Observation of asteroseismic red giant stars with SPICA, MIRCX and MYSTIC

Mathieu Vrard and S02/S03 ISSP team

Mathieu Vrard, CHARA Science Meeting, Tucson, March 13th, 2024

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 talk by D.Mourard)

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Asteroseismology+interferometry science program (S02&S03)

S02 : Main-Sequence (MS) focus

Participants: M. Vrard, O. Creevey, Mourard D., Deheuvels S., Belkacem K., Lebreton Y., Morel T., Nardetto N., Salabert D.

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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Asteroseismology+interferometry science program (S02&S03)

S02 : Main-Sequence (MS) focus

Target list:

-Comprising northern asteroseismic targets+PLATO targets.

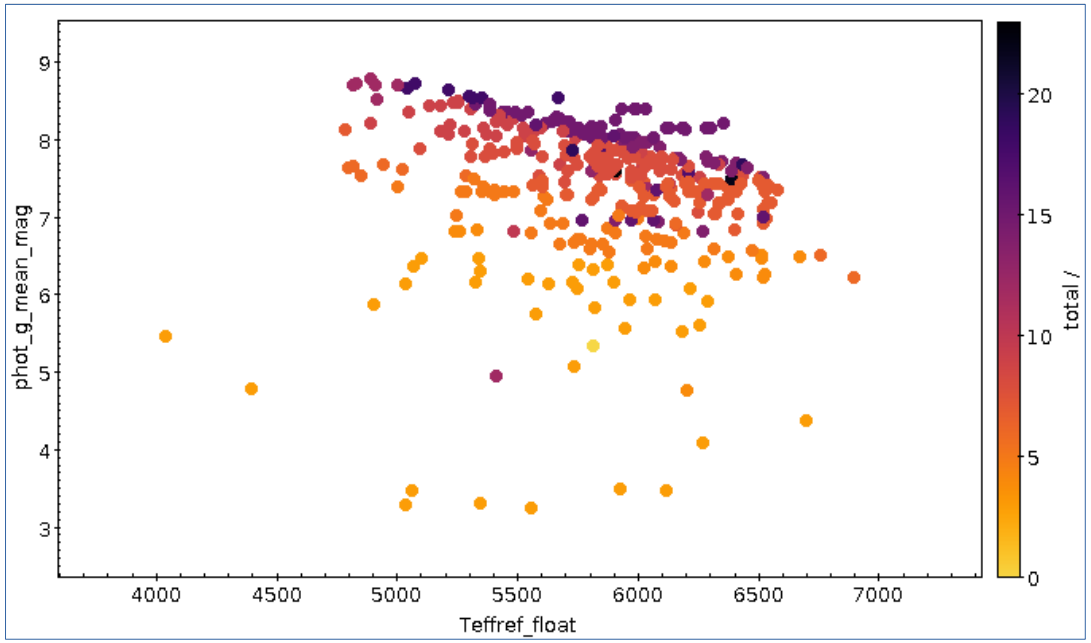
-Notebook developed to crossmatch targets with several external catalogues (extinction, simbad, gaia, …) => 340 potential targets

-Assuming 1 % angular diameters => calculate σ_R

Selection and priority (P0,P1) on

$\sigma_R + V_{mag} + \delta$ + coverage HR diagram

=> 50 P0 targets, 290 P1 targets



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

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Asteroseismology+interferometry science program (S02&S03)

S03 : Sub-giant and red giant stars focus

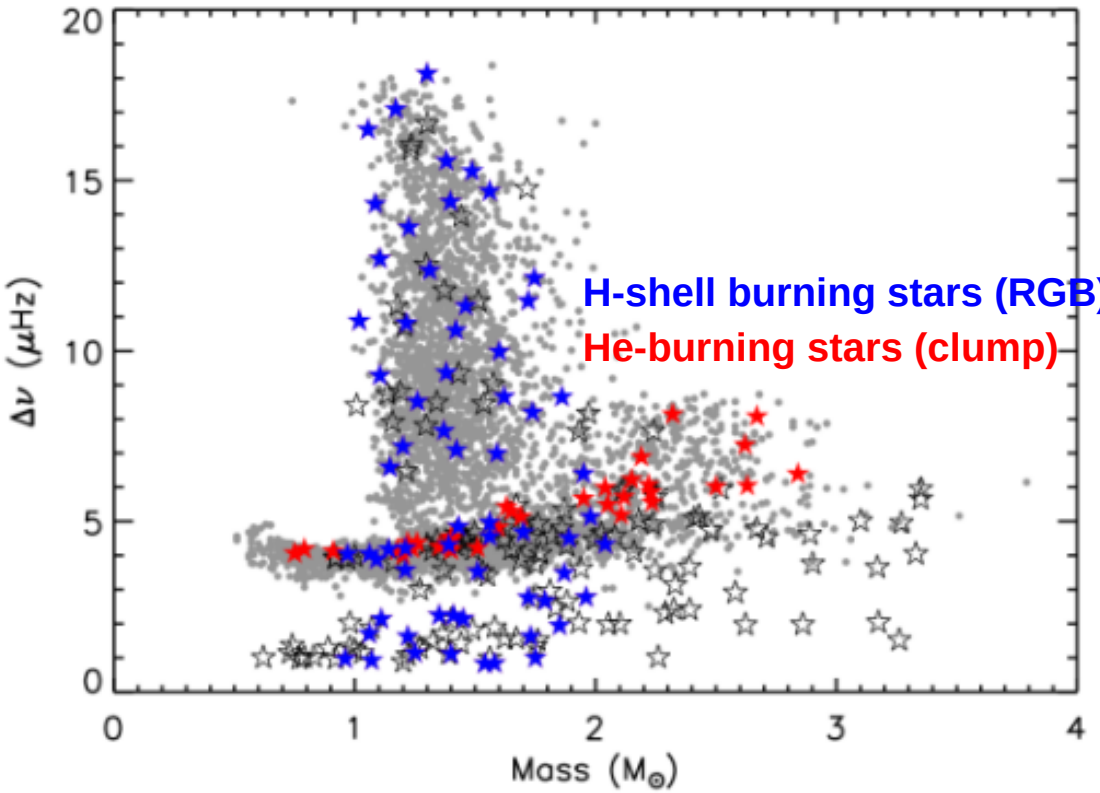
Participants: M. Vrard, O. Creevey, Mourard D., Deheuvels S., Belkacem K., Lebreton Y., Morel T., Nardetto N., Salabert D.

Target list (from Sébastien Deheuvels work):

-Subgiants and red giants with excellent seismic data and large enough predicted angular diameter (θ>0.2)

-236 stars in *Kepler* and CoRoT data that corresponds to those criteriums

-60 P0 targets selected following evolutionary stages, masses and $\Delta\nu$



$\Delta\nu$-Mass plane for P0 red giants and red clump targets (courtesy of Romina Ibañez-Bustos)

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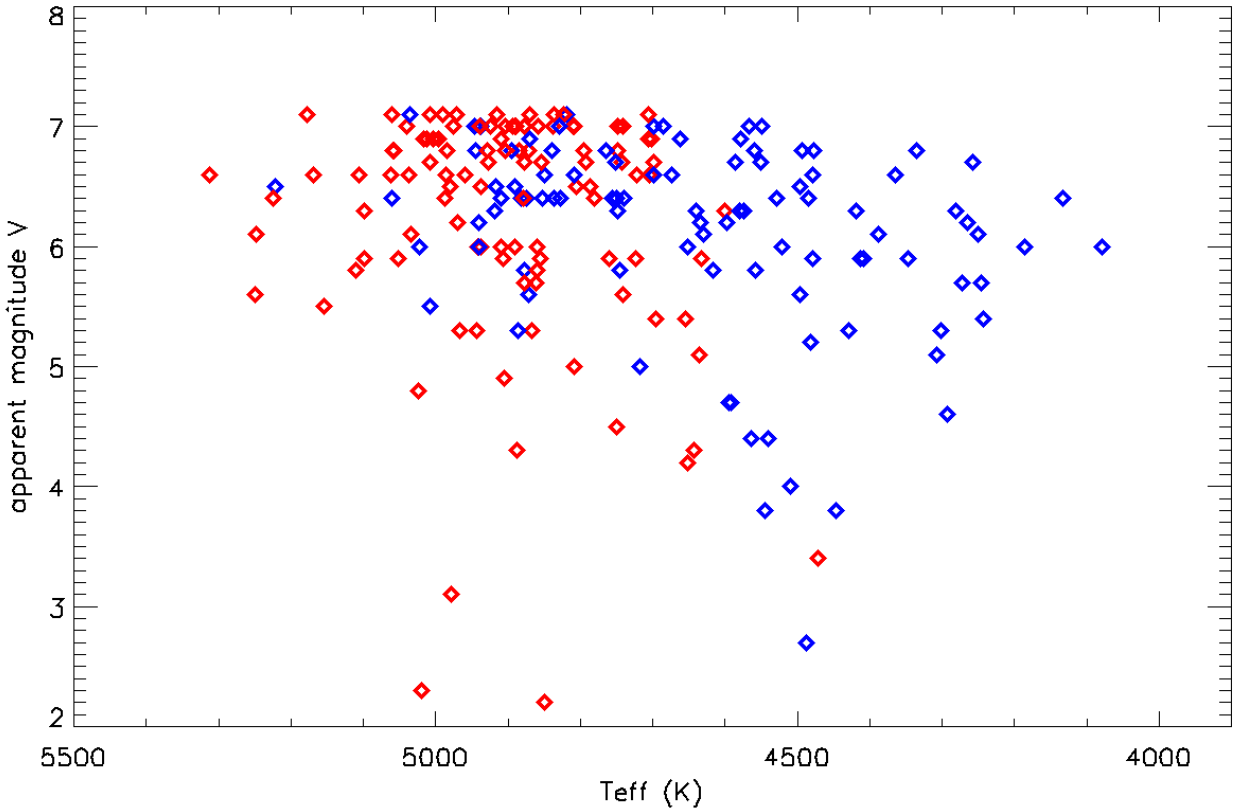
Asteroseismology+interferometry science program (S02&S03)

S03 : Sub-giant and red giant stars focus

-New red giant sample from the TESS bright star sample (Hon et al., 2022)
Selected with V<8, θ>0.2, δ>-20°

-211 red giant targets with measured seismic quantities



Apparent magnitude as a function of T_{eff} for the selected 211 stars

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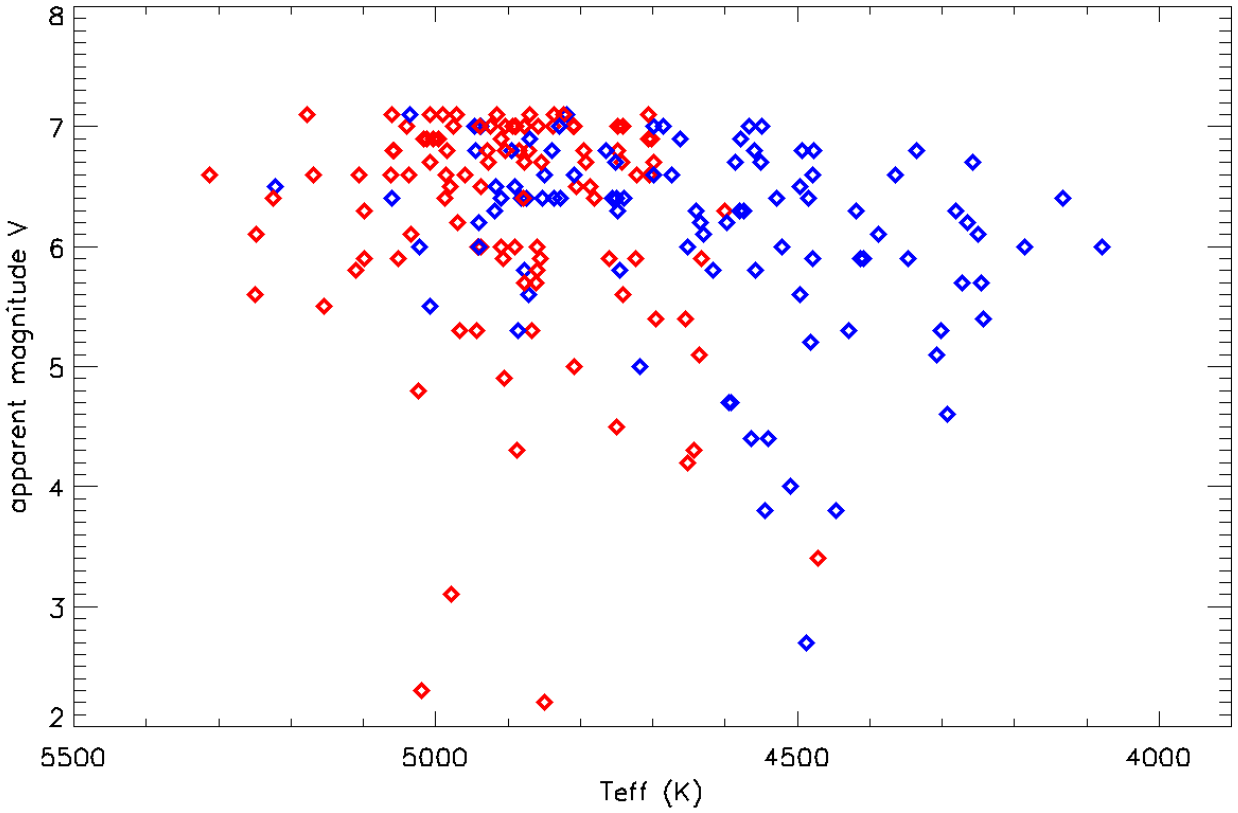
Final catalog where we pick the stars to observe during the next 2 years
=> 447 red giant stars and 340 main-sequence potential targets
110 P0 targets (50 S02, 60 S03)



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CHARA Interferometric observations for S02/S03 ISSP stars

-**SPICA:** Several bad nights at the beginning of the run, the exploitable observations began in August 2023

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-5 stars were observed with **SPICA** between August and November 2023 (2 S02, 3 S03)
Some stars observed several times: 8 observations in total.

-**MIRCX** and/or **MYSTIC** data for 4 observations (2 stars between September and November)

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-Exploitable data for most of those: 7 out of 8 observations (4 stars: 1 S01, 3 S03)

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CHARA Interferometric observations for S02/S03 ISSP stars

SPICA data

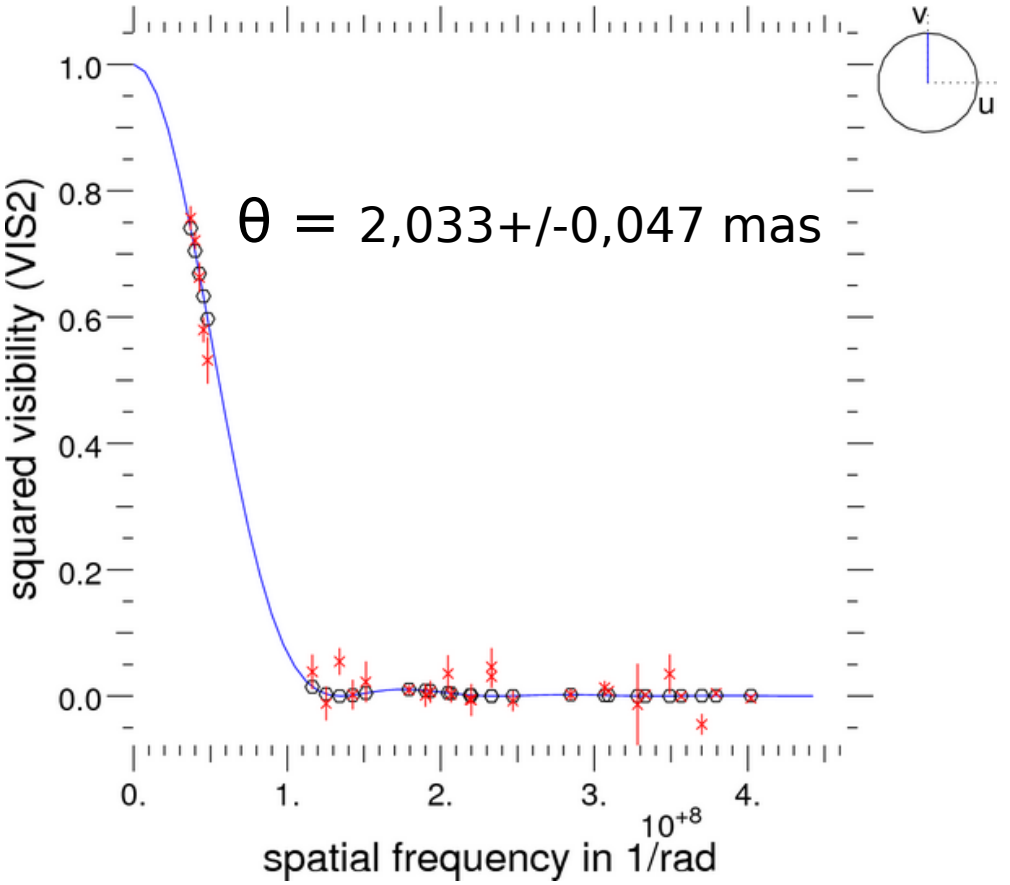
-4 stars (7 observations) observed between August 9th and November 10th 2023 with exploitable observations

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

-1 main-sequence (S02), 3 red giants (S03) targets

-The squared visibilities are noisy but sufficiently coherent to extract a θ value

However...



SPICA October 14th 2023 observations of HD27371

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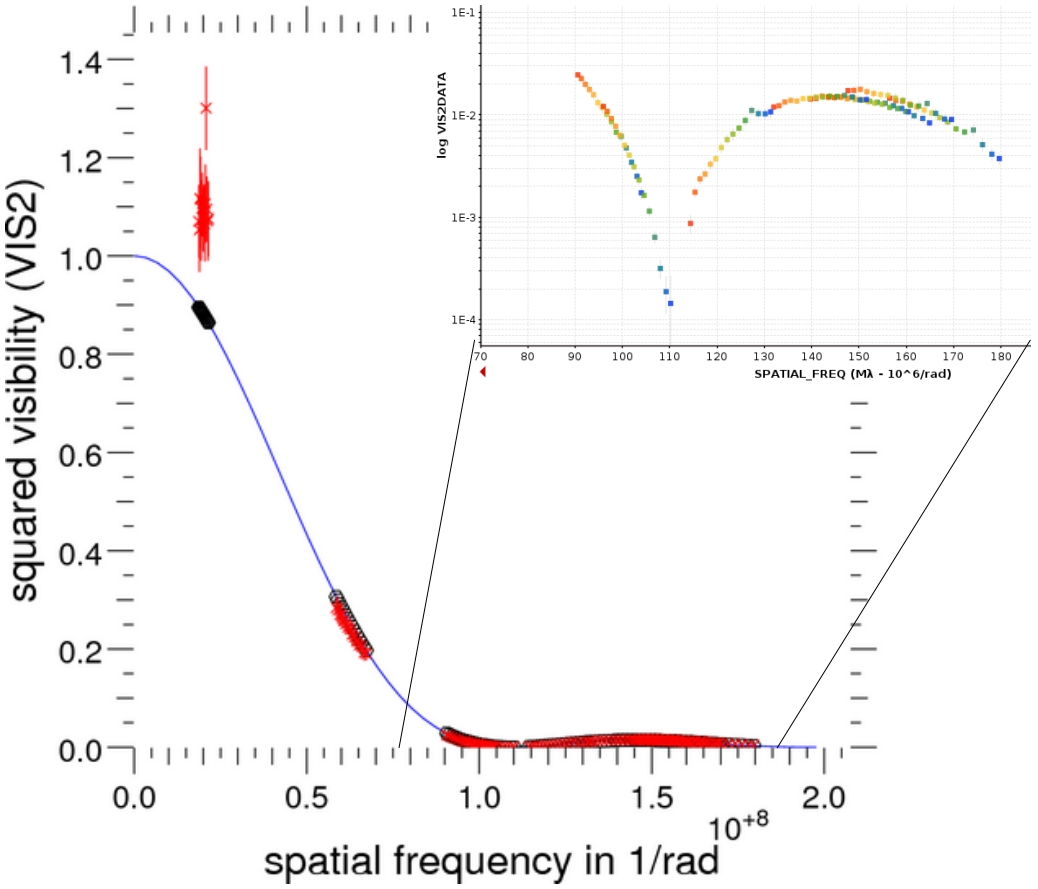
CHARA Interferometric observations for S02/S03 ISSP stars

MIRCX/MYSTIC data

-Observations during October and November nights. Also one MYSTIC observation during September



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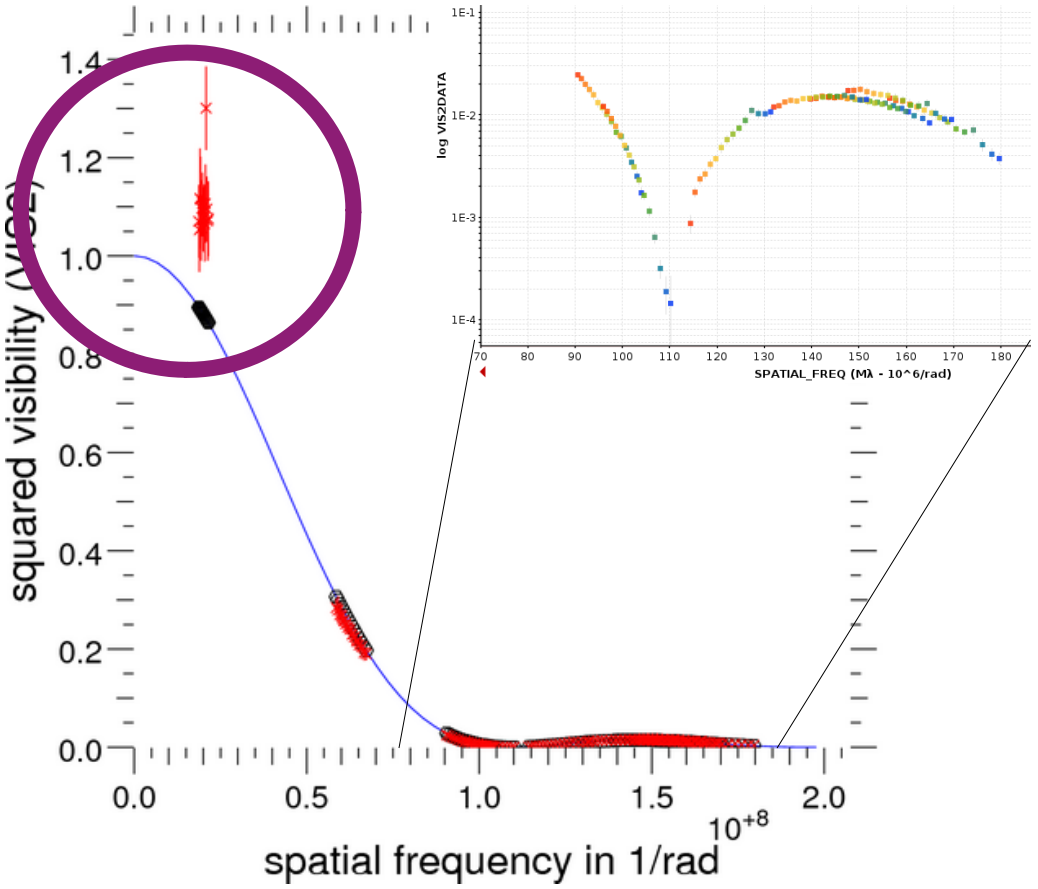
However, problem with S1S2 base for October and November nights
=> suppressed those bases in the analysis

-The S1S2 bases can't be trusted for SPICA also for the October and November nights



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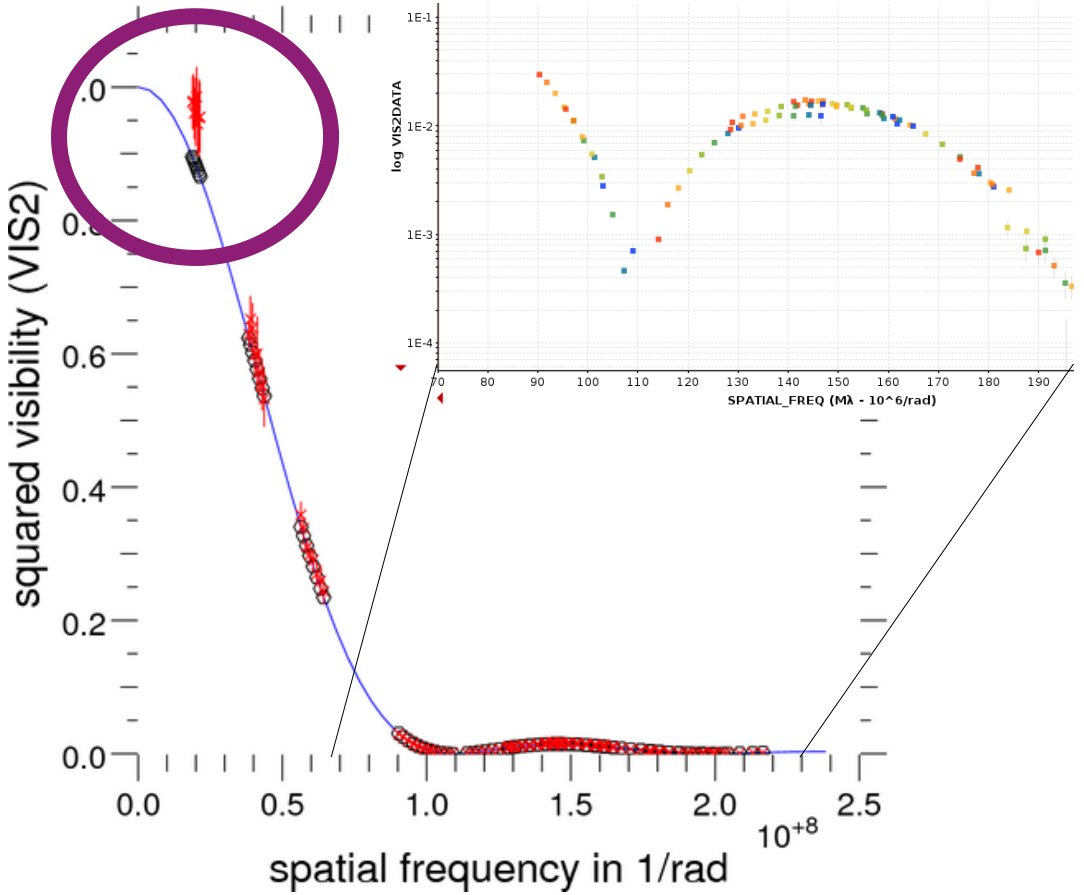
-Not solved in November



MIRCX November 10th 2023 observations of HD27371

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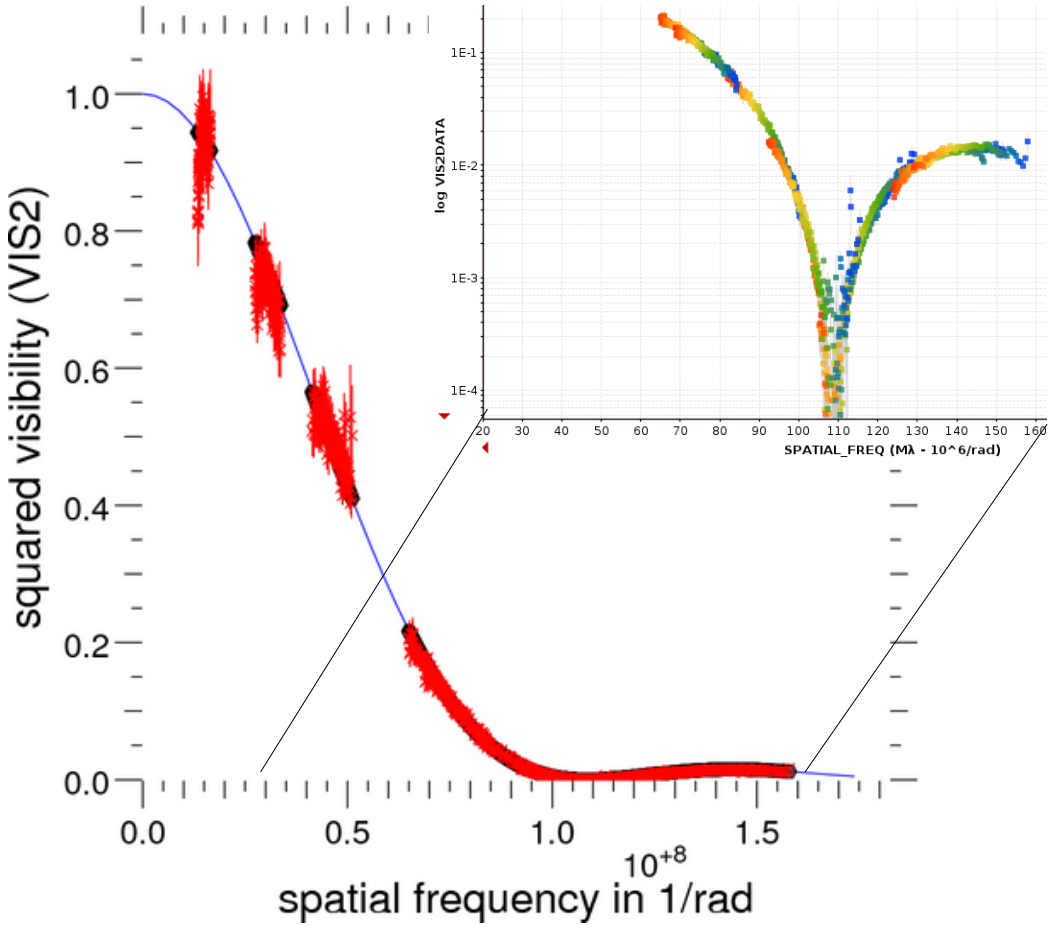
CHARA Interferometric observations for S02/S03 ISSP stars

MIRCX/MYSTIC data summary

-MYSTIC: 2 red giant stars (4 observations) observed between September 26th and November 10th 2023

-MIRCX: 2 red giant stars (3 observations) observed between October 14th and November 10th 2023

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



MYSTIC September 26th 2023 observations of HD27371

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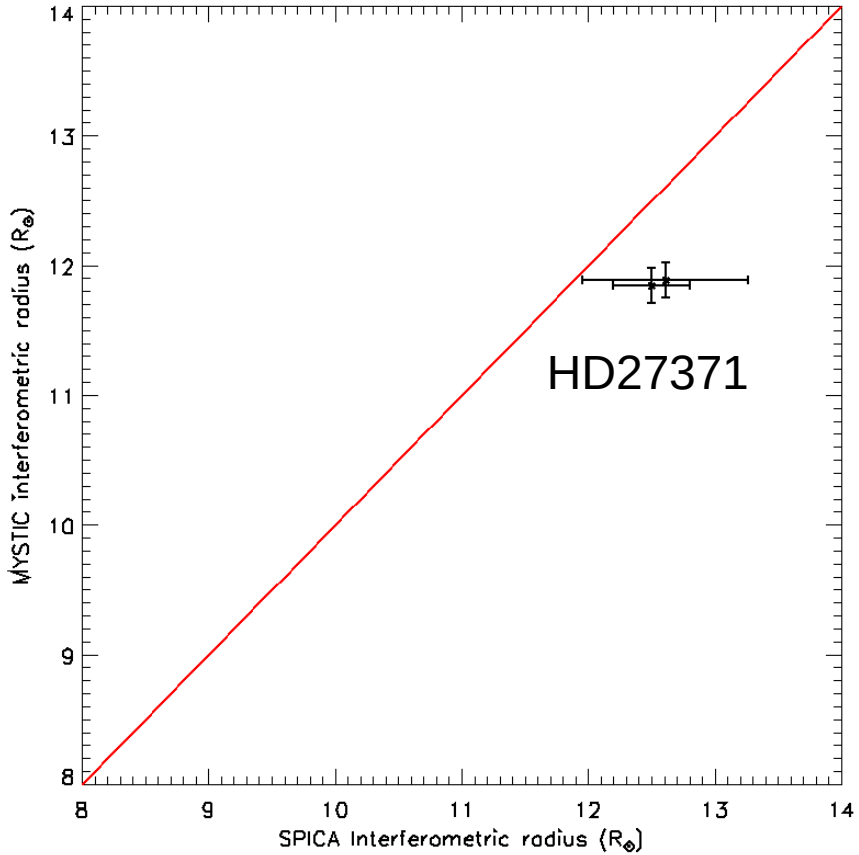
SPICA and MIRCX/MYSTIC result comparison

-Interferometric radius computed with Gaia parallaxes

<u>-MYSTIC/SPICA comparison:</u>
Putting out stars with no short baselines:
2 observations in September and November 2023
=> good agreement when short baselines are present
=> but larger uncertainties on SPICA



MYSTIC and SPICA interferometric radius

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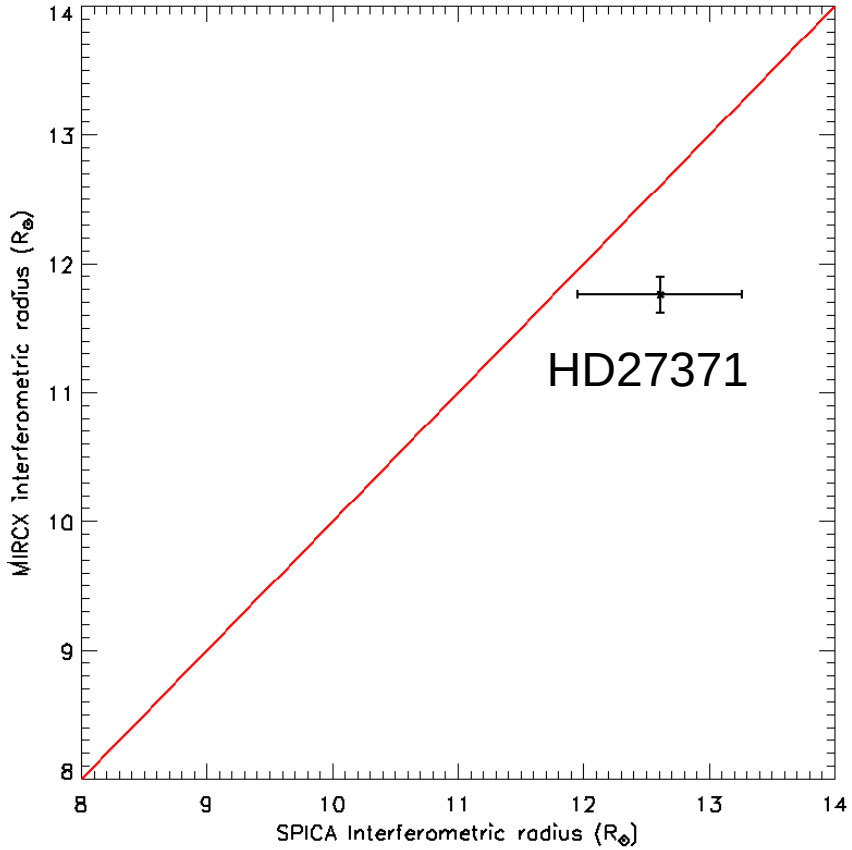

MIRCX and SPICA interferometric radius

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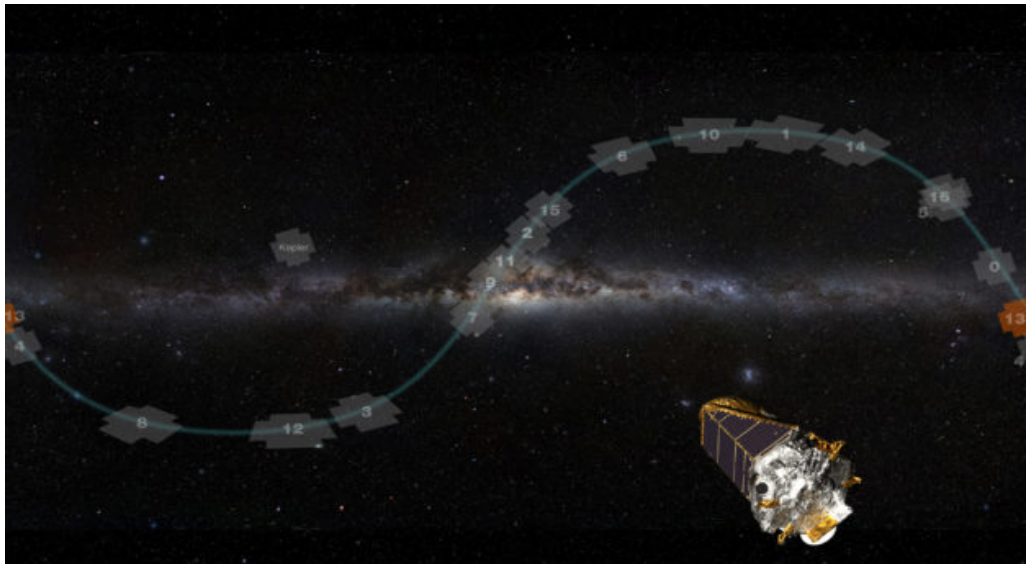
Asteroseismic radius determination

-Seismic data ($\Delta\nu$,ν_{max}) comes from K2 mission (2014-2018)
Pope et al. (2019) for red gaints
Schoffield et al. (2019) for the main sequence star



-T_{eff} comes from Gaia photometry

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

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

$\Delta\nu \sim \langle\rho\rangle$
ν_{max}: frequency of maximum oscillation

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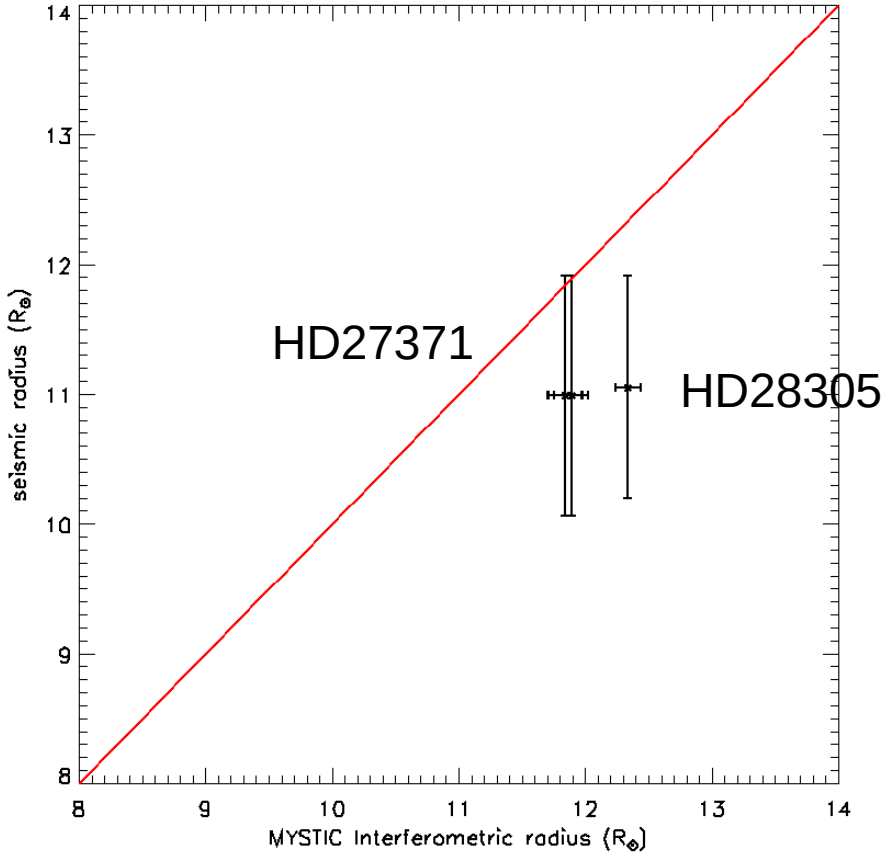
Interferometric and asteroseismic radius (R) comparison

-**MYSTIC** Interferometric radius and asteroseismic radius can be compared for 2 stars: 4 observations between September and November 2023

-Agreement between the two radius estimations at 2-σ uncertainties

-10% uncertainties for asteroseismic R, way lower for interferometry => real potential of improvement



Comparison between MYSTIC Radius and asteroseismic Radius

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Interferometric and asteroseismic radius (R) comparison

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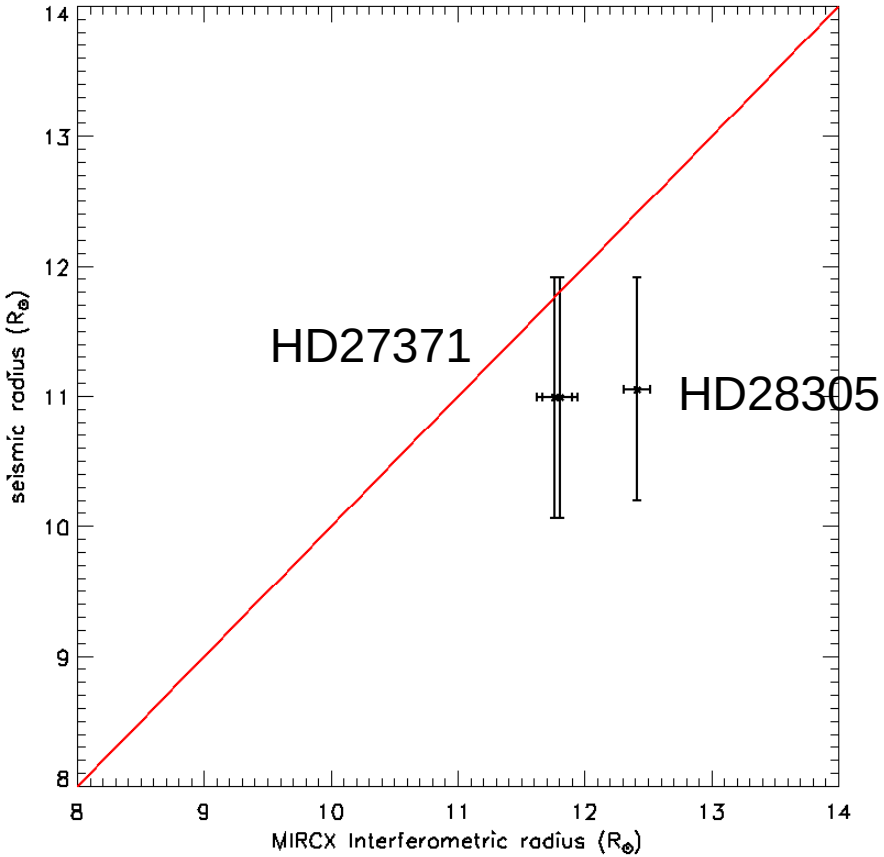

Comparison between MIRCX Radius and asteroseismic Radius

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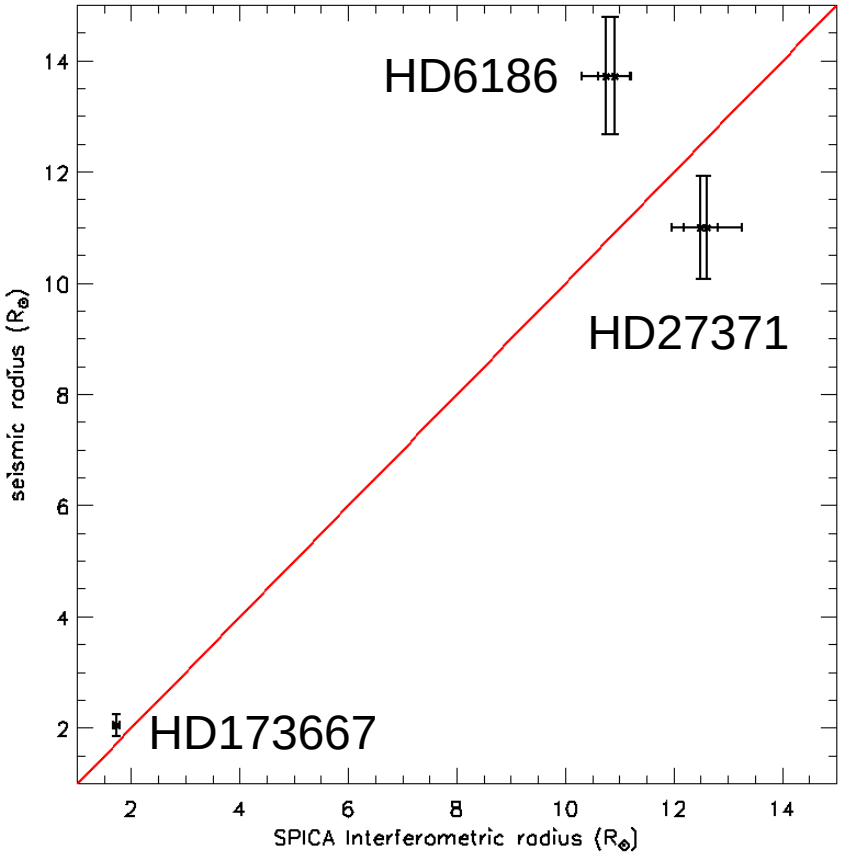
Interferometric and asteroseismic radius (R) comparison

-**SPICA** Interferometric radius and asteroseismic radius can be compared for 3 stars: 5 observations between August and November 2023

-The agreement is less apparent and uncertainties are larger for SPICA compared to MIRCX/MYSTIC
=> still need some development to obtain similar precision than MIRCX/MYSTIC



Comparison between MIRCX Radius and asteroseismic Radius

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Conclusion

-The observations of asteroseismic targets will permit to obtain better constraints on the asteroseismic scaling relations, thus on galactic archeology and stellar ages.

-5 asteroseismic targets were observed with SPICA (2 with MIRCX/MYSTIC) in 8 observations, 7 of them are exploitable

-Vibration problems caused S1S2 bases to be inexploitable for October and November nights => this has to be solved soon

-For the exploitable data we have an agreement between SPICA and MYSTIC/MIRCX

-Agreement between MIRCX/MYSTIC and asteroseismic observations. There is still some work with SPICA

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Thank you for your attention

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