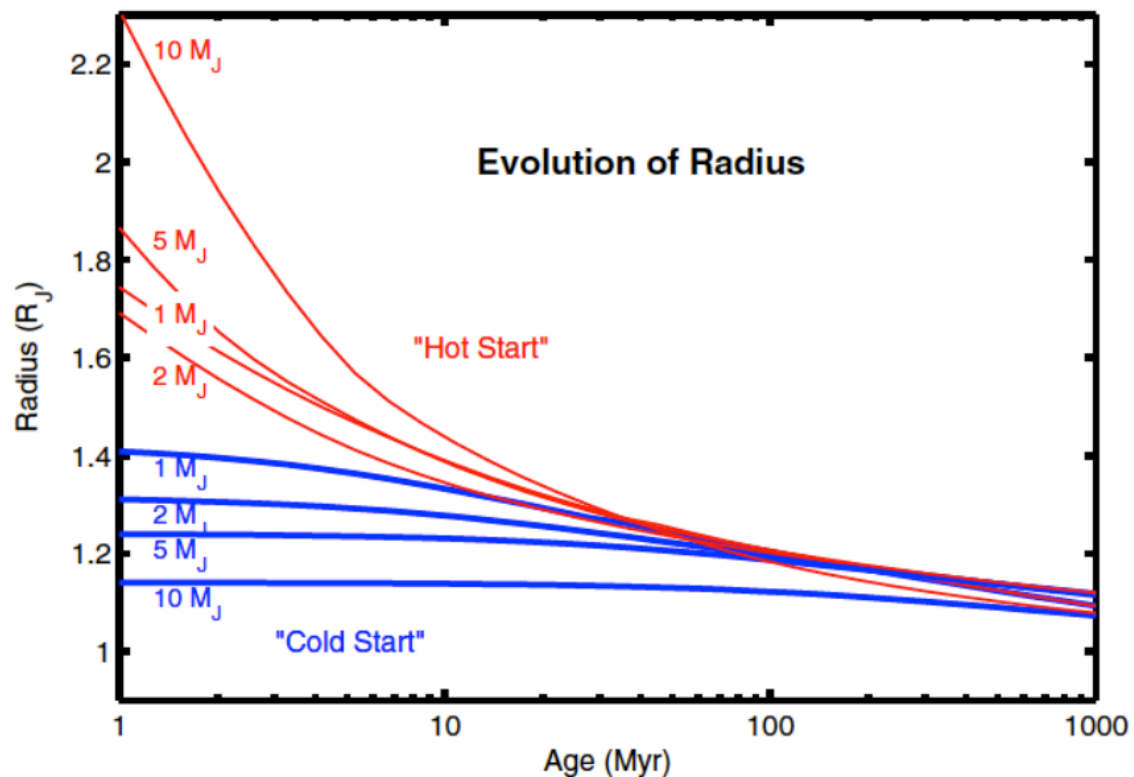
1. Many properties of the stars depend on its age (e.g. luminosity, activity)



1. Formation and migration mechanisms;
2. Evolution of planet interiors;
3. Effect of stellar irradiation on planet atmosphere

# Formation and migration mechanisms

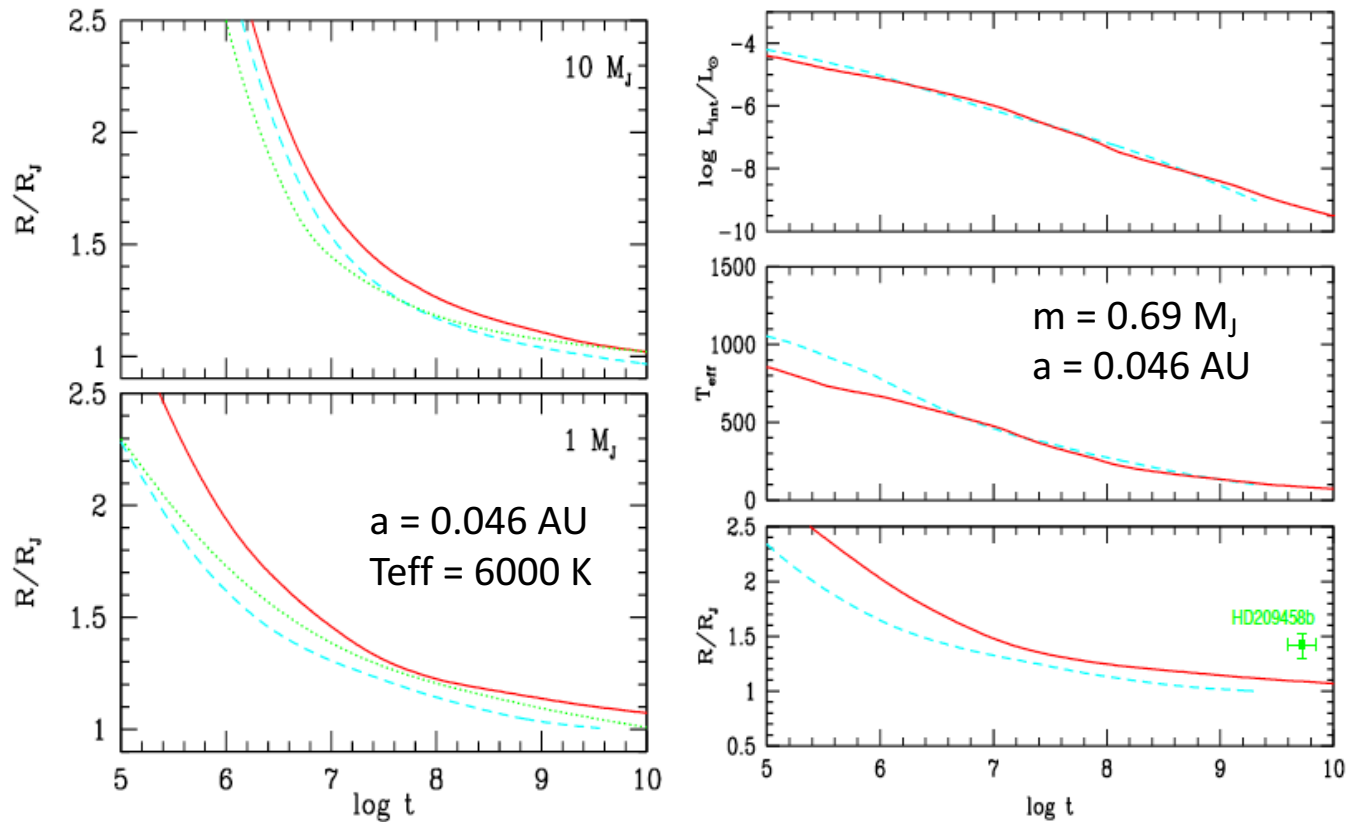
1. Precise age determinations of transiting young planets may help to determine how they form;
1. Migration within protoplanetary disks or dynamical interactions occur on different timescale;



Spiegel & Burrows (2012)

# Evolution of irradiated planets

The main properties of close-in planets depend both on age and stellar irradiation



(Baraffe et al. 2003)



# How do we to measure the age of single star?



Type	Method	PMS	MS
Semifundamental	Nucleocosmochronometry		X
	Kinematic	X	X
Model -dependent	Isochrones	X	X
	asterosismology		X
Empirical	Gyrochronology		X
	Activity		X
	Lithium	X	

(adapted from Soderblom et al. 2010)

# Kinematic Ages

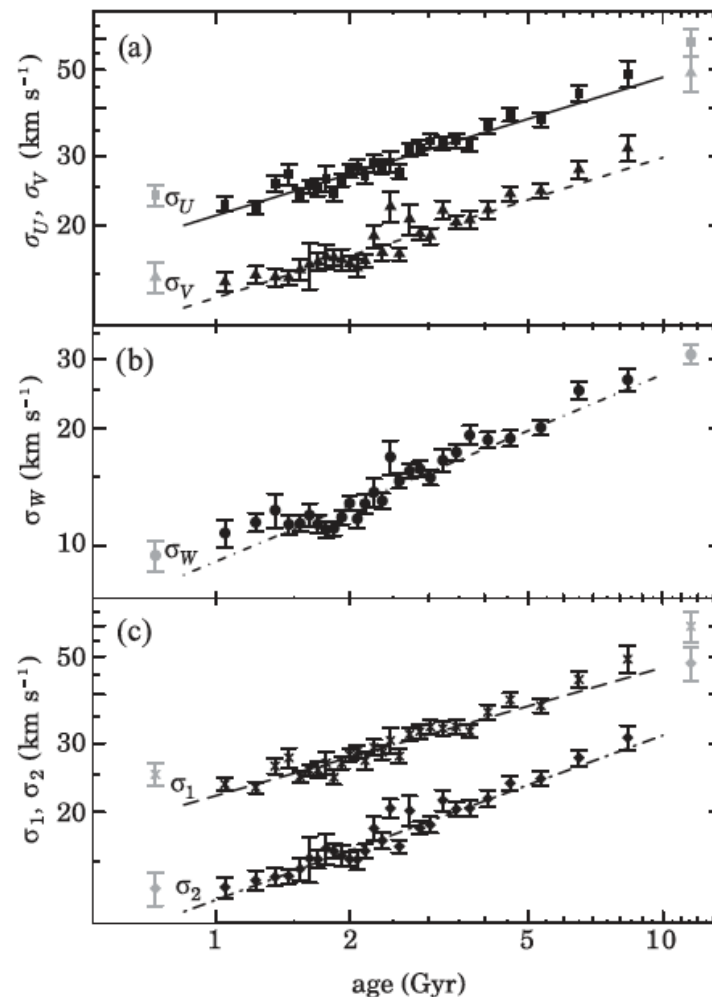
## 1. Tracing back the motion of a group

- ✓ Work only with young group (<100-200 Myr) recently dispersed
- ✓ Require high precision velocities (Gaia DR2 very promising)

## 2. Correlation between age and velocity dispersion

- ✓ Work for individual old stars
- ✓ Low precision. Useful for studying large sample (Almeida-Fernandes & Rocha-Pinto 2018)

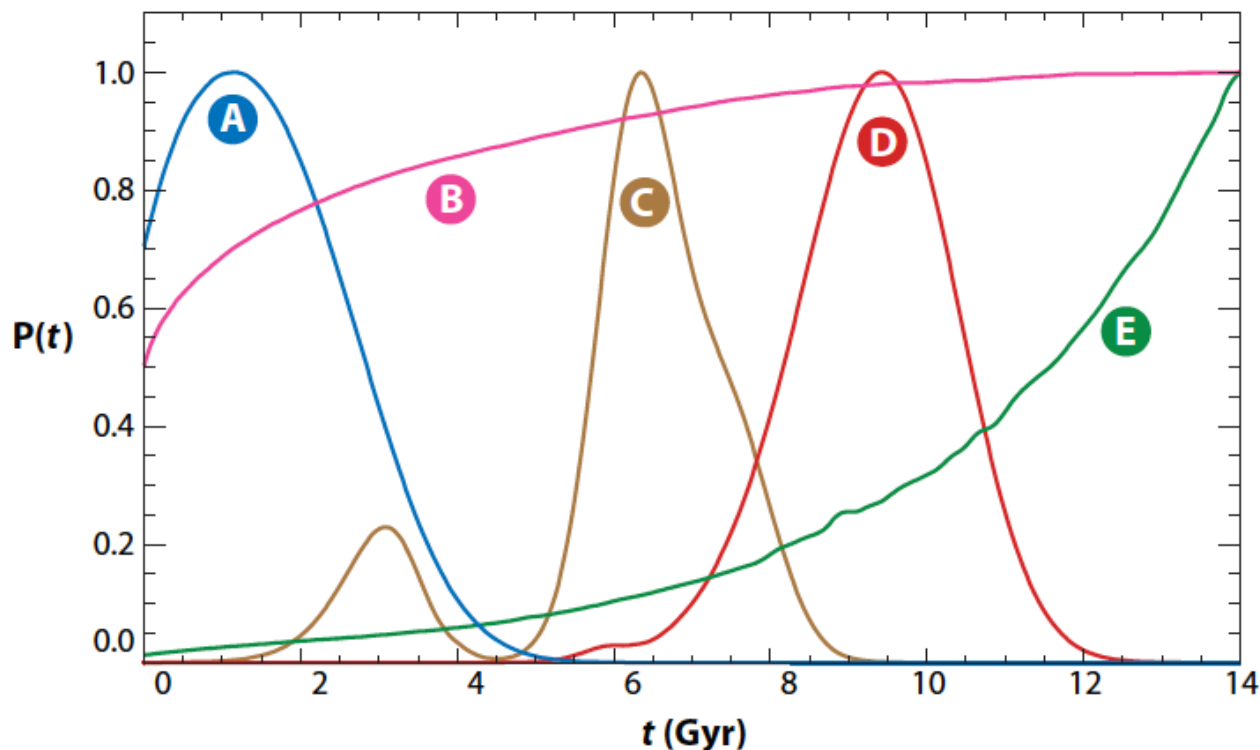
Very relevant in the Gaia Era



(Almeida-Fernandes & Rocha-Pinto 2018)

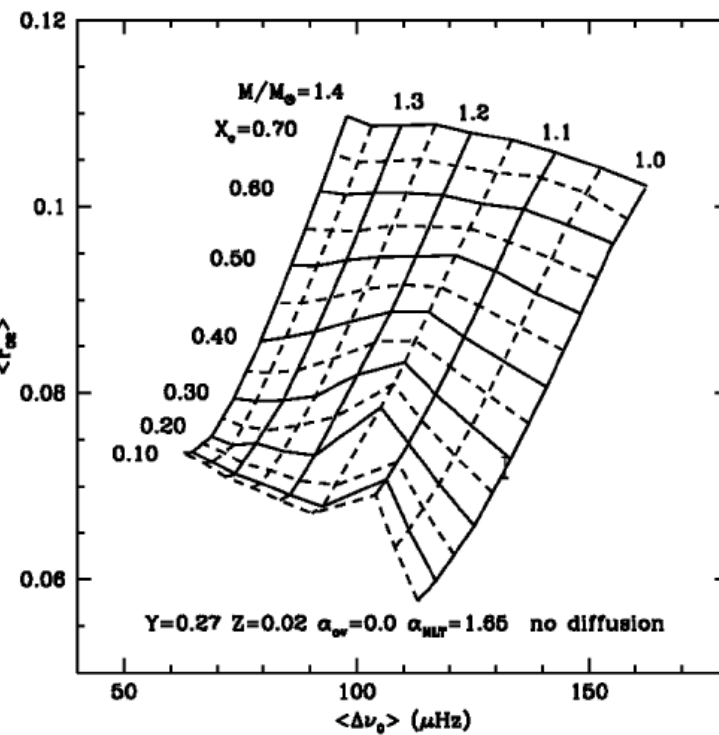
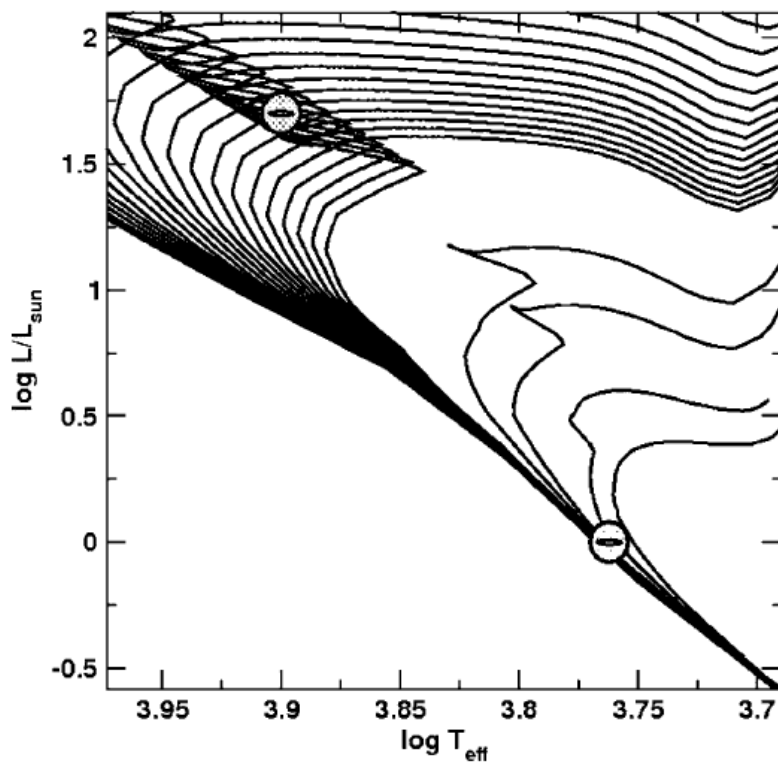
# Isochrone fitting

- ✓ Full set of stellar parameters required (Teff, parallax,  $A_v$ , photometry, [Fe/H])
- ✓ Work better for more massive, evolved stars or PMS (uncertainties on the models)
- ✓ Not efficient for low-mass MS stars (Most of the potential ARIEL targets)



**Example:** PDF of age based on isochronal fitting for 5 solar MS stars (adapted from Takeda et al. 2007)

# Astereoseismology



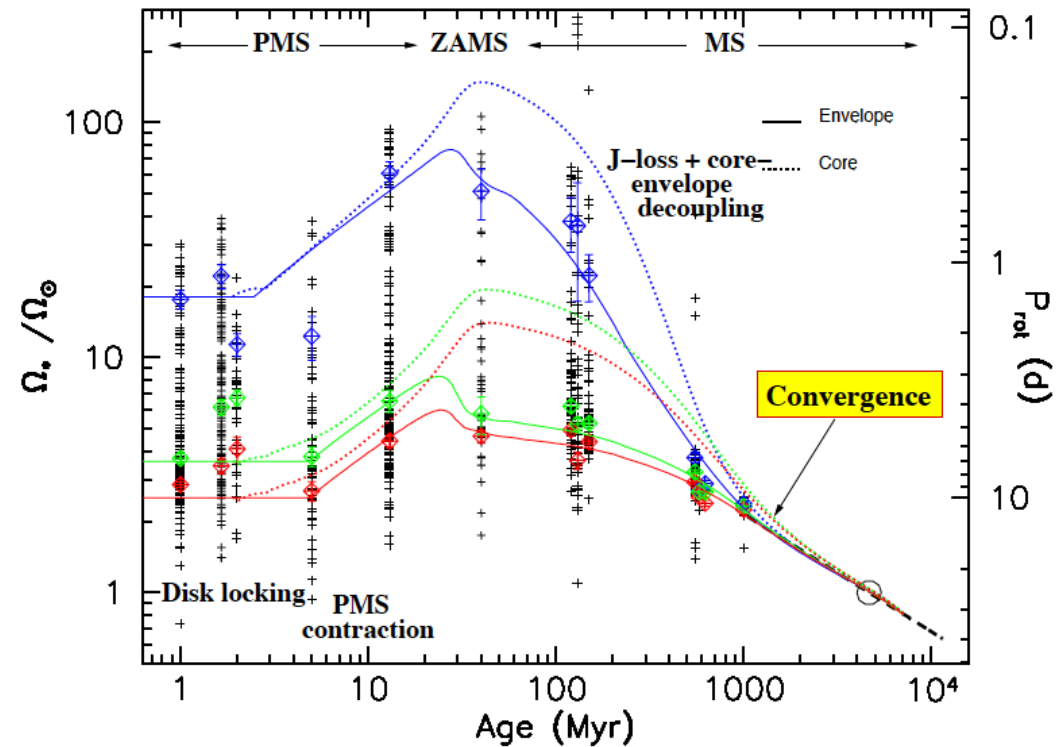
(Lebreton & Montalbán 2008)

- ✓ Full set of stellar parameters required
- ✓ Very efficient for MS solar mass stars
- ✓ Precision  $\sim 10\%$
- ✓ Several survey coming soon (TESS, PLATO)



# Gyrochronology

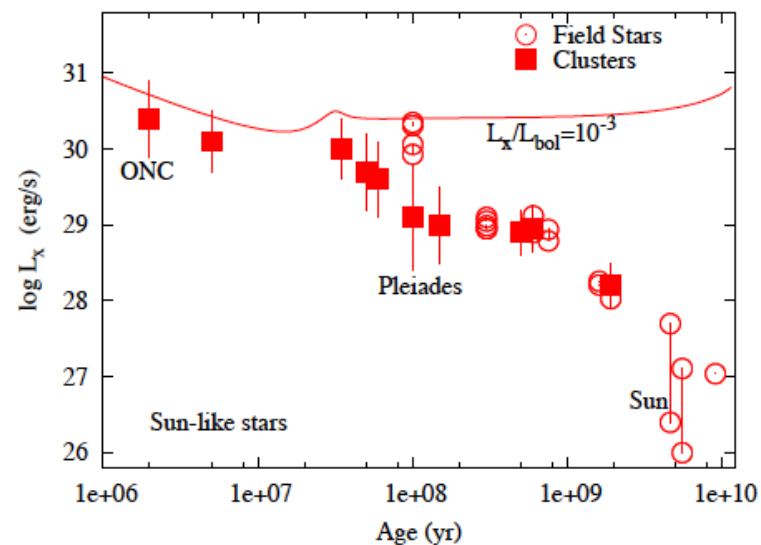
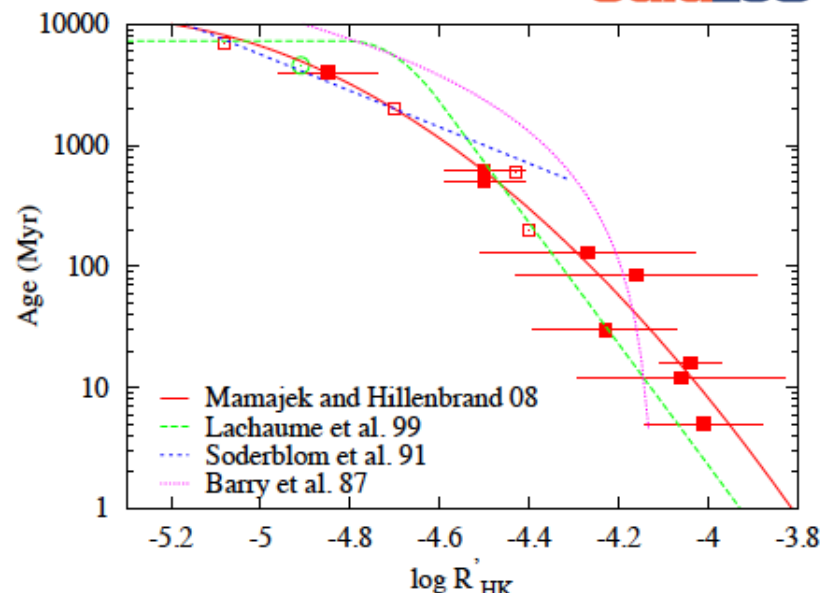
- ✓ Work for stars older than 100-500 Myr
- ✓ Not very efficient for mass  $< 0.4 M_{\odot}$
- ✓ Precision  $\sim 20\%$
- ✓ Poor calibration at age  $> 1$  Gyr  
(see Jeffries 2014)



(Adapted from Gallet & Bouvier 2013)

# Activity

- ✓ Work for stars older than 100-500 Myr
- ✓ Not very efficient for mass  $< 0.4 M_{\odot}$
- ✓ Precision  $\sim 60\%$
- ✓ Better calibrated but less precise than gyrochronology (see Jeffries 2014)



(Jeffries et al. 2014)



# A database of stellar ages for ARIEL targets

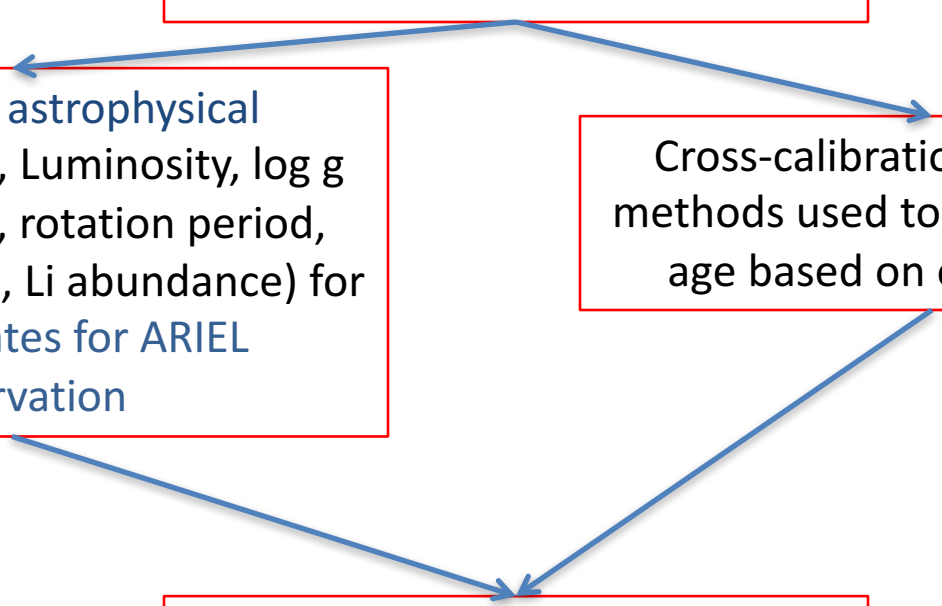


Gaia, TESS, PLATO, Gaia-ESO,  
Apogee, sky mapper, literature  
etc..

Database of astrophysical  
parameters (Teff, Luminosity, log g  
[Fe/H], parallax, rotation period,  
activity indicators, Li abundance) for  
the candidates for ARIEL  
observation

Cross-calibration of different  
methods used to estimate stellar  
age based on open clusters

Database of stellar ages (with  
errors) for the candidate of ARIEL  
observations

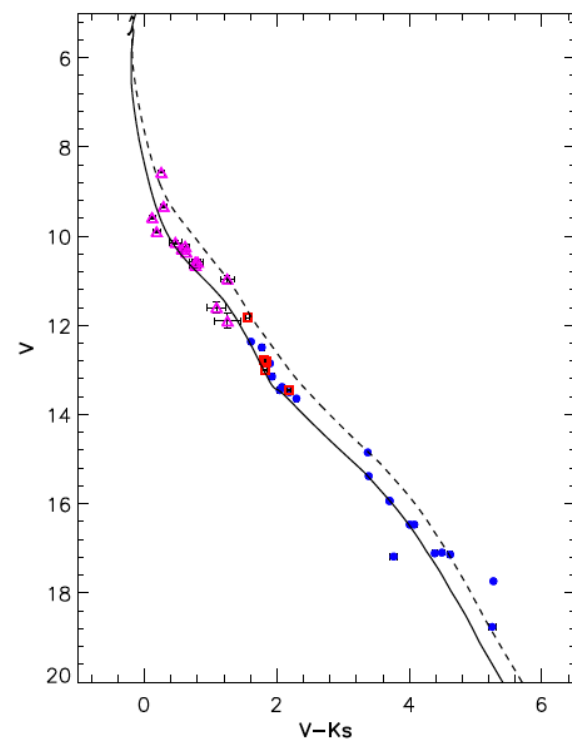
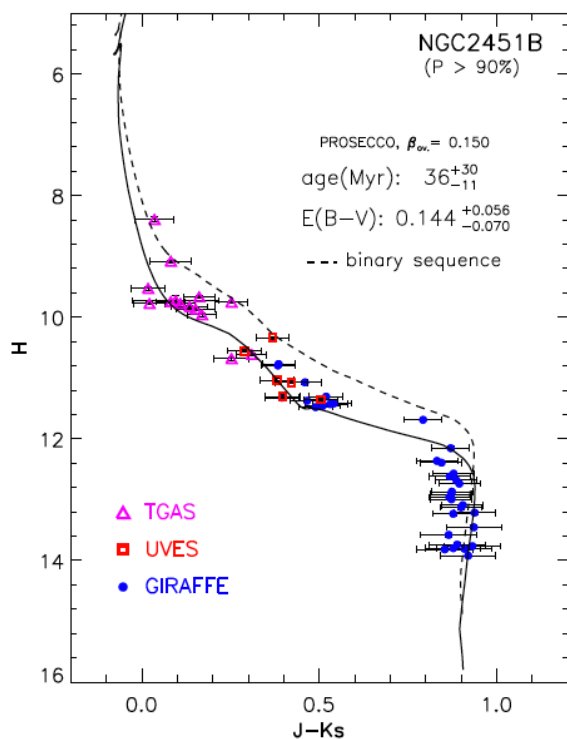


# Accuracy and precision of age estimates for ARIEL

Set of well-studied clusters with homogeneously determined ages



Database of astrophysical parameters for this set of well know clusters



(Randich et al. 2018)

1. Cross-calibration of the different methods on a single scale;
2. Empirical determination of the errors based on the scatter within the clusters



# Conclusions



- Accurate and precise determinations of the ages of the planet hosting stars are fundamental to address several open issues and fully exploit the ARIEL data;
- Determine the age of single low mass MS stars is a open problem. Several methods are available, but better calibration and error estimates are required;
- The Arcetri group has started a project based on data from Gaia and Gaia-ESO to improve the accuracy and precision of the age in several star clusters;
- Starting from this work we plan to cross-calibrate the different method used for the estimate ages in single stars and use this calibration to calculate ages of ARIEL targets