Observation of asteroseismic low-mass stars with SPICA, MIRCX and MYSTIC

M. Vrard, D. Mourard, O. Creevey, S. Deheuvels
and the ISSP team

Mathieu Vrard, CHARA Science Meeting 2025, Nice, France, April 28th, 2025

The ISSP project

5-year ERC Advanced Grant 2020 (#101019653) project

Aim : completing and exploiting a large (1000) survey of homogeneous interferometric measurements for various scientific purposes: bring constraints on stars hosting exoplanets, seismic relations, SBCR measurements, activity, binaries,…

(see previous talks by D. Mourard, J. Jonàk and R. Ibañez-Bustos)

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Asteroseismology+interferometry science program (S02&S03)

S02 : Main-Sequence (MS)
S03 : Sub-Giants (SG) and Red Giants (RG)

Participants: Vrard M., Mourard D., Creevey O., Deheuvels S. and ISSP team

Scientific objectives:

-Calibrating the **radius seismic scaling relation** covering a range of masses and metallicities

-Model-independent masses using $\Delta\nu$($\Delta\nu \sim \langle\rho\rangle$) and interferometric radius.

-Using interferometric constraints on model to obtain more precise **stellar ages**

-Detailed analysis to obtain high-precision stellar parameters and test different physical ingredients in stellar models.

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Scaling relations situation

-Scaling relations are used to deduce stellar Radius (R) and Mass (M) with asteroseismic parameters

$$\frac{R}{R_\odot} \simeq \left(\frac{\nu_{max}}{\nu_{max,\odot}}\right)\left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-2}\left(\frac{T_{eff}}{T_{eff,\odot}}\right)^{1/2}$$

$\Delta\nu \sim \langle\rho\rangle$

ν_{max}: frequency of maximum oscillation

T_{eff}: effective temperature

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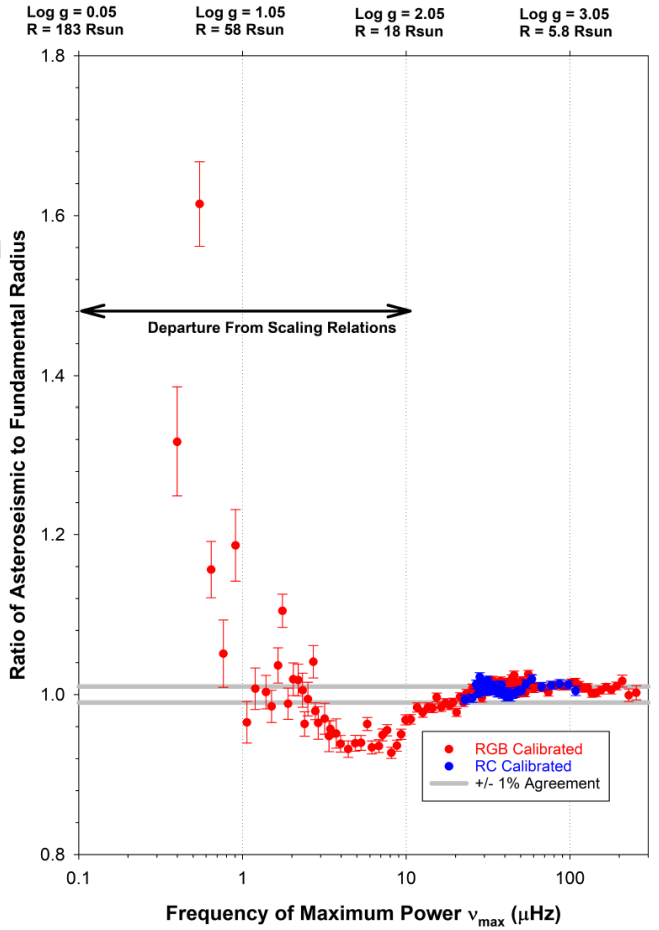
-Seismic scaling relations has shown great agreement with other methods to obtain stellar Radius (R) and Mass (M)

-However, observations show a clear breakdown of those relations in some cases (gaia R, dynamical R)



Ratio between asteroseismic R and fundamental R (obtained with T_{eff}, Luminosity L and gaia parallax) as a function of ν_{max}

(courtesy of Marc Pinsonneault)

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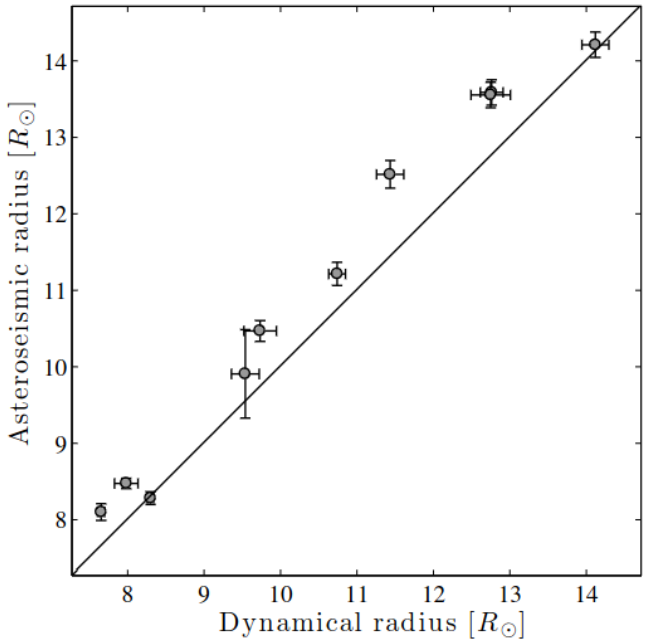

Asteroseismic R as a function of dynamical R (with binaries) (Gaulme et al. 2016)

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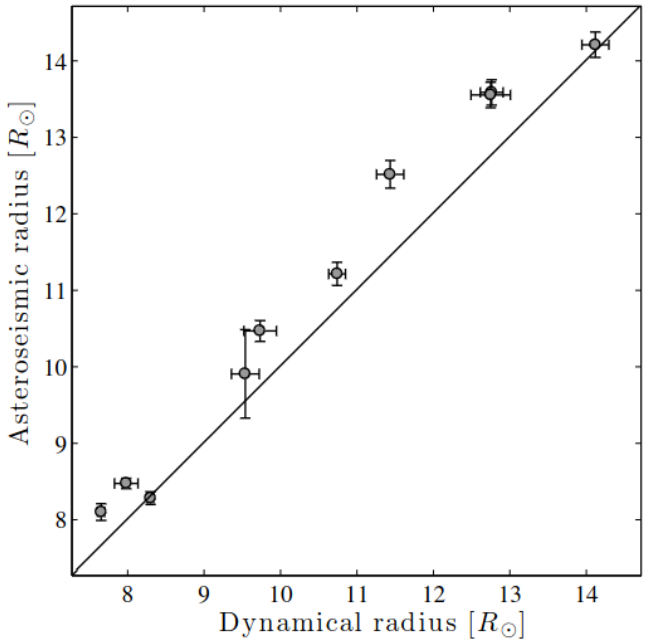
Need other reliable independent measurements



Asteroseismic R as a function of dynamical R (with binaries) (Gaulme et al. 2016)

Target list

List selection participants: Vrard M., Mourard D., Creevey O., Deheuvels S. and S02/S03 collaborators

-Comprising northern asteroseismic targets (*Kepler*, K2, TESS,...)+PLATO Input Catalog (PIC) targets.

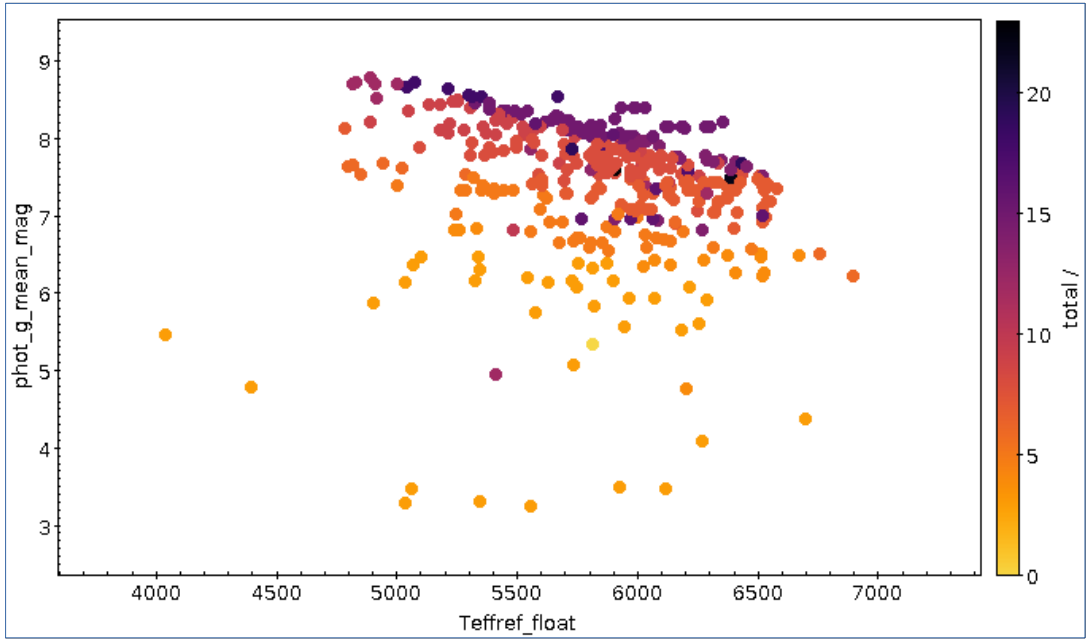
-Notebook developed to crossmatch targets with several external catalogues (extinction, simbad, gaia, …)

-Assuming 1 % angular diameters => calculate σ_R

Selection and priority (P0,P1) on $\sigma_R + V_{mag} > 8 + \delta > -30°$ + θ>0.2mas + coverage of HR diagram

=> **447 S03 (RG/SG) + 340 S02 (MS) targets**

110 P0 targets (50 S02, 60 S03), 677 P1 targets



*Stellar magnitude as a function of the T_{eff} of selected **S02** targets. Courtesy of Orlagh Creevey*

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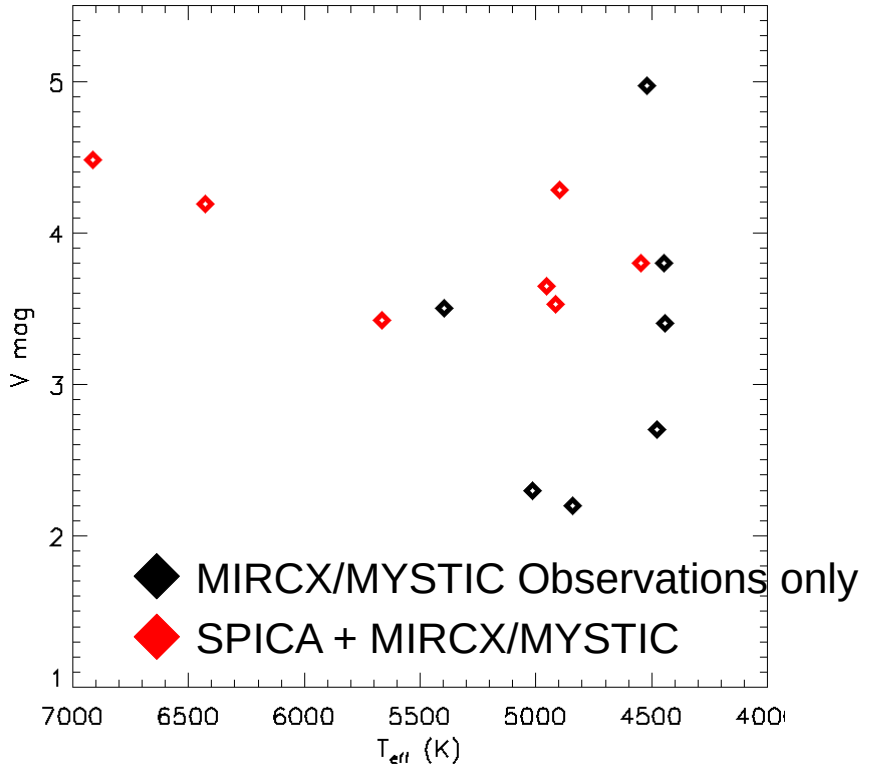
CHARA Interferometric observations for S02/S03 ISSP stars

-**MIRCX/MYSTIC:** 15 stars (5 MS, 10 RG) observed between October 2023 and November 2024, 20 observations in total

-Exploitable data for all of those, except one MIRCX target without calibrator

-**SPICA:** 9 stars (5 MS, 4 RG) observed between August 2023 and November 2024, 17 observations in total

-Exploitable data for 7 stars (3 MS, 4 RG) but less reliability due to less stability in the fringes and lack of shortest bases



Stellar magnitude as a function of the T_{eff} for the observed stars with MIRCX/MYSTIC and SPICA

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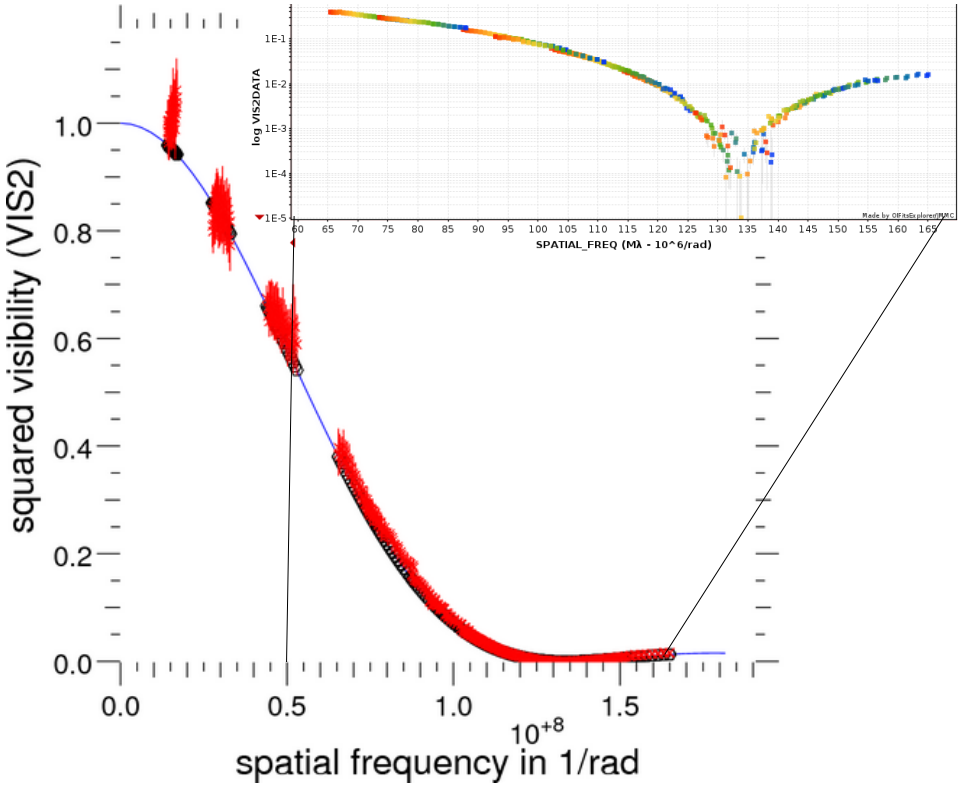
MIRCX/MYSTIC data analysis

-Exploitable data for all observations

-Most observed stars are big enough to reach the first 0 in visibility, even with MYSTIC

-θ measured with root-squared LD fit and fixed Claret coefficients

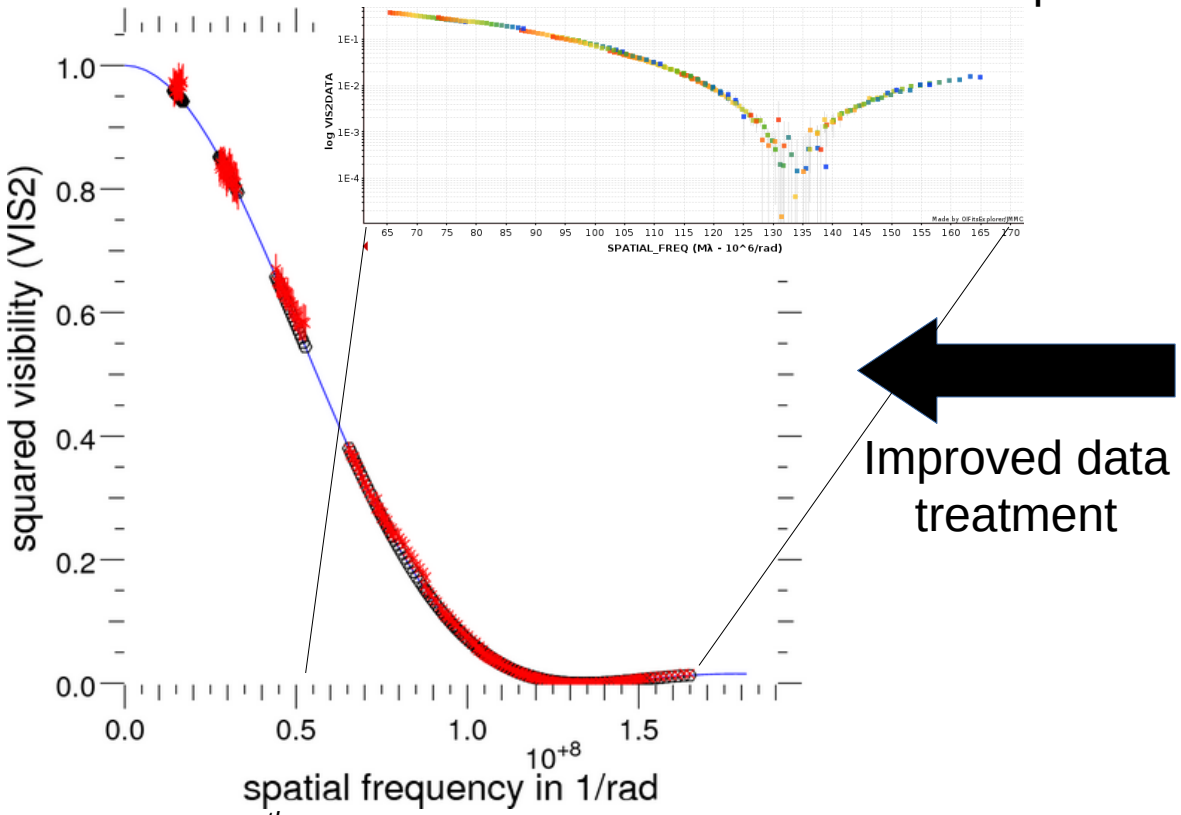
-Results in coherence with previous observations



MYSTIC July 4th 2024 observations of HD161797 (S02)

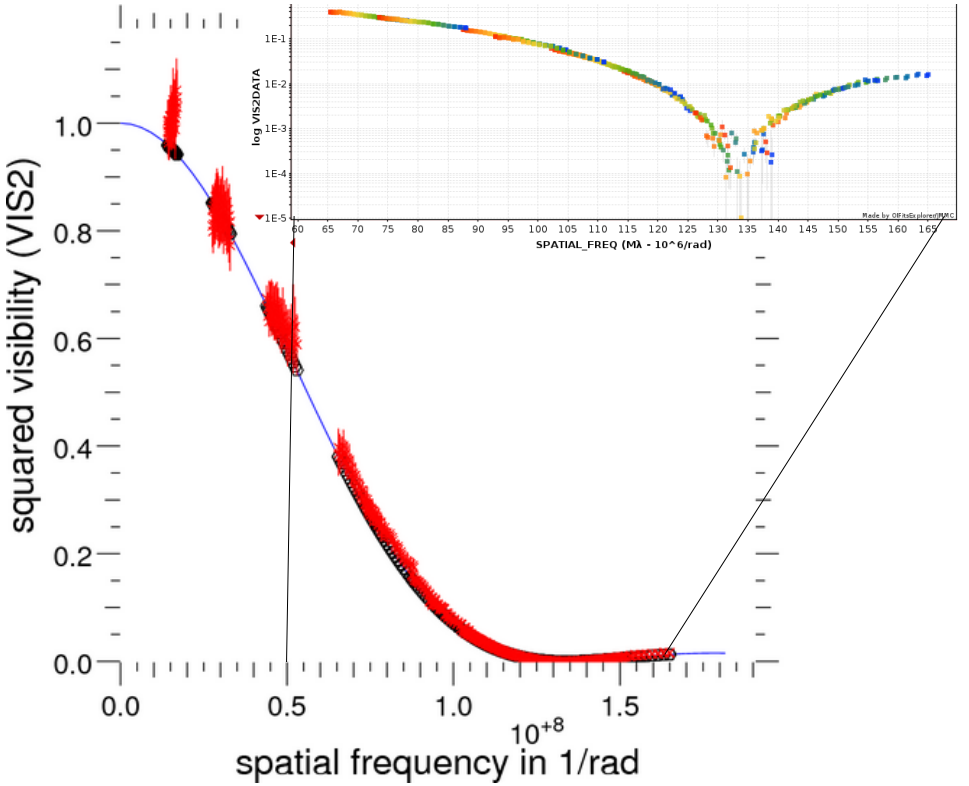
MIRCX/MYSTIC data analysis

Data treatment improvement



MYSTIC July 4th 2024 observations of HD161797 (S02), second treatment

Improved data treatment



MYSTIC July 4th 2024 observations of HD161797 (S02)

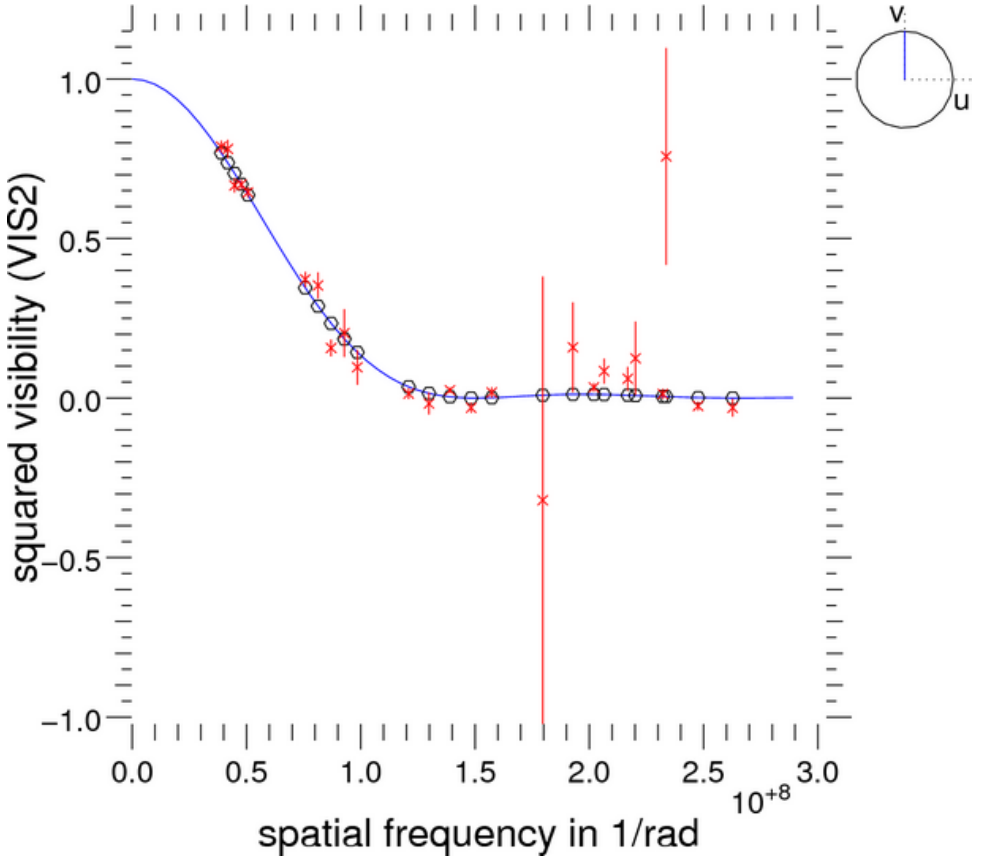
SPICA data analysis

-Exploitable data for 7 stars

-The visibilities appears noisier because of fringes stability

-θ measured with root-squared LD fit and fixed Claret coefficients

-Results in coherence with previous observations and with MIRCX/MYSTIC data



SPICA July 4th 2024 observations of HD161797 (S02)

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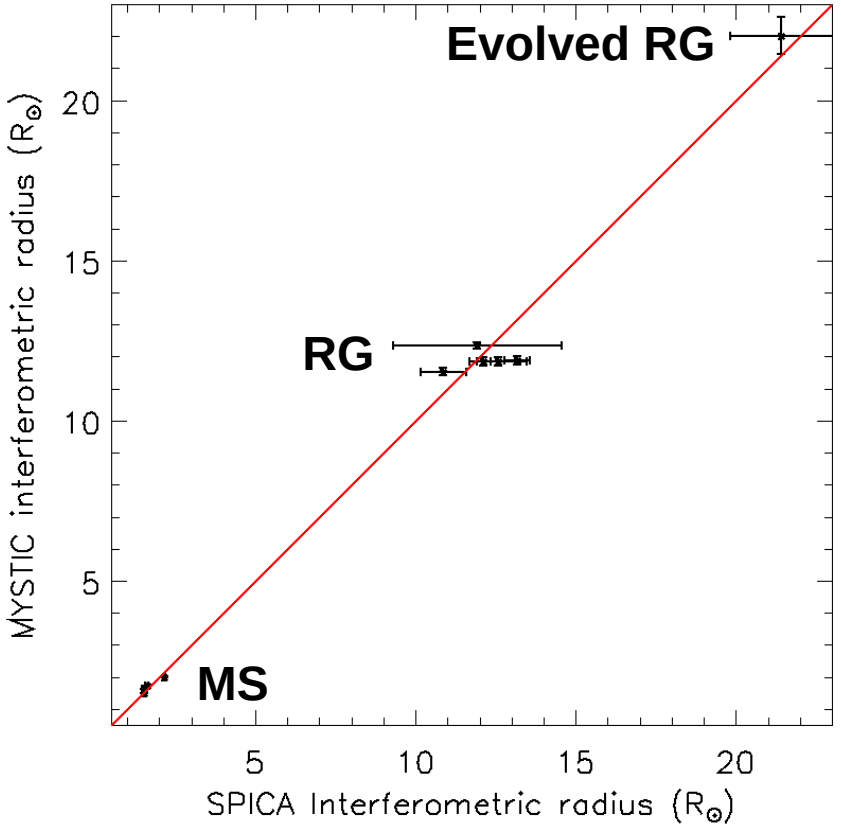
Comparison SPICA and MIRCX/MYSTIC radius

-Interferometric radius computed with gaia parallaxes

-MIRCX/MYSTIC results very close
(except HD185395)

-SPICA/MIRCX and SPICA/MYSTIC have more differences, still coherent

-Larger uncertainties on SPICA due to noisier visibilities



Comparison between MIRCX and SPICA Radius

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Asteroseismic radius determination

-Computation of asteroseismic Radius (R) with the scaling relation:

$$\frac{R}{R_\odot} \simeq \left(\frac{\nu_{max}}{\nu_{max,\odot}}\right)\left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-2}\left(\frac{T_{eff}}{T_{eff,\odot}}\right)^{1/2}$$

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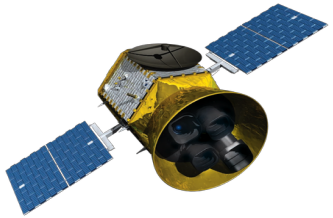


TESS satellite

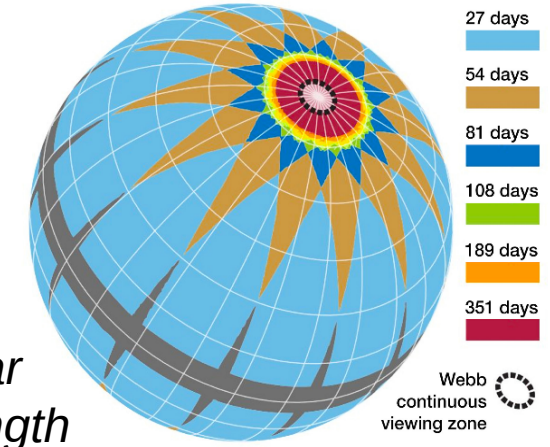
-Origin of asteroseismic data ($\Delta\nu$,ν_{max}): mainly K2 (Pope et al. 2019, Schoffield et al. 2019) and TESS missions (Hon et al., 2022)

-Origin of T_{eff} data: **(1)** APOGEE

(2) Gaia Benchmark stars

(3) PASTEL

(4) Soubiran et al. (2022)



TESS 1st year observation length

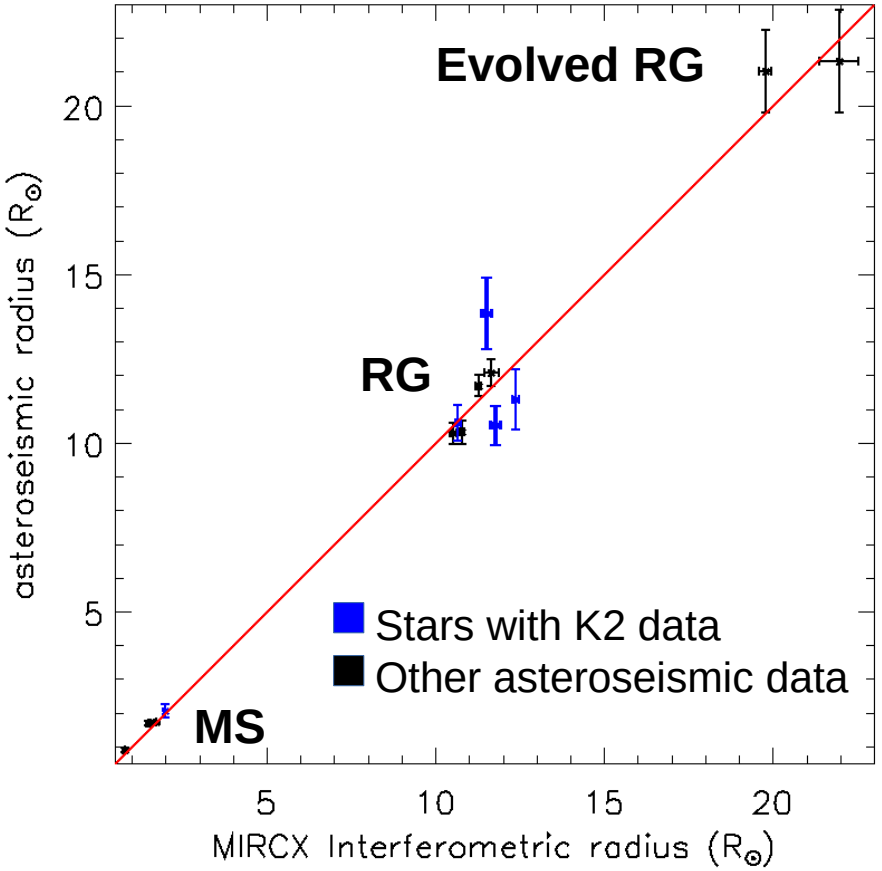
Interferometric and asteroseismic radius (R) comparison

MIRCX/MYSTIC radius

-Good agreement between interferometric data and asteroseismology

-3 groups of stars: main-sequence, around the clump and evolved targets

-Good agreement except for stars with K2 data
=> descrepancies probably linked to the low resolution of asteroseismic data



Comparison between MIRCX Radius and asteroseismic Radius

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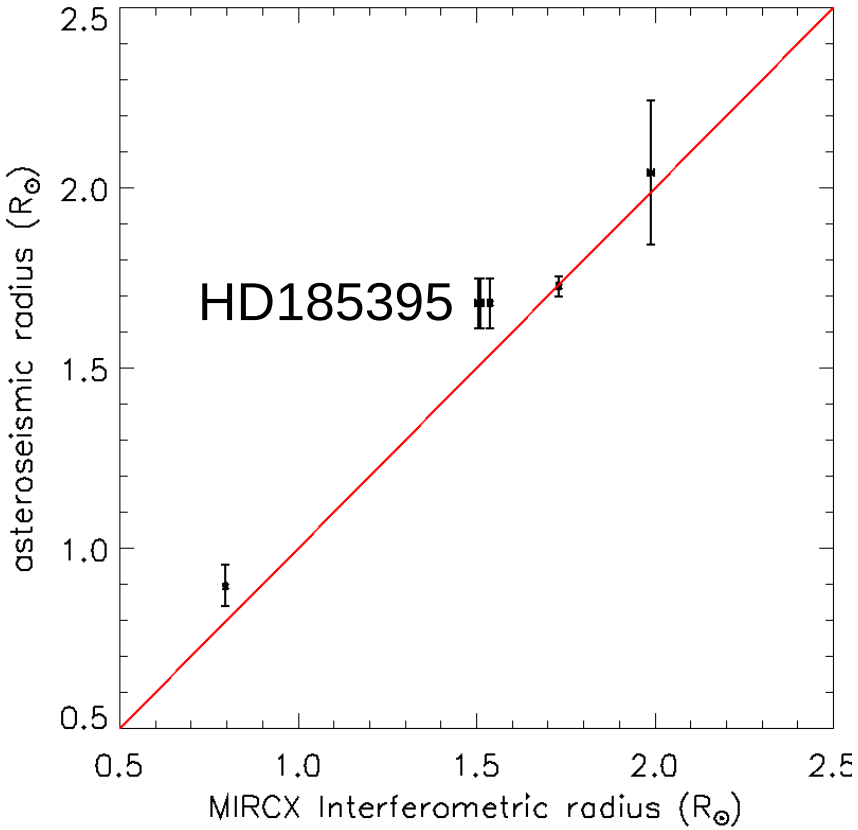
-Only disagreement with good asteroseismic data: HD185395



*Comparison between MIRCX Radius and asteroseismic Radius for **MS** targets*

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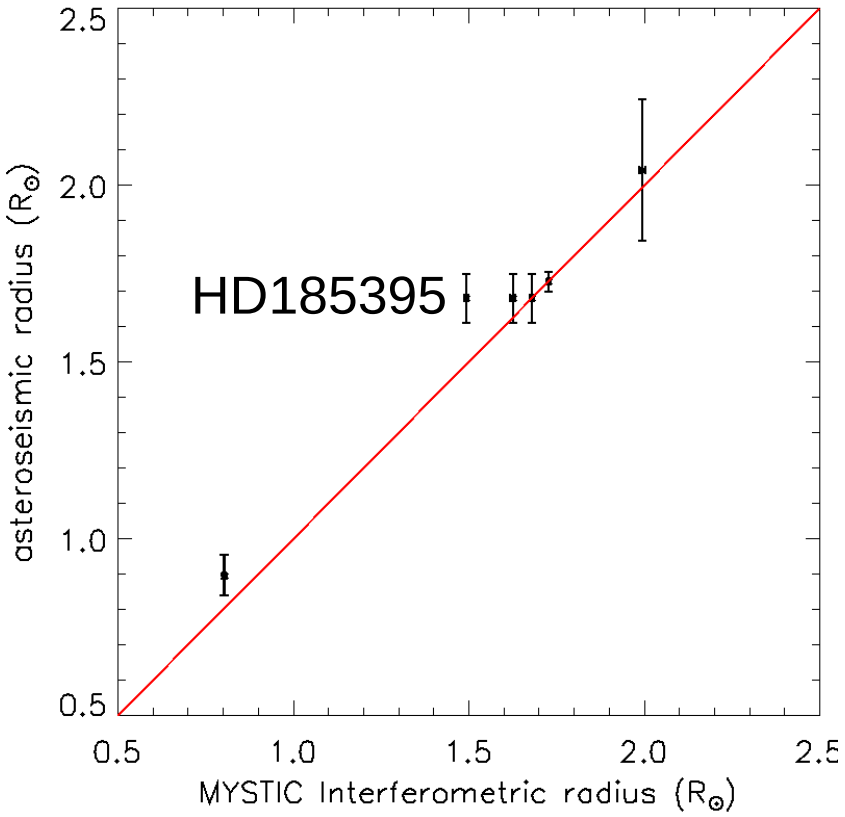
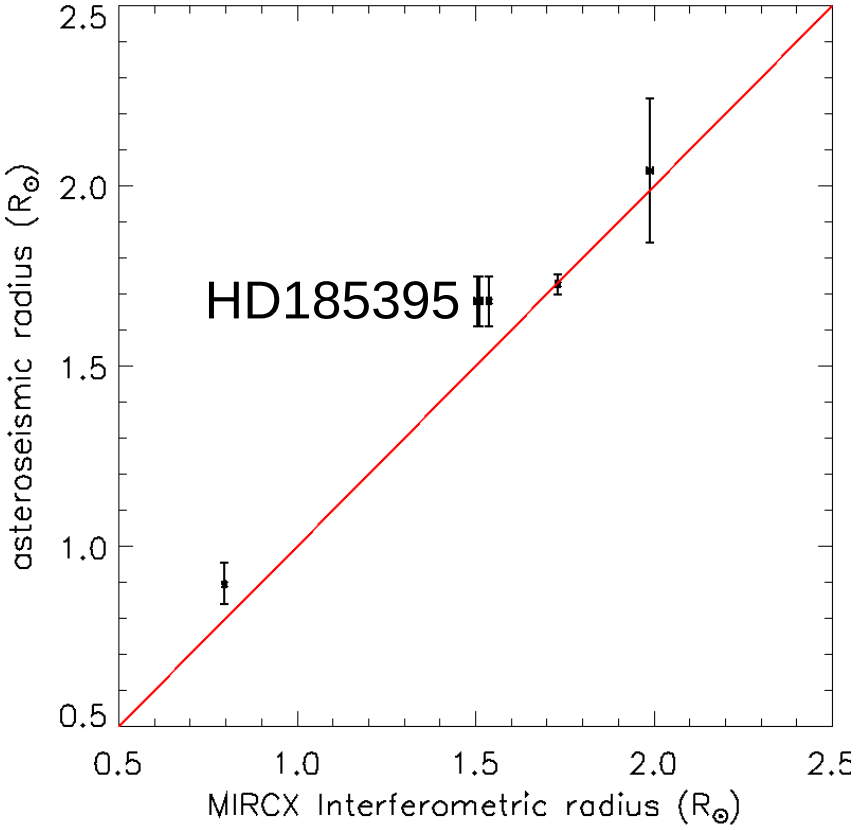
Interferometric and asteroseismic radius (R) comparison



*Comparison between MYSTIC Radius and asteroseismic Radius for **MS** targets*



*Comparison between MIRCX Radius and asteroseismic Radius for **MS** targets*

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Interferometric and asteroseismic radius (R) comparison

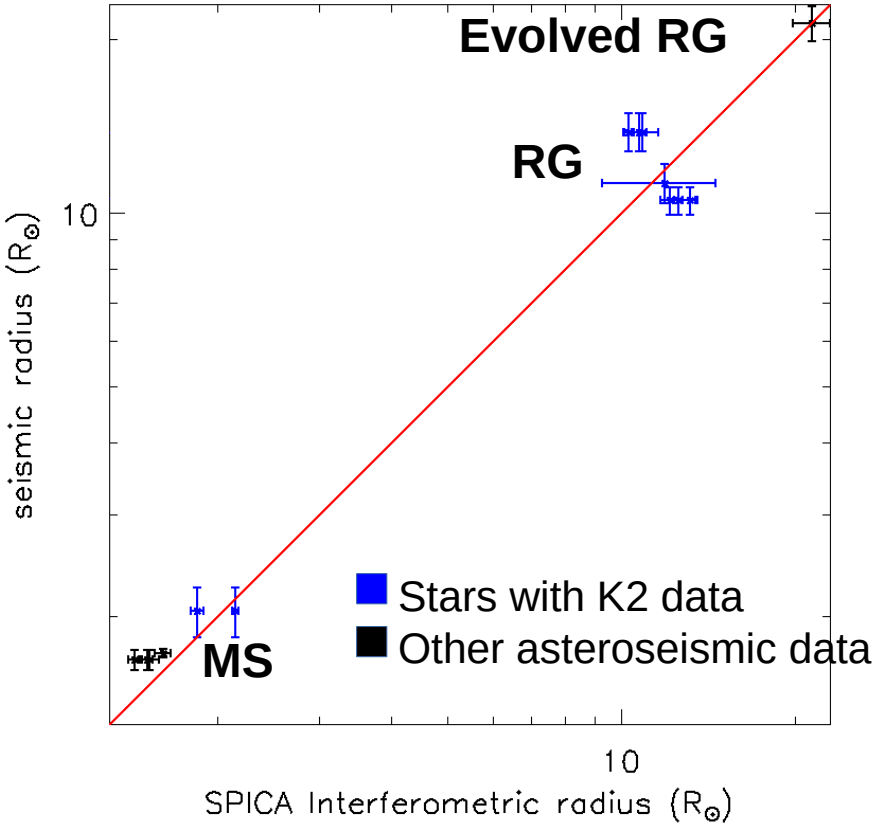
SPICA radius

-Results coherent with asteroseismic Radius

-However larger uncertainties than for MIRCX/MYSTIC radius, mainly around the clump for K2 data
=> descrepancies probably linked to the low resolution of asteroseismic data

-3 groups of stars: main-sequence, around the clump and evolved targets

-Needs MIRCX/MYSTIC data to strengthen some SPICA fit



Comparison between SPICA Radius and asteroseismic Radius

Conclusion

-15 stars observed with MIRCX/MYSTIC (5 MS, 10 RG), all exploitable, 20 observations in total

-9 stars observed with SPICA (5 MS, 4 RG), 7 exploitable observations

-Good agreement between MIRCX/MYSTIC and SPICA observations, noisier results on SPICA

-So far no discrepancies between interferometric and asteroseismic radius
Exception for HD185395 who exhibit a different behavior as a function of wavelength

-Survey will continue in order to complete the sample of stars and confirm the first results

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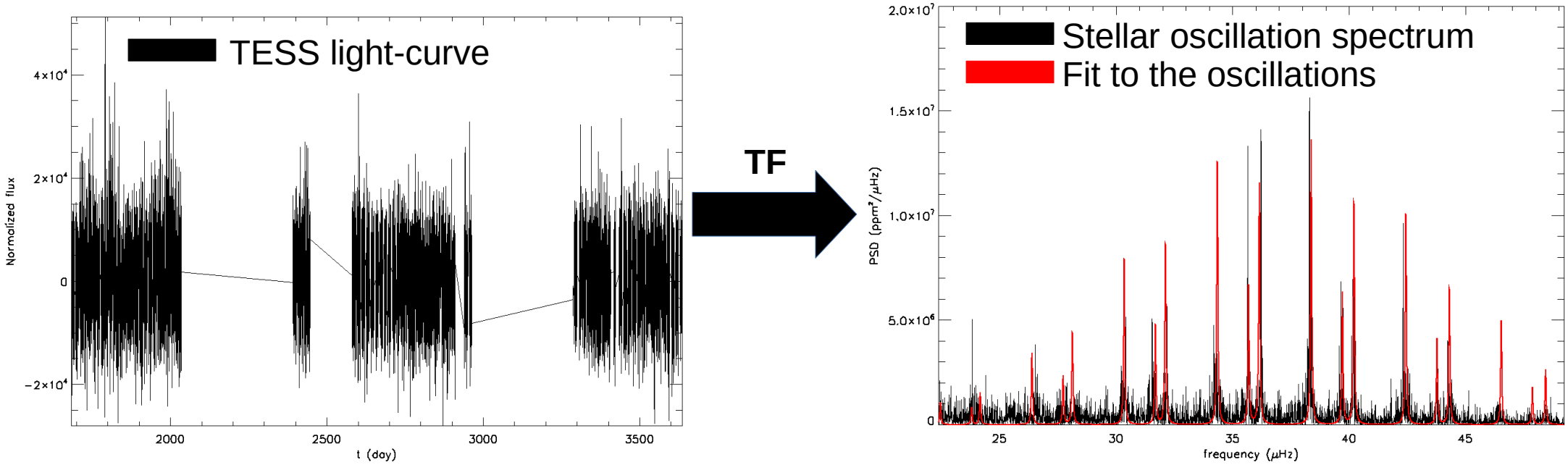
Perspectives

-Several articles in preparation, including one on the scaling relations

-The data analysis is continuing with a thorough analysis of the asteroseismic data
Objective: assess the potential for asteroseismology and interferometry to bring better stellar parameters determination (mass, age, ...)



Thank you for your attention

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