

Study of surface brightness and magnetic activity of ISSP dwarf stars

Romina Ibañez-Bustos, Nicolas Nardetto, Denis Mourard

April 28th, 2025

Study of surface brightness and magnetic activity of ISSP dwarf stars

+ few subgiants & giants

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CHARA/SPICA ISSP Project

S01: Exoplanet host stars

S02 & S03: Asteroseismic stars

S04: Surface brightness - color relation (SBCR)

S05: Limb darkening

S06: Binaries

S07: Rotation

S08: Winds & environments

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

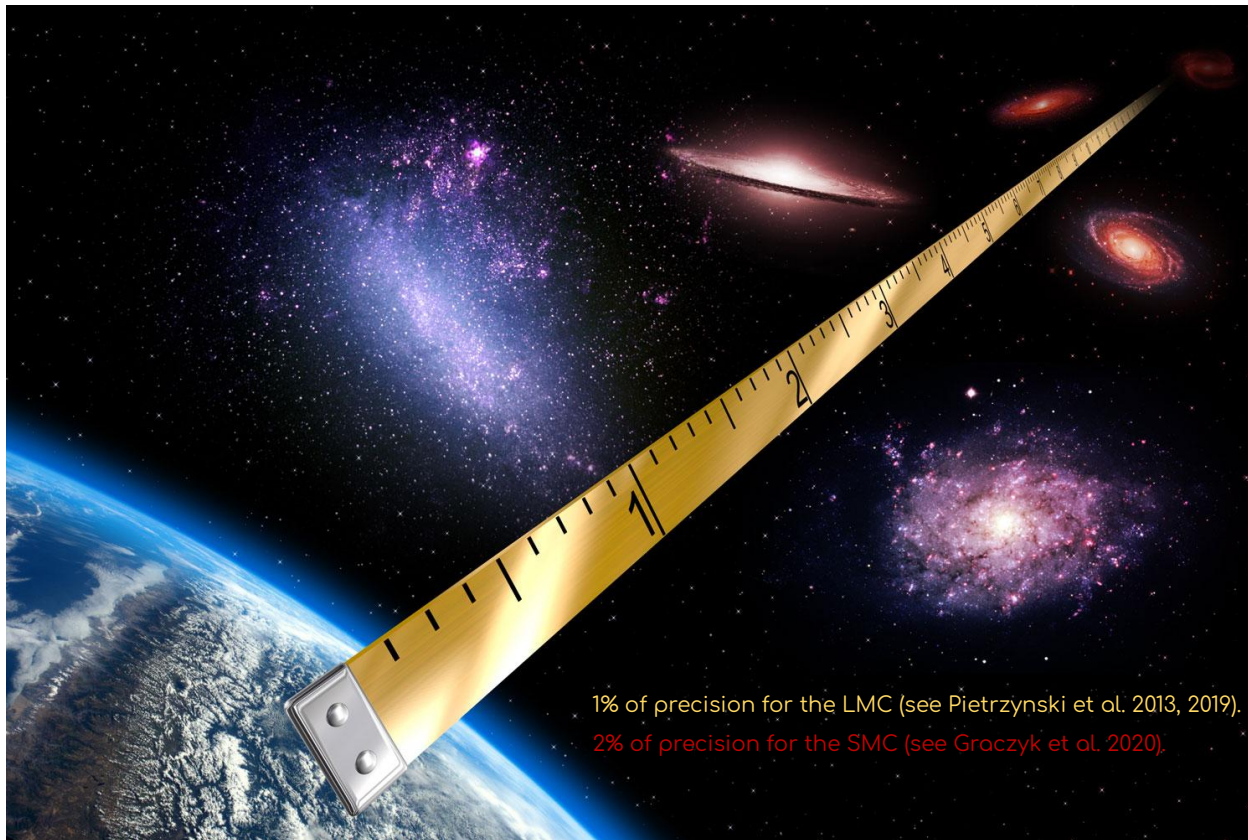


Image credit:
Observatoire de Paris

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

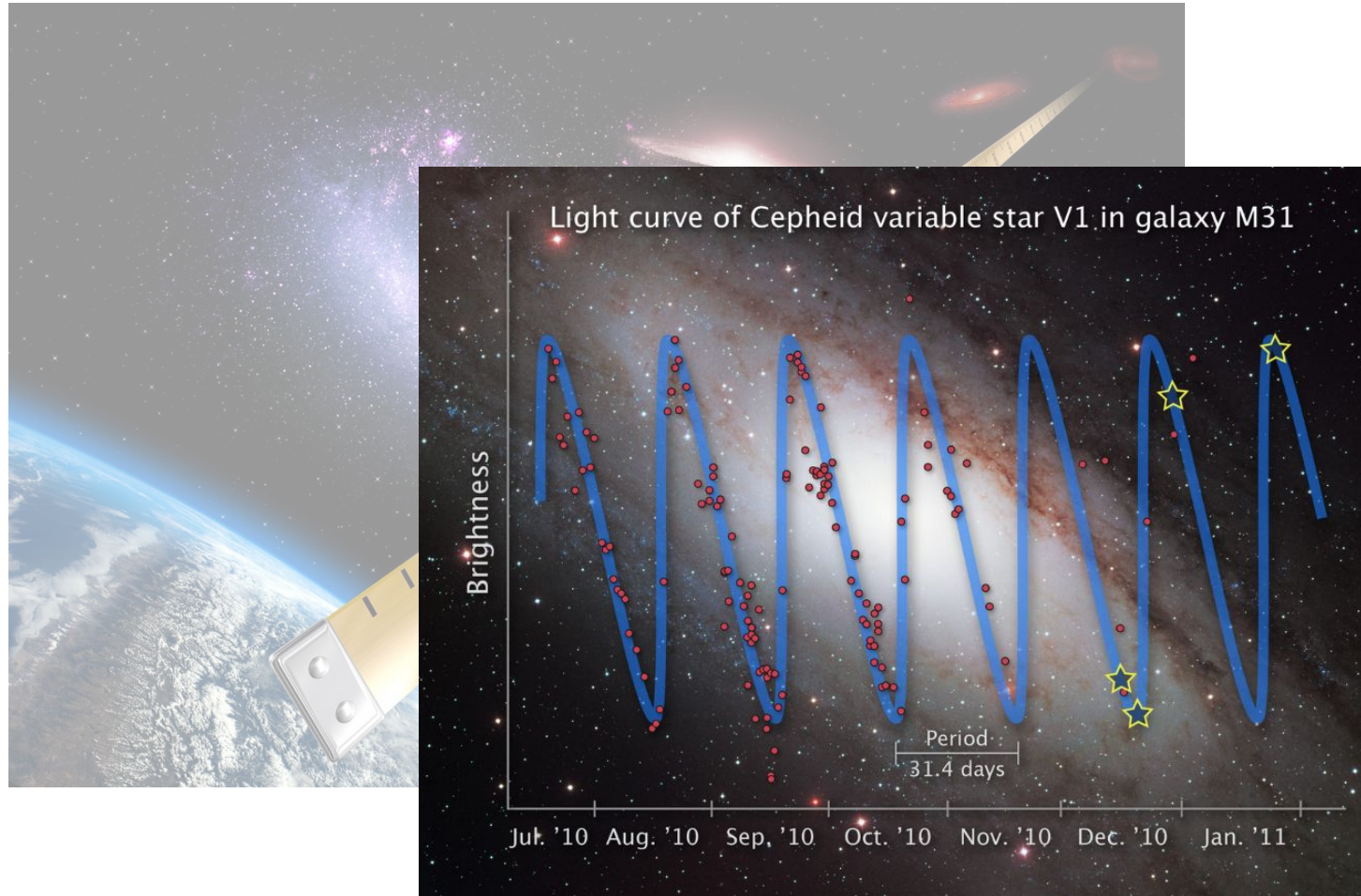
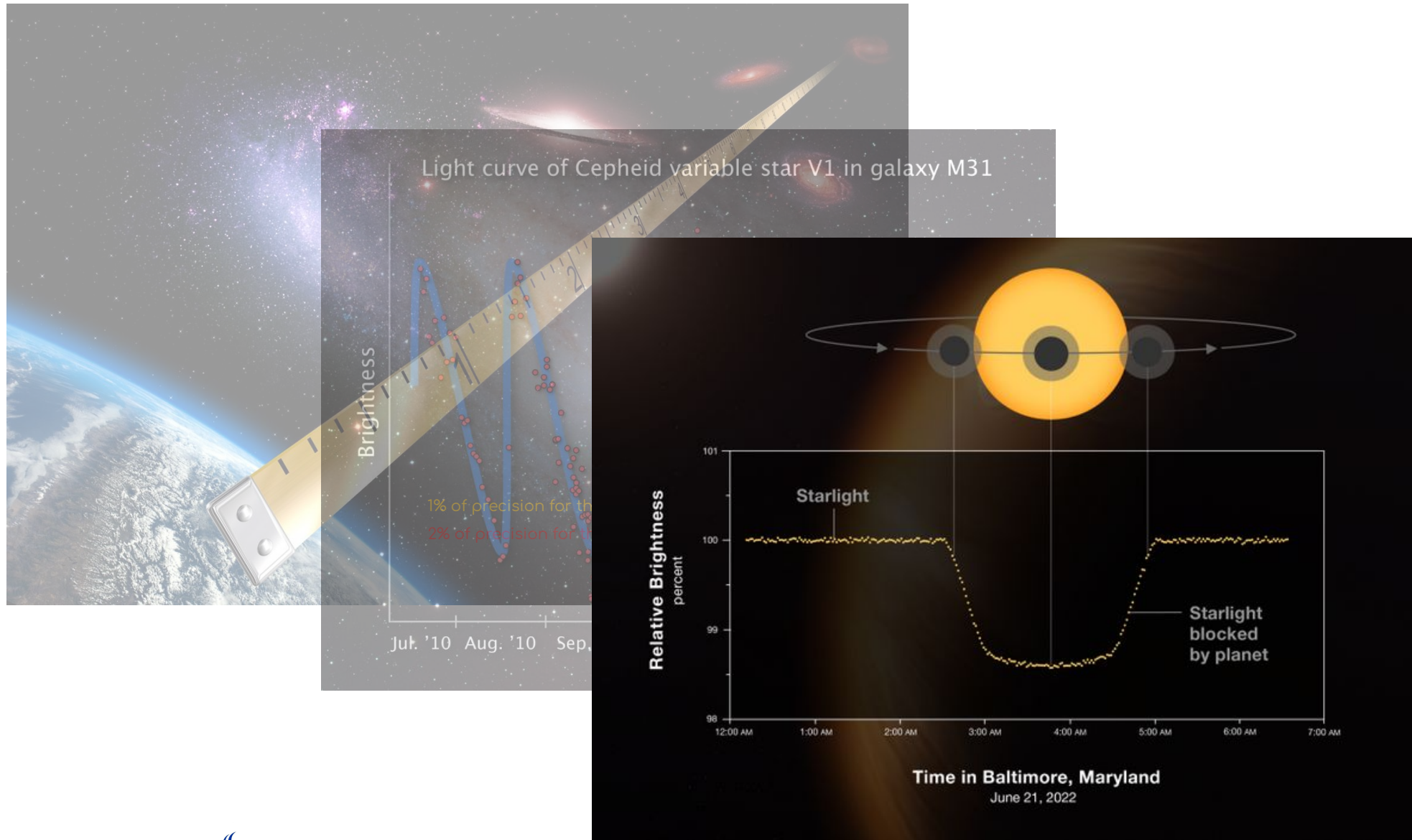


Image credit:
AFH

SBCRs used in the Baade-Wesselink (BW) method of Cepheid distance determination (see Nardetto et al. 2023, 2024).

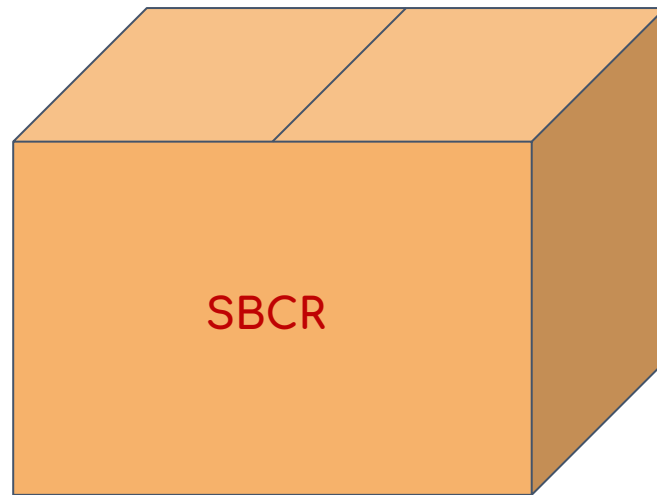
CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



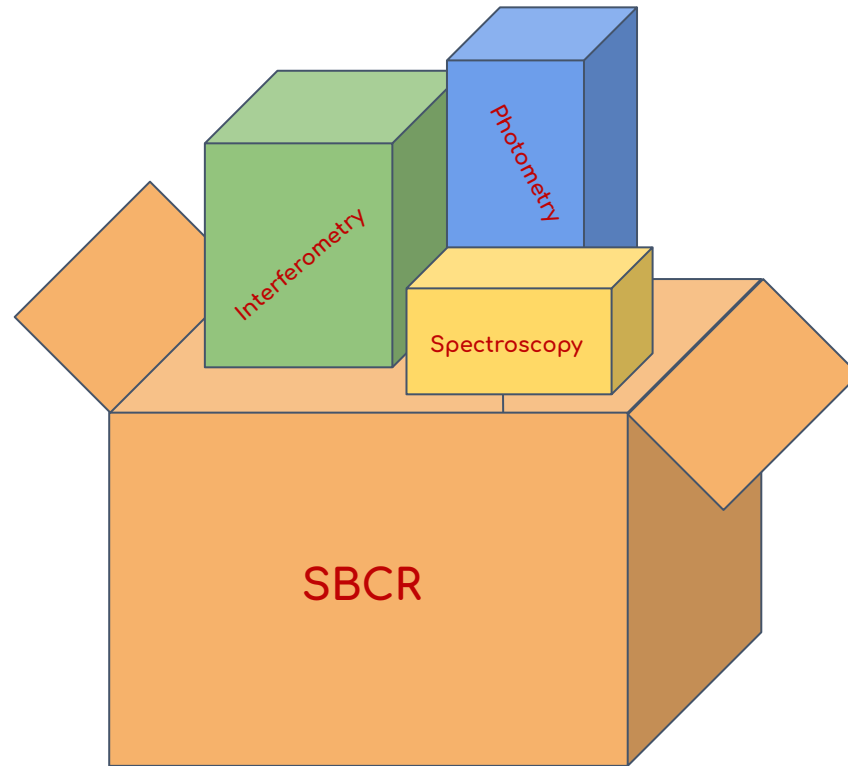
The radius of the planet can be derived from the stellar radius through the transit (see Ligi et al. 2016).

Image credit:
NASA, ESA, CSA, STScI

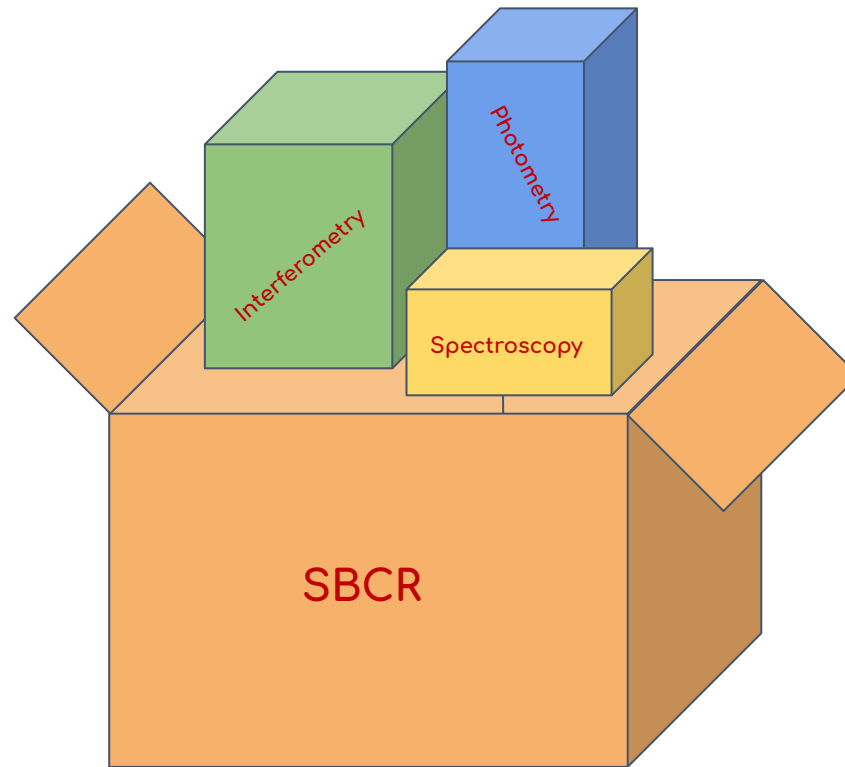
CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



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CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



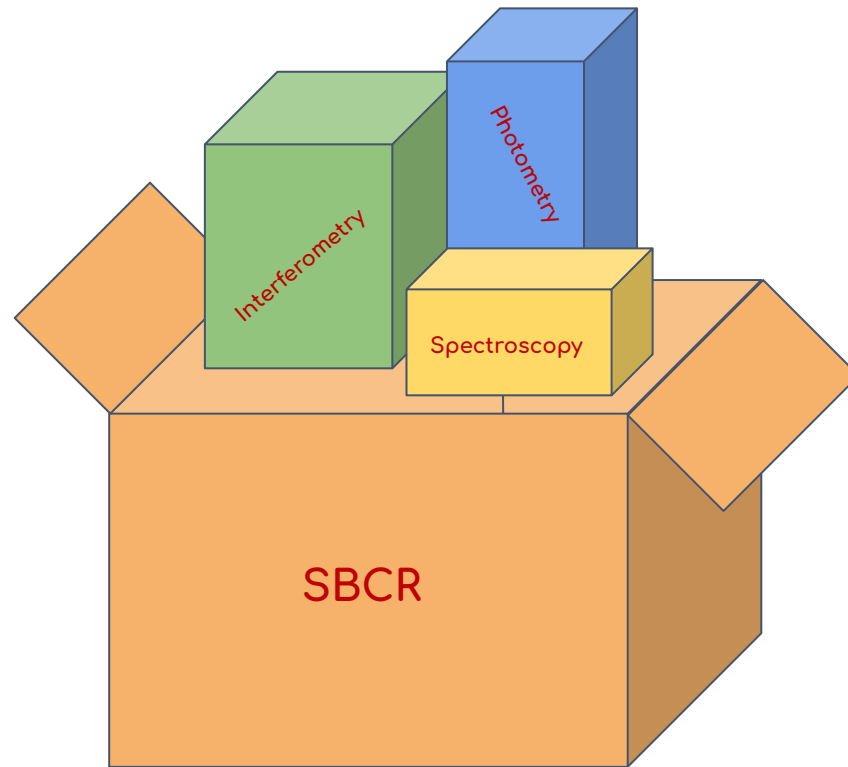
INTERFEROMETRY: θ_{LD}

$$F_{\lambda} = 4.2196 - 0.1 m_{\lambda 0} - 0.5 \log \theta_{LD}$$

PHOTOMETRY: $m_{\lambda 1} - m_{\lambda 2}$

$$F_{\lambda} = \alpha + \beta (m_{\lambda 1} - m_{\lambda 2})$$

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



INTERFEROMETRY: θ_{LD}

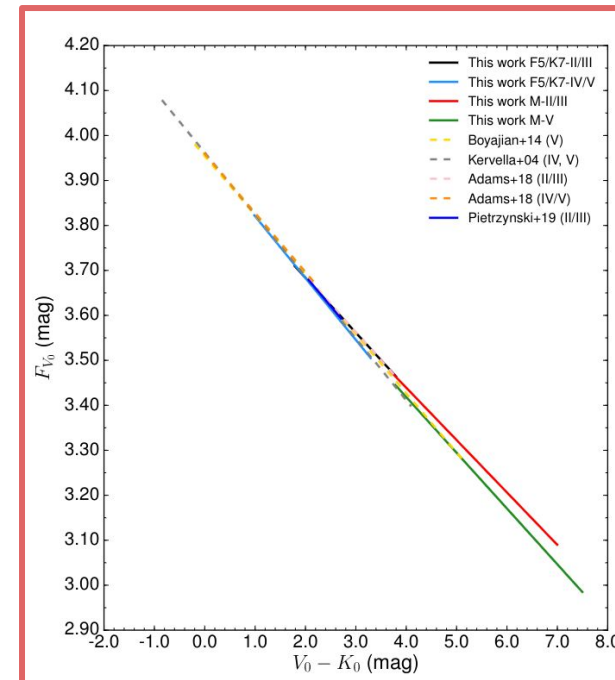
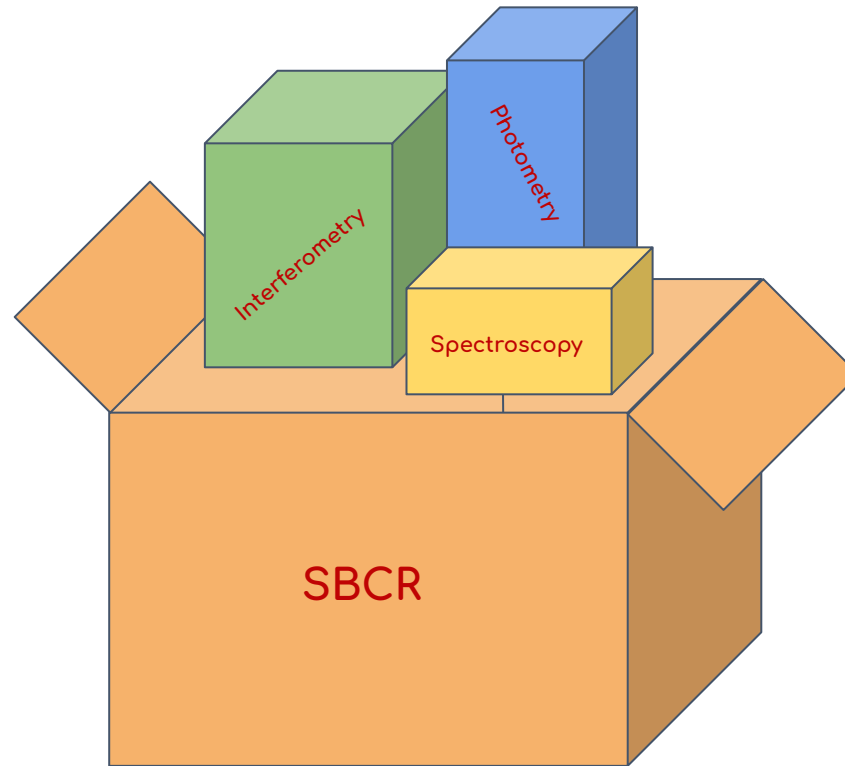
$$F_{\lambda} = 4.2196 - 0.1 m_{\lambda 0} - 0.5 \log \theta_{LD}$$

PHOTOMETRY: $m_{\lambda 1} - m_{\lambda 2}$

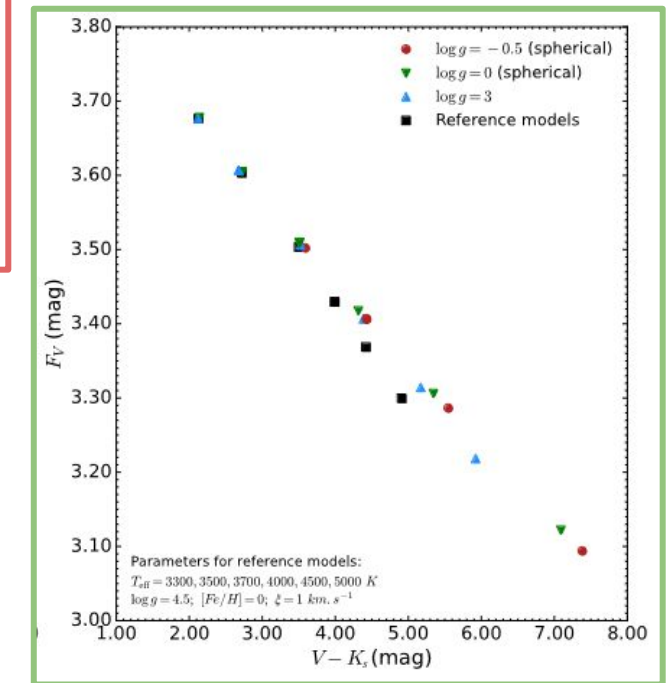
$$F_{\lambda} = \alpha + \beta (m_{\lambda 1} - m_{\lambda 2})$$

SPECTROSCOPY: $T_{eff}, \log g$

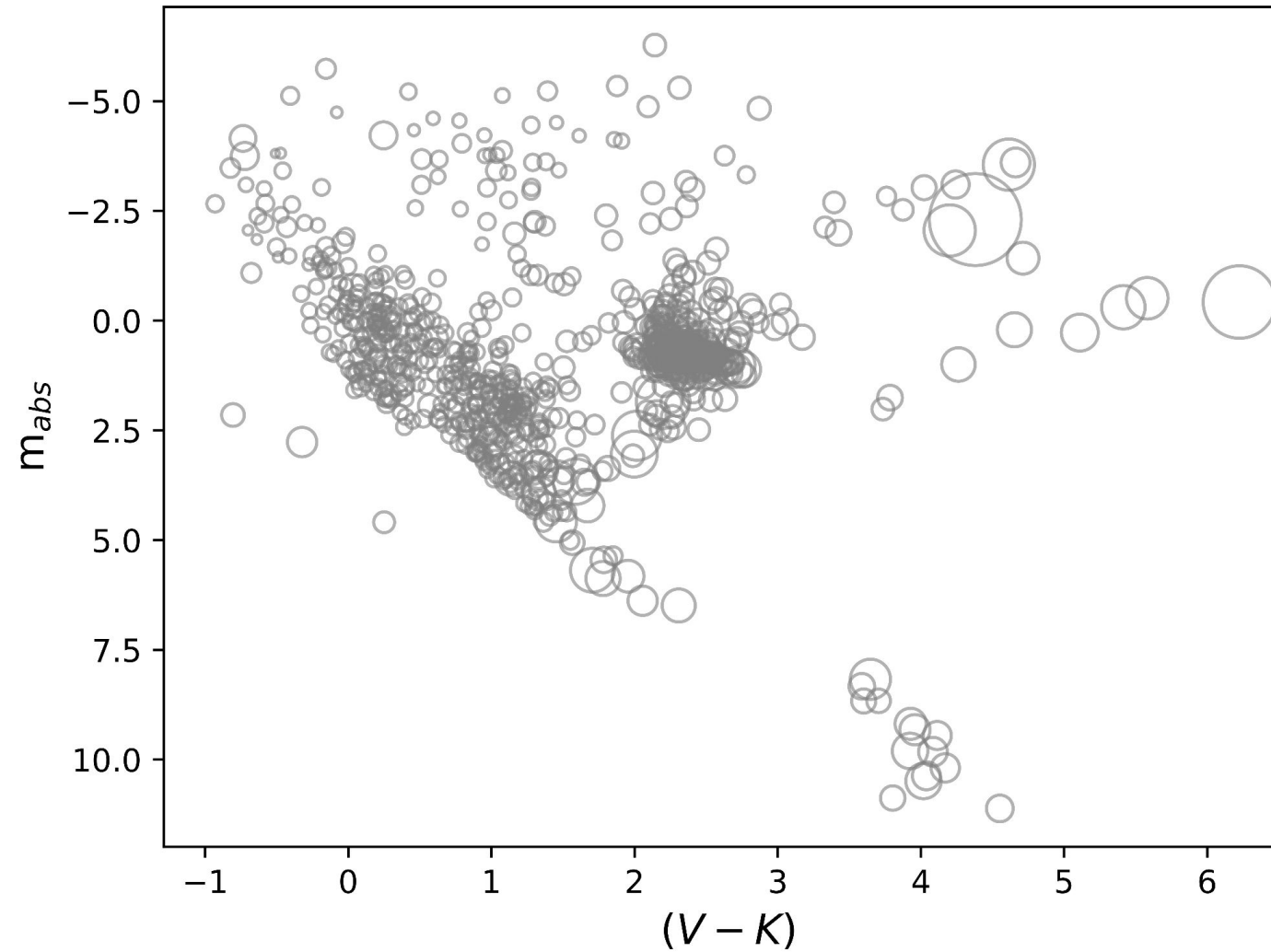
CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



see Salsi et al. 2020, 2021, 2022.



CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

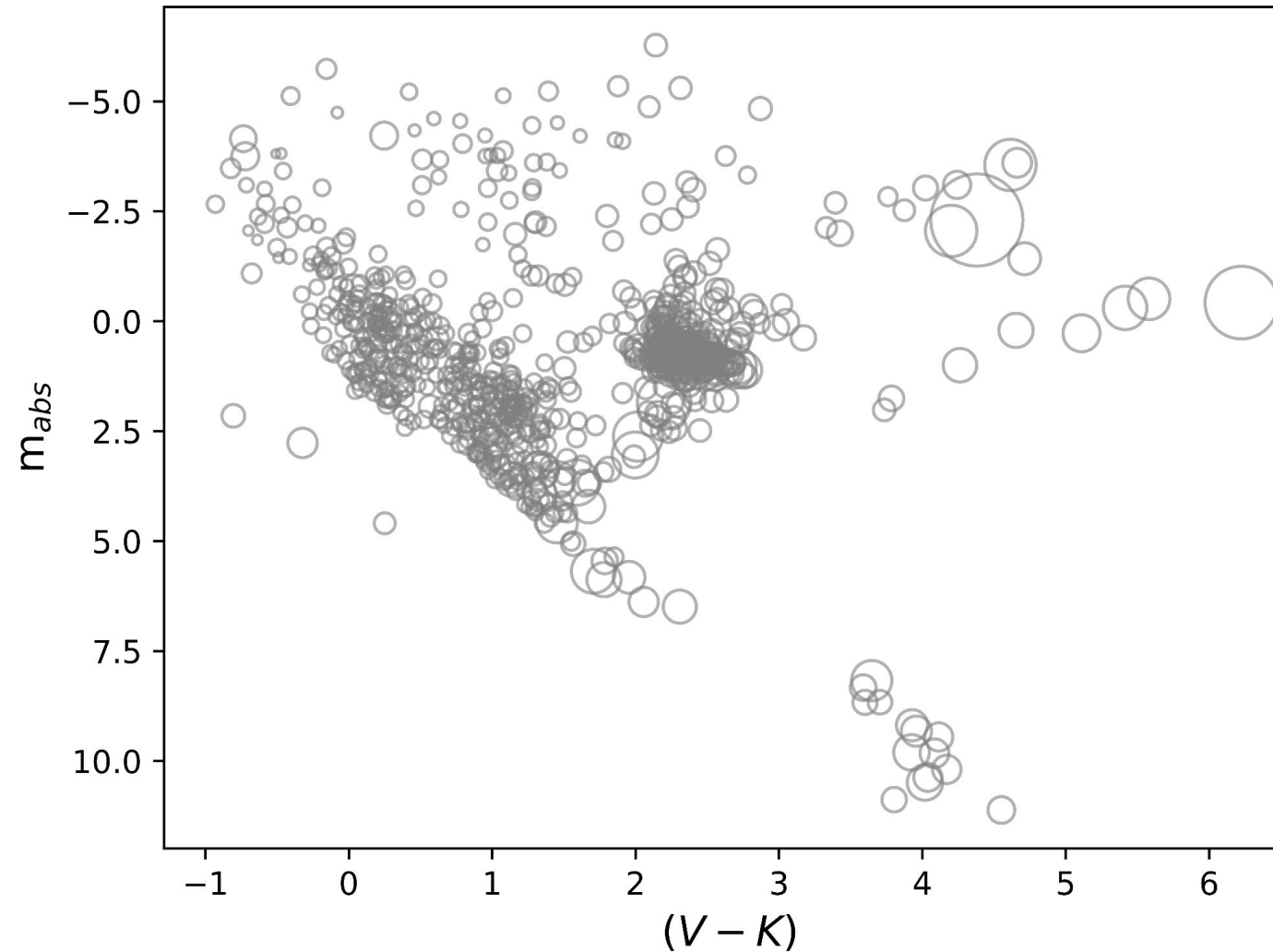


INTERFEROMETRY: θ_{LD}

PHOTOMETRY: $m_{\lambda_1} - m_{\lambda_2}$

Main goal : Calibrate the SBCR over the whole HRD as homogeneously as possible with an precision between 1 and 2 %.

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



INTERFEROMETRY: θ_{LD}

PHOTOMETRY: $m_{\lambda_1} - m_{\lambda_2}$

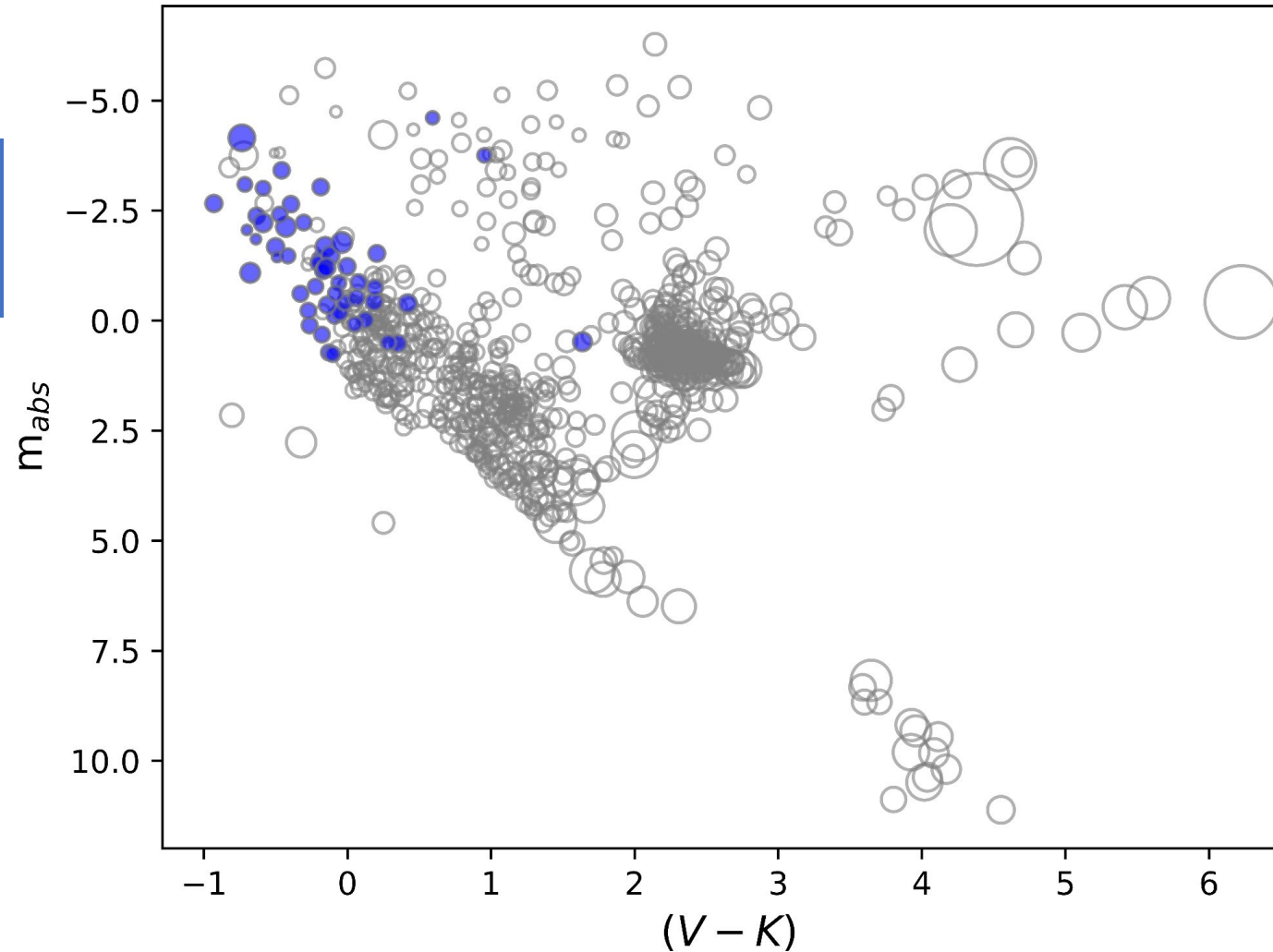
Main goal : Calibrate the SBCR over the whole HRD as homogeneously as possible with an precision between 1 and 2 %.

SPECTROSCOPY: T_{eff} , $\log g$

Main goal : Relocate the stars in the HR diagram.

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

Goal: Calibrate the SBCR for B1-3 IV/V stars at 1-2% to calibrate H0 for Araucaria.



INTERFEROMETRY: θ_{LD}

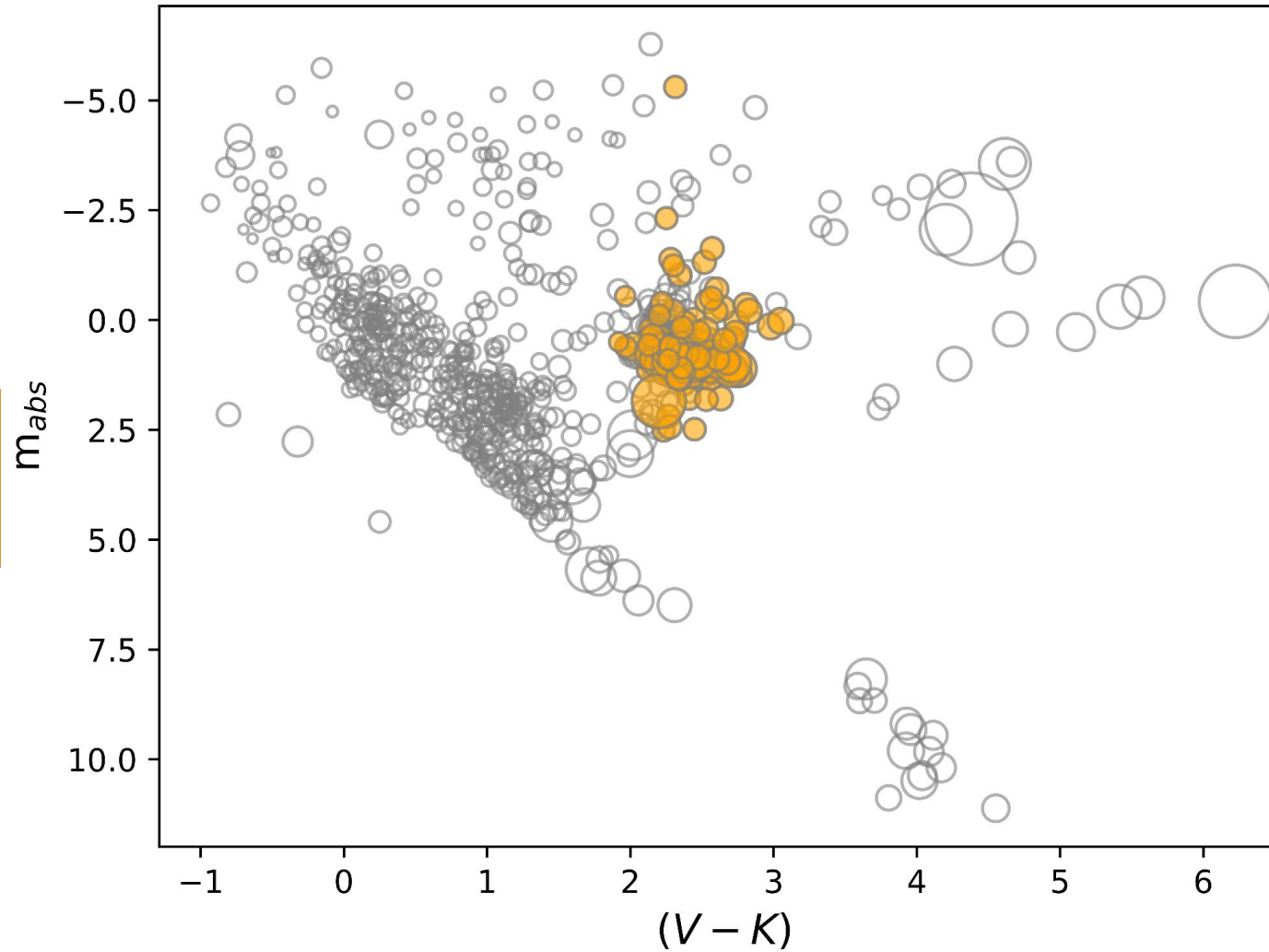
PHOTOMETRY: $m_{\lambda_1} - m_{\lambda_2}$

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SPECTROSCOPY: $T_{eff}, \log g$

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CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



Goal: Calibrate the SBCR for KIII stars at 1% to improve the distance to LMC for Araucaria.

INTERFEROMETRY: θ_{LD}

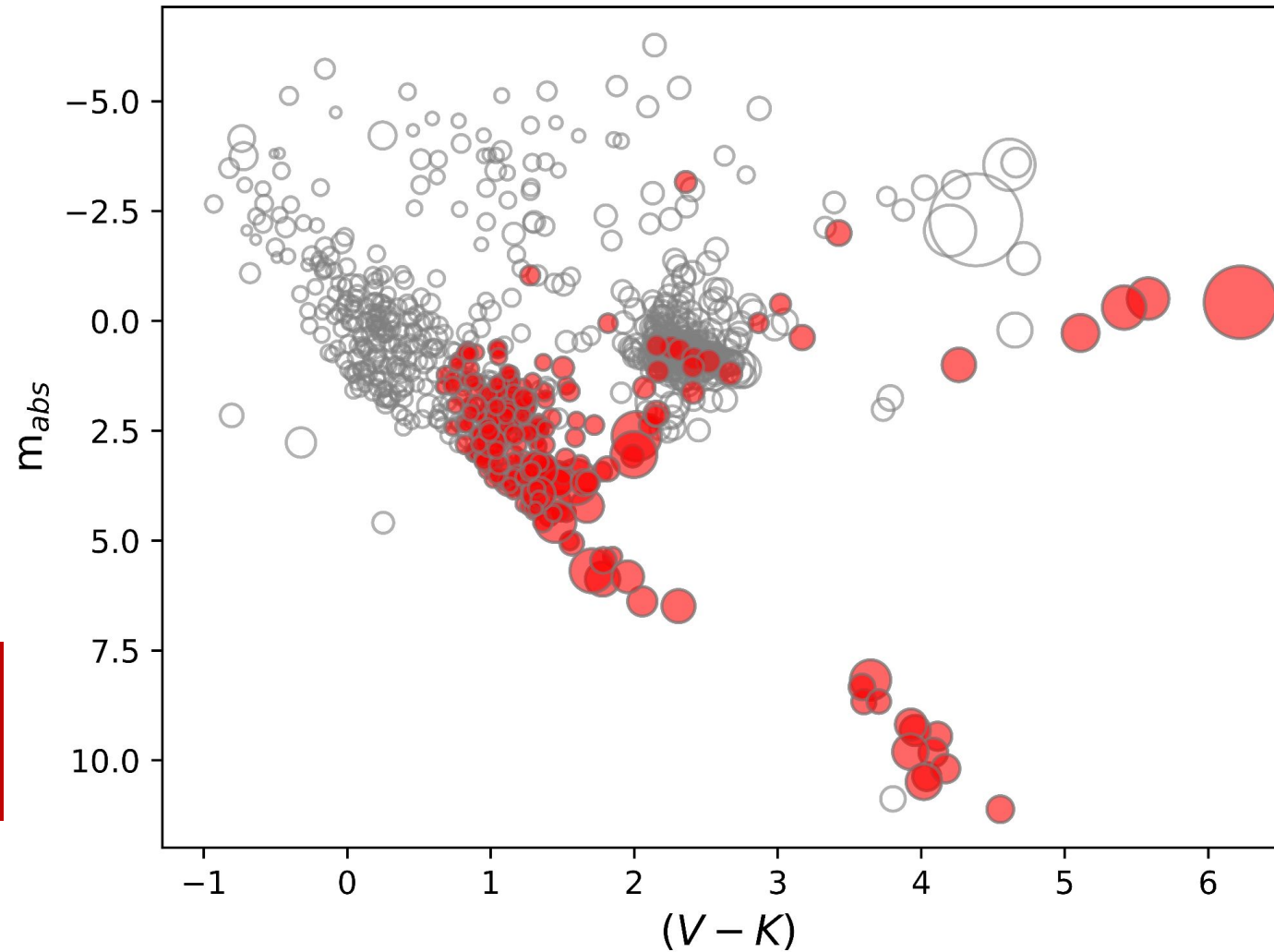
PHOTOMETRY: $m_{\lambda_1} - m_{\lambda_2}$

Main goal : Calibrate the SBCR over the whole HRD as homogeneously as possible with an precision between 1 and 2 %.

SPECTROSCOPY: $T_{eff}, \log g$

Main goal : Relocate the stars in the HR diagram.

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



Goal: Calibrate the SBCR for late-type IV/V stars at 2% for PLATO mission.

INTERFEROMETRY: θ_{LD}

PHOTOMETRY: $m_{\lambda_1} - m_{\lambda_2}$

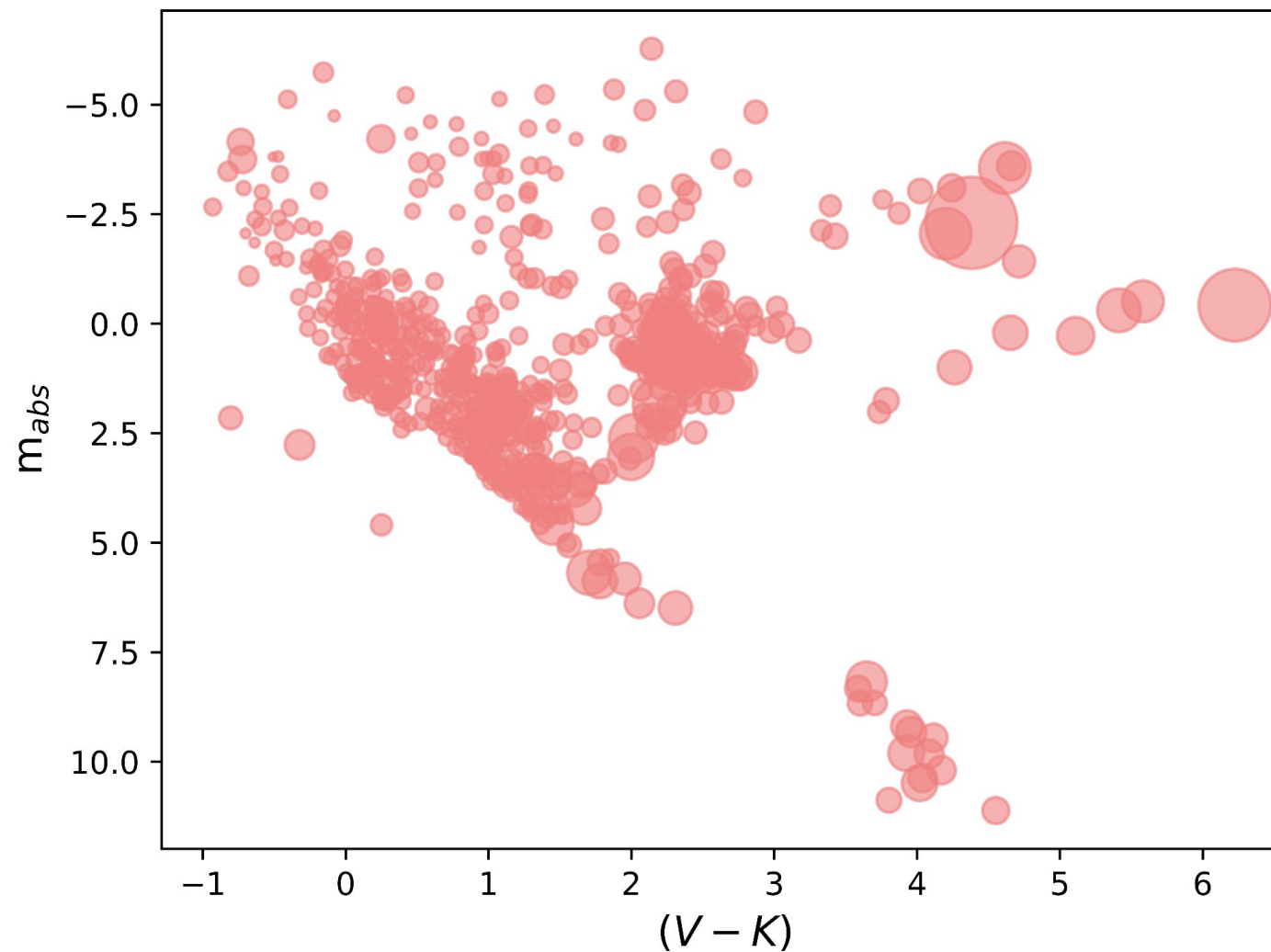
Main goal : Calibrate the SBCR over the whole HRD as homogeneously as possible with an precision between 1 and 2 %.

SPECTROSCOPY: T_{eff} , $\log g$

Main goal : Relocate the stars in the HR diagram.



CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



Sample : 888 stars in total with:

- $SpT = [B0 - M3]$
- $SpC = [V, IV, >II]$.

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

Following the ideas and concepts from Salsi et al. (2020, 2021)...

stars with very low activity level over all the HRD

JSDC: flag = 0

SIMBAD: MAIN_type = STAR

good photometry

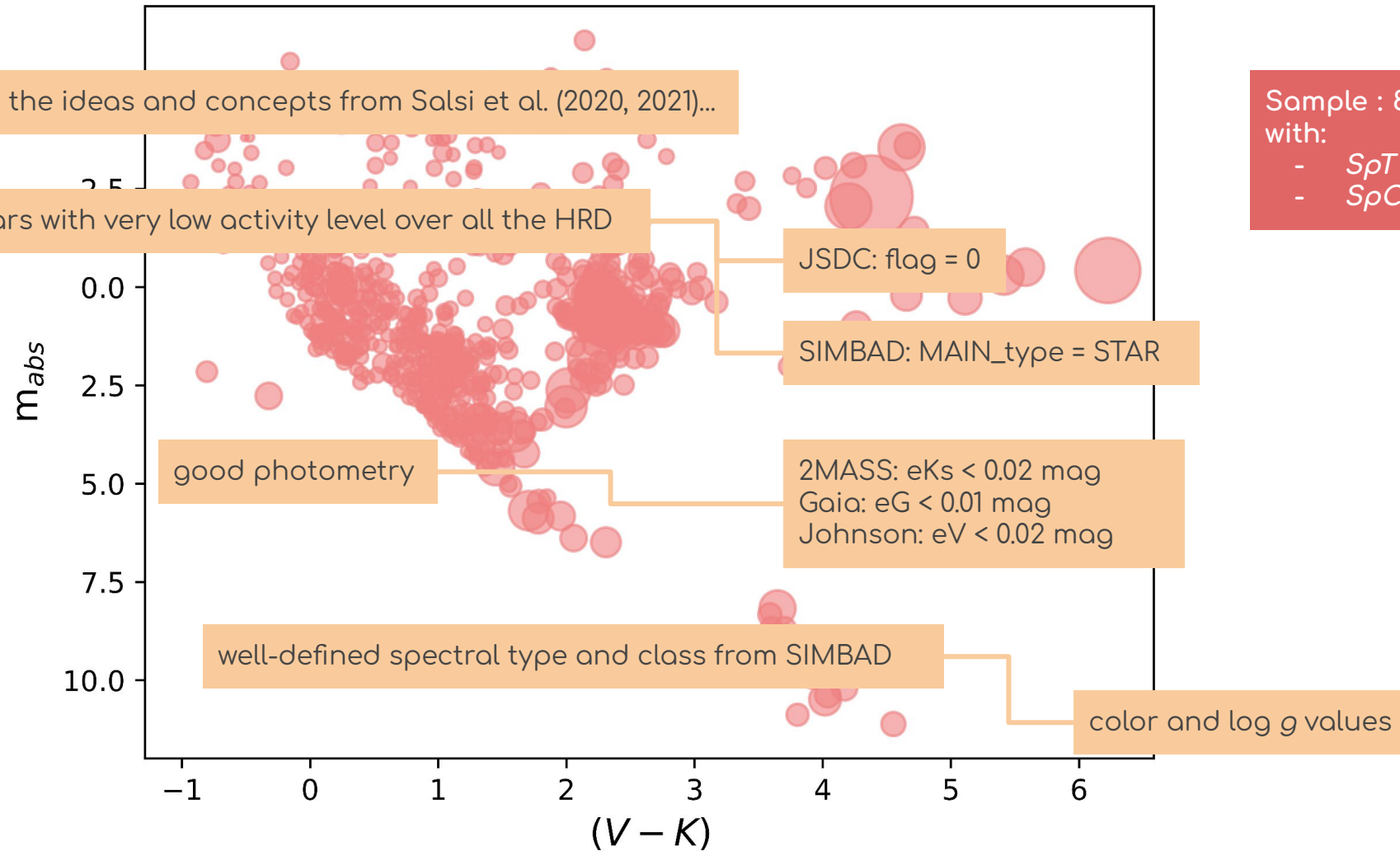
2MASS: eKs < 0.02 mag
Gaia: eG < 0.01 mag
Johnson: eV < 0.02 mag

well-defined spectral type and class from SIMBAD

color and log g values

Sample : 888 stars in total with:

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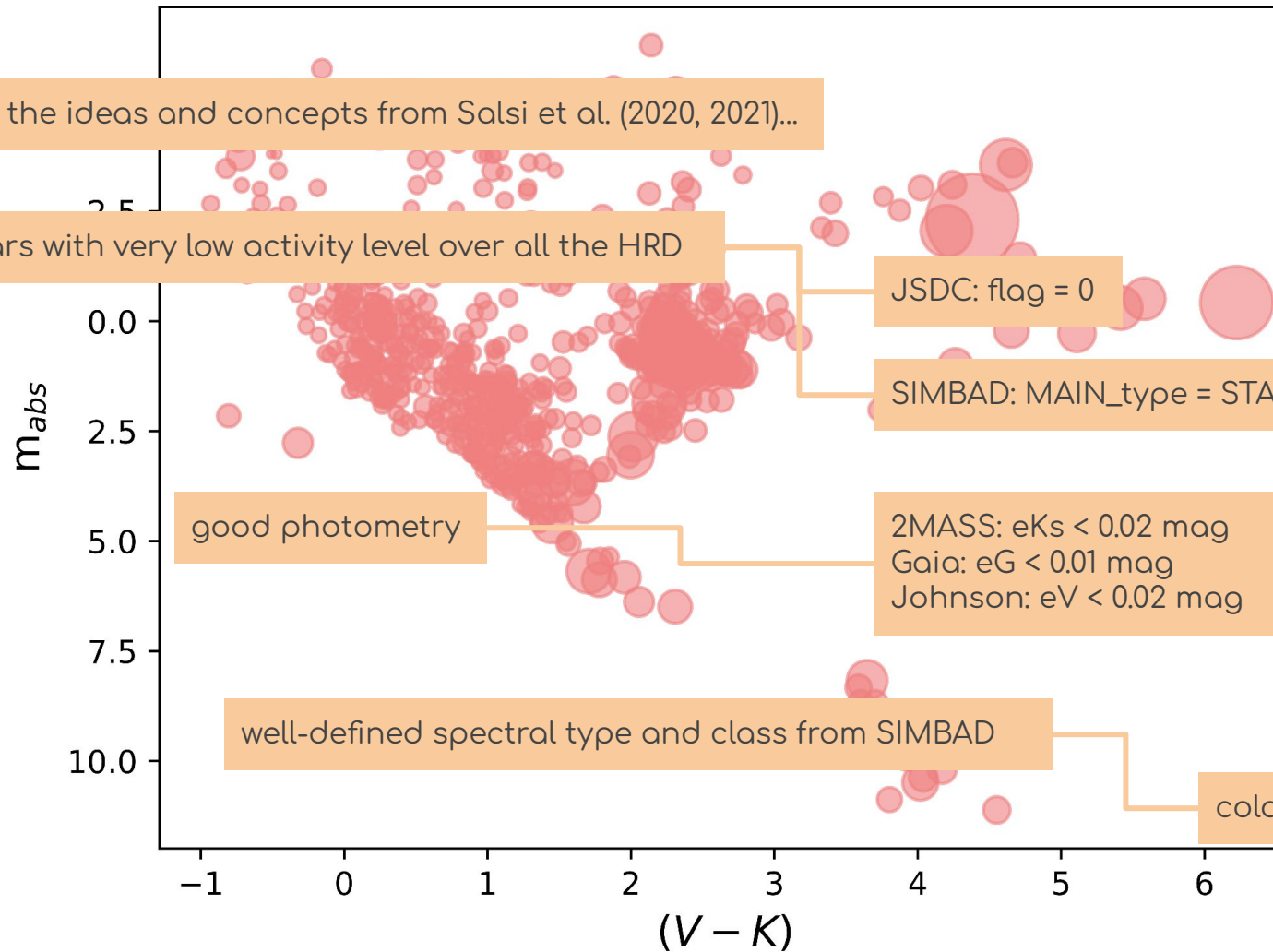
well-defined spectral type and class from SIMBAD

color and log g values

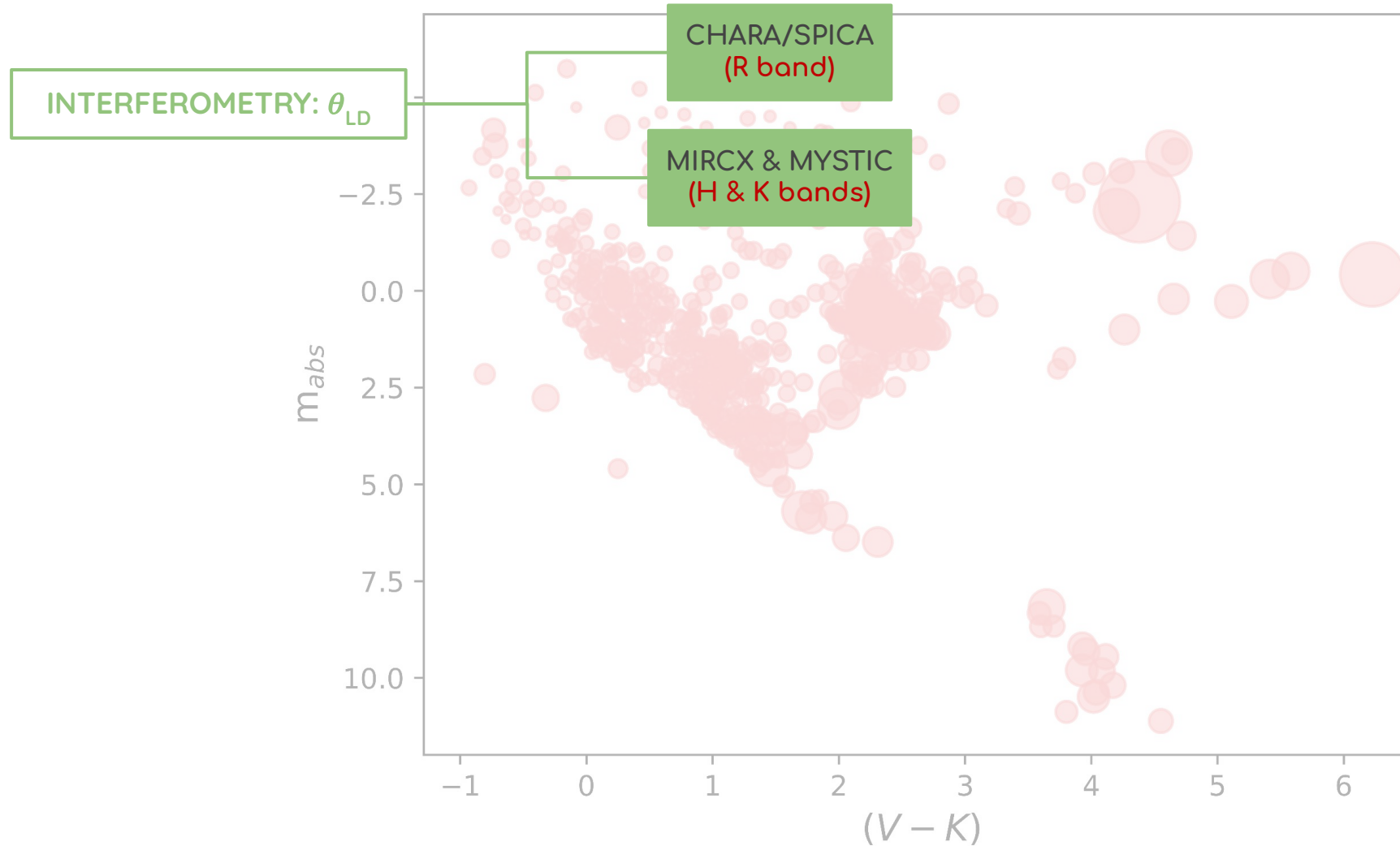
Sample : 888 stars in total with:

- SpT = [B0 - M3]
- SpC = [V, IV, >III].

Main idea : To observe 2 stars per sub-spectral channel.



CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

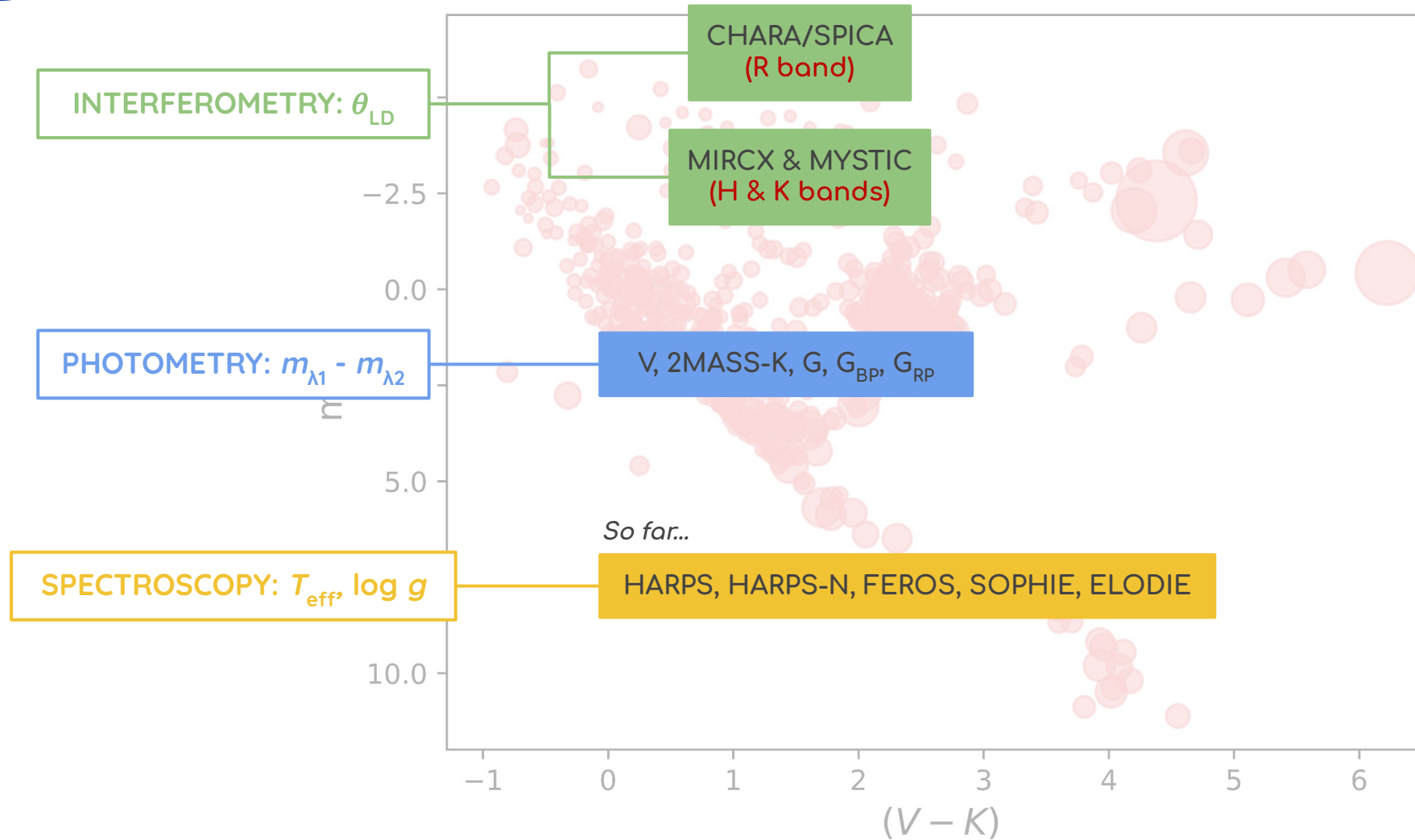


Sample : 888 stars in total with:

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CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

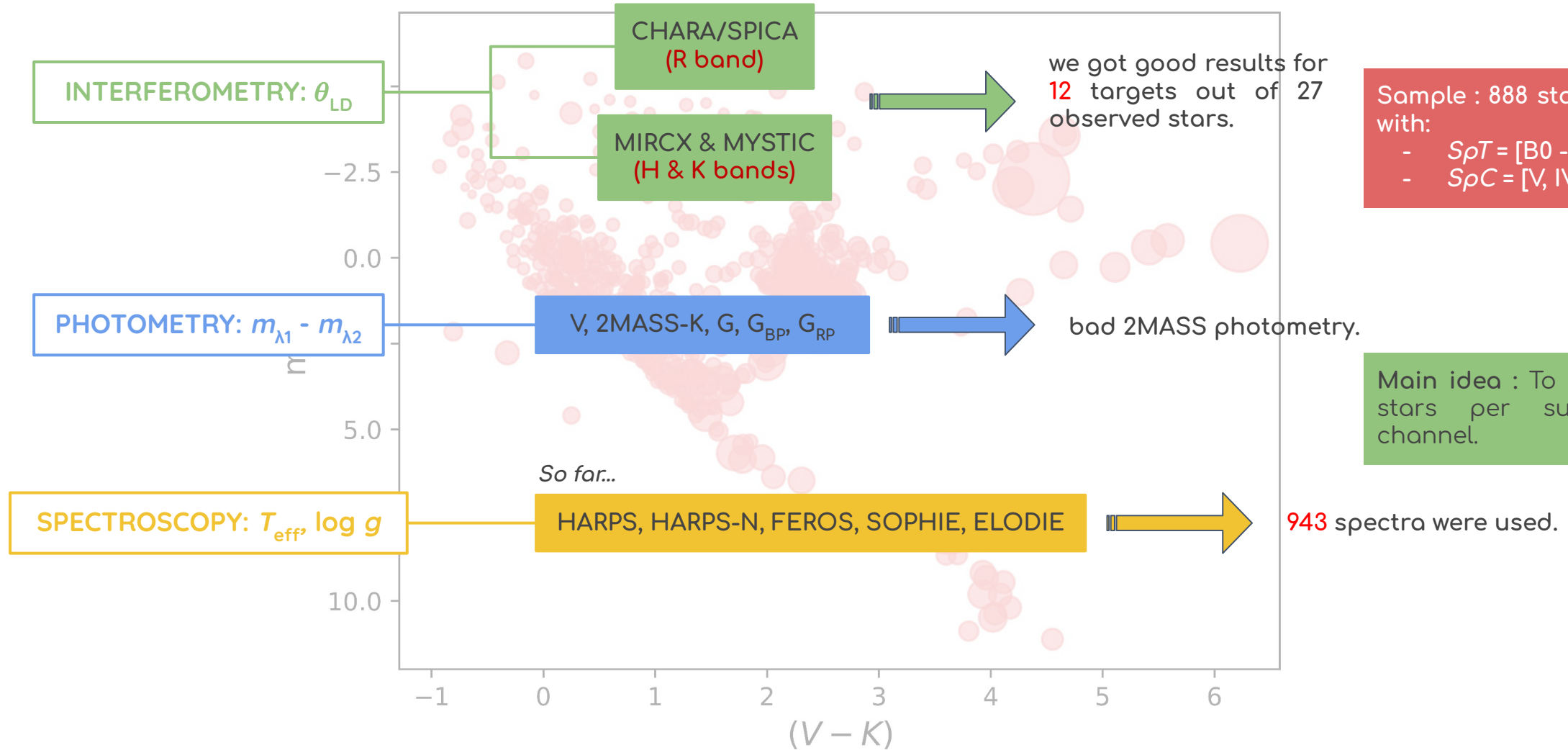


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CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)





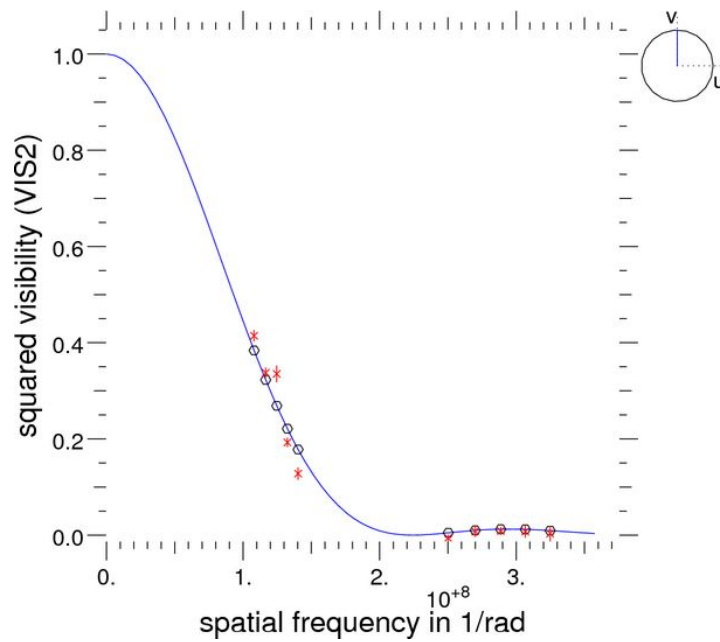
CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

INTERFEROMETRY: θ_{LD}

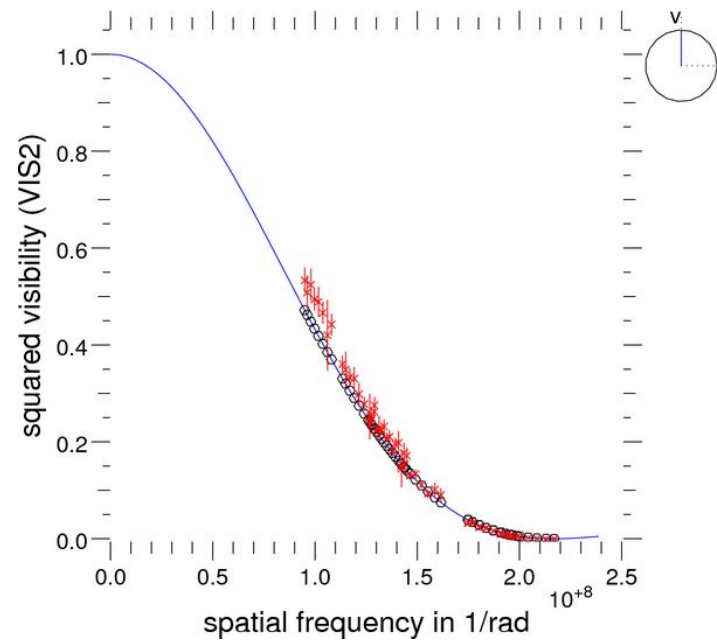
CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

INTERFEROMETRY: θ_{LD}

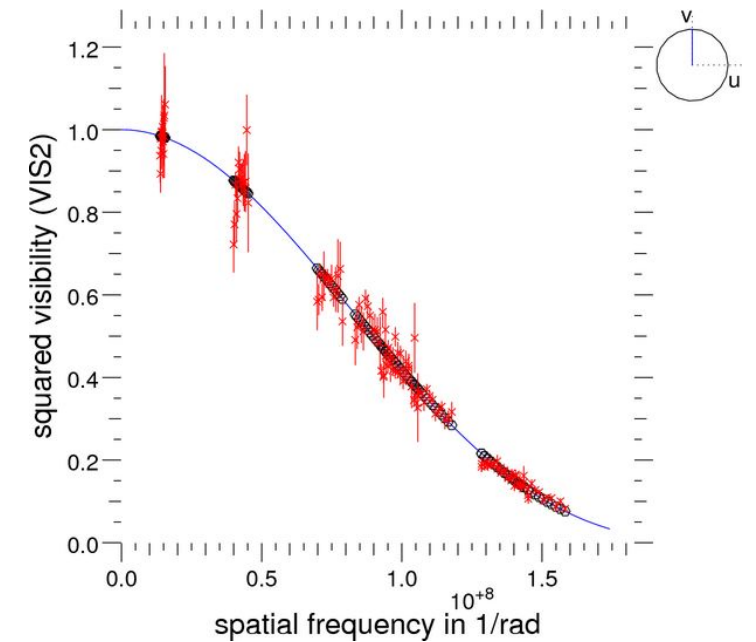
HD 142860, F6V, March 22nd 2024



SPICA



MIRCX

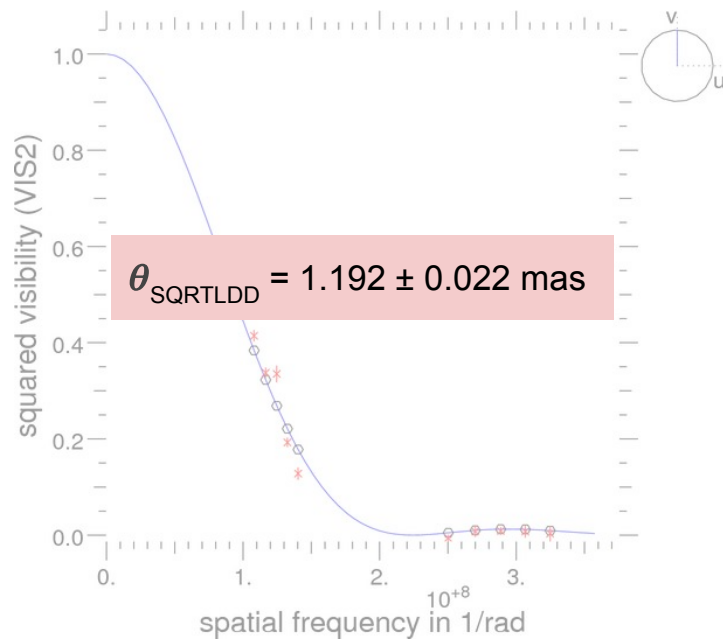


MYSTIC

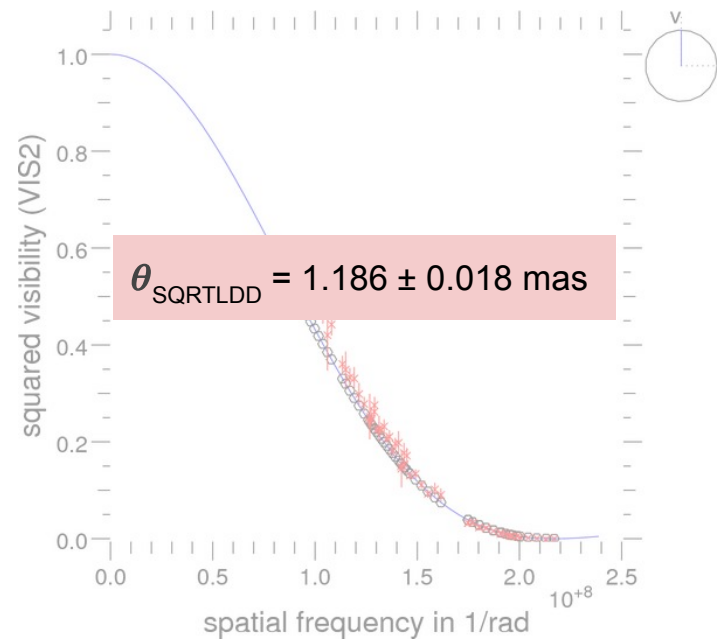
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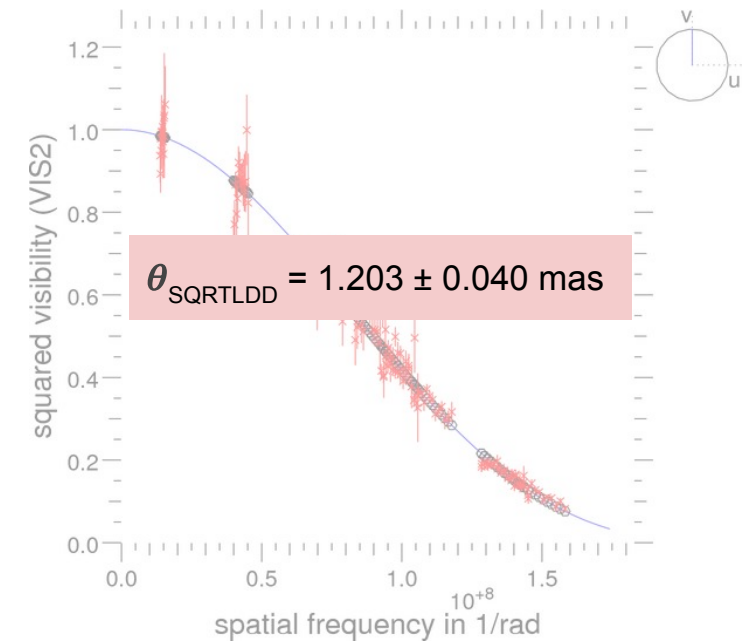
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SPICA



MIRCX



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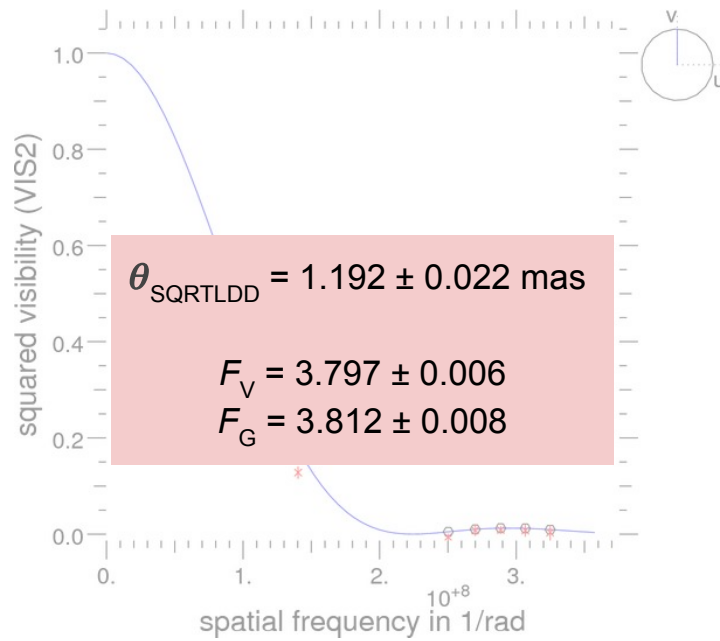
$\theta_{SQRTLDD}$ computed with oimodeler.

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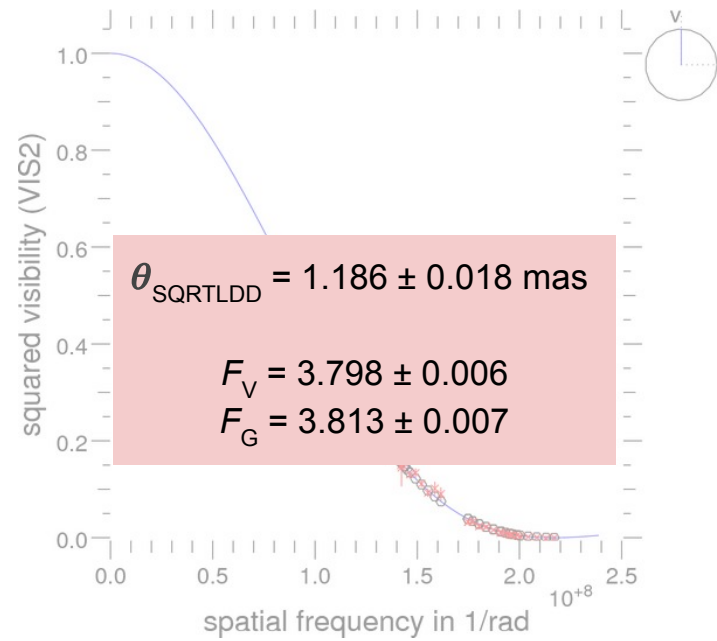
INTERFEROMETRY: θ_{LD}

HD 142860, F6V, March 22nd 2024

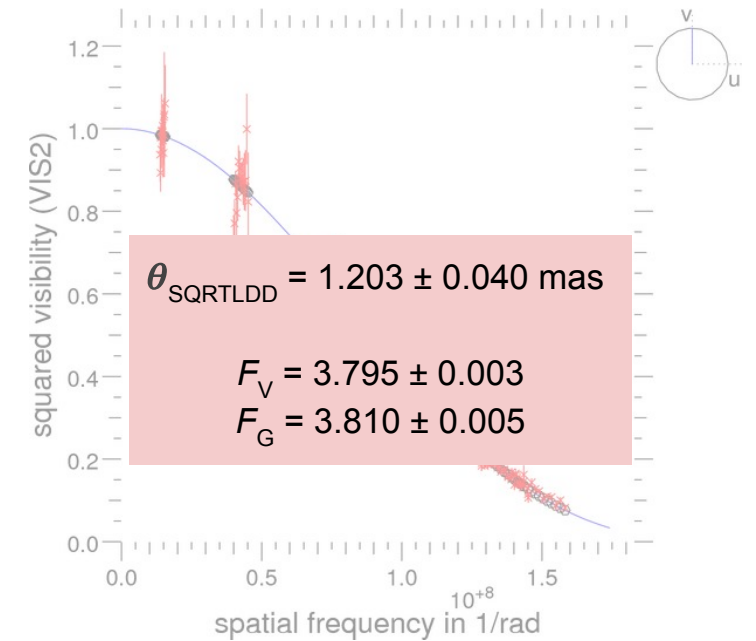
$$F_{\lambda} = 4.2196 - 0.1 m_{\lambda 0} - 0.5 \log \theta_{LD}$$



SPICA



MIRCX

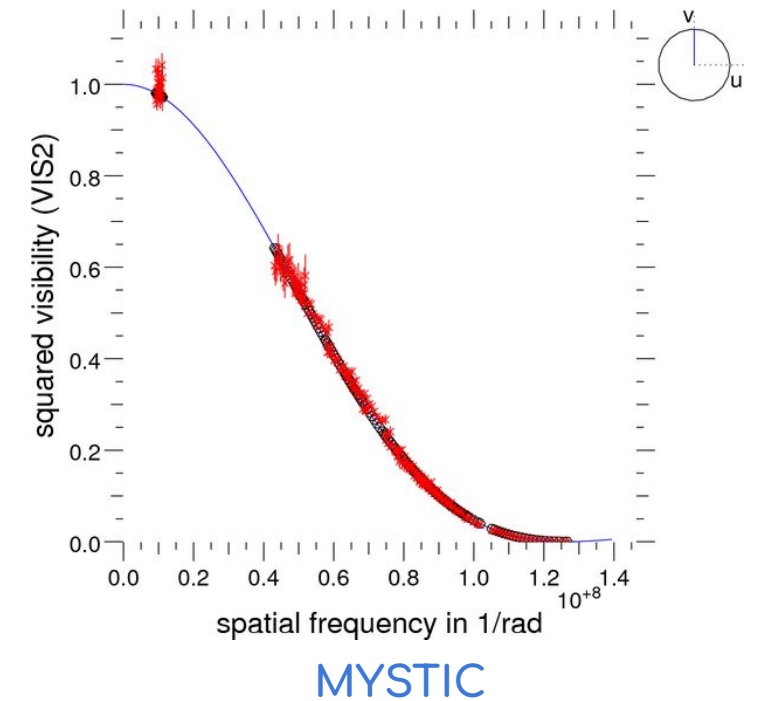
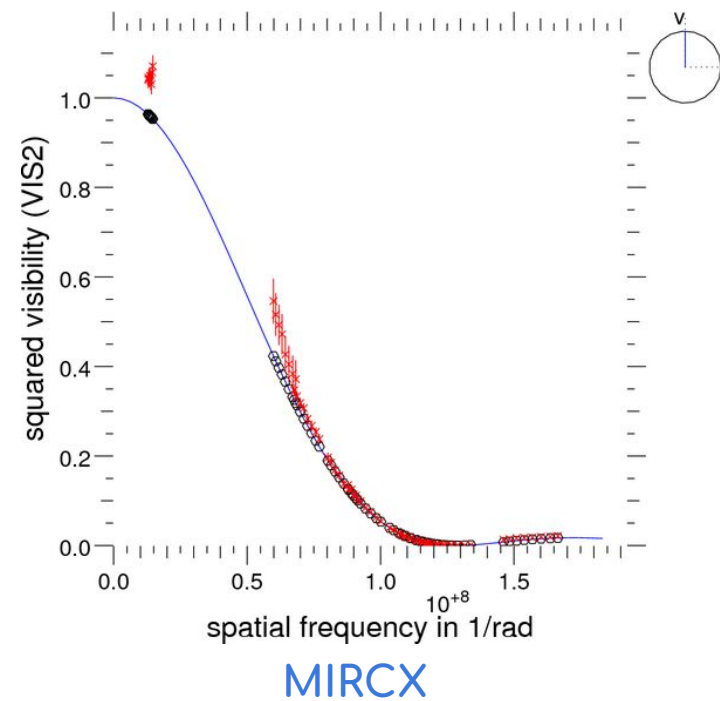


MYSTIC

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

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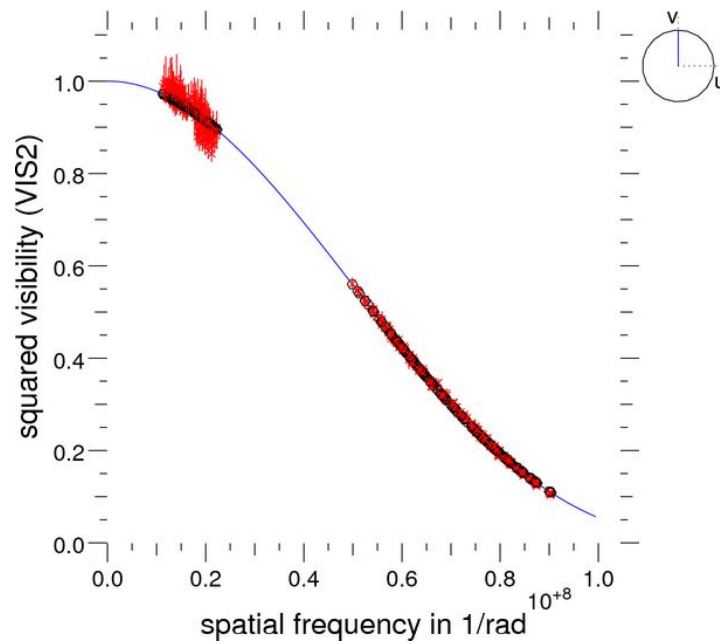
HD 10700, G8V, Aug. 18th 2024



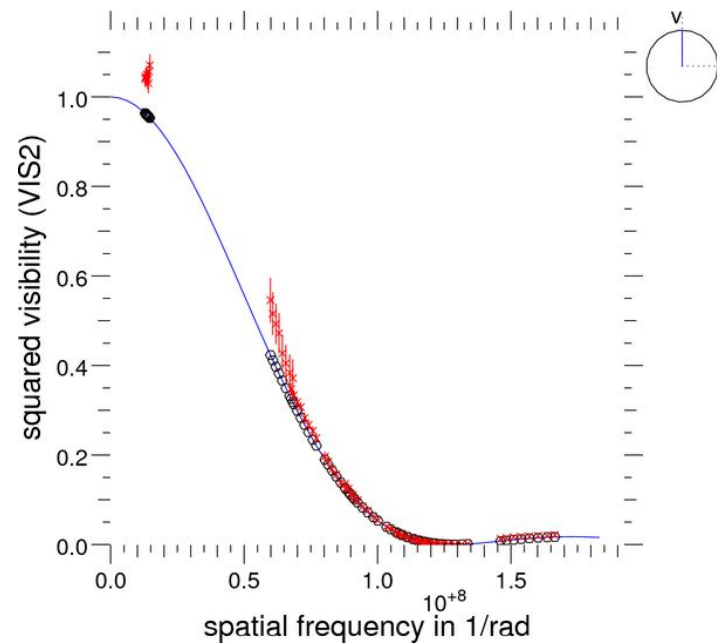
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INTERFEROMETRY: θ_{LD}

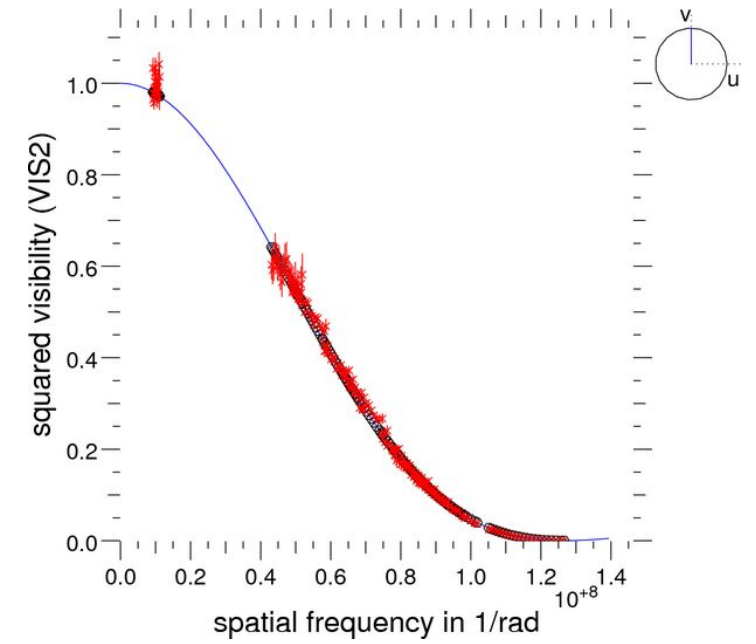
HD 10700, G8V, Aug. 18th 2024



PIONIER



MIRCX

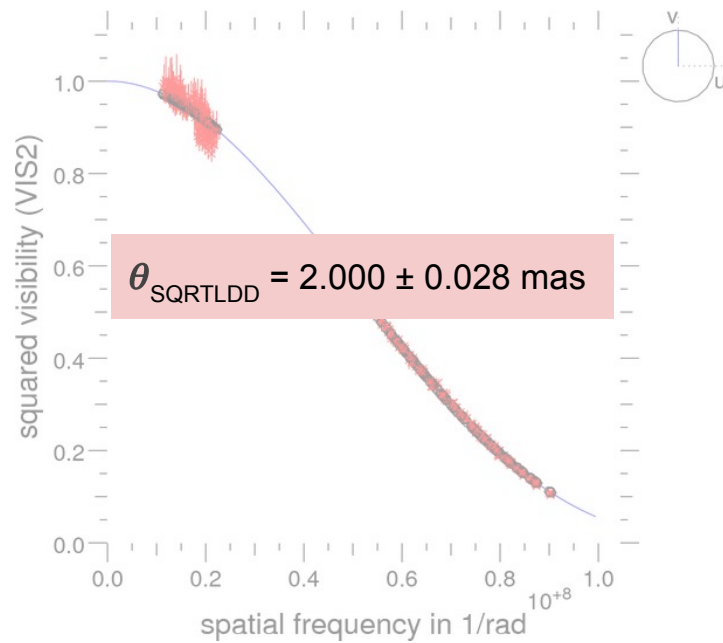


MYSTIC

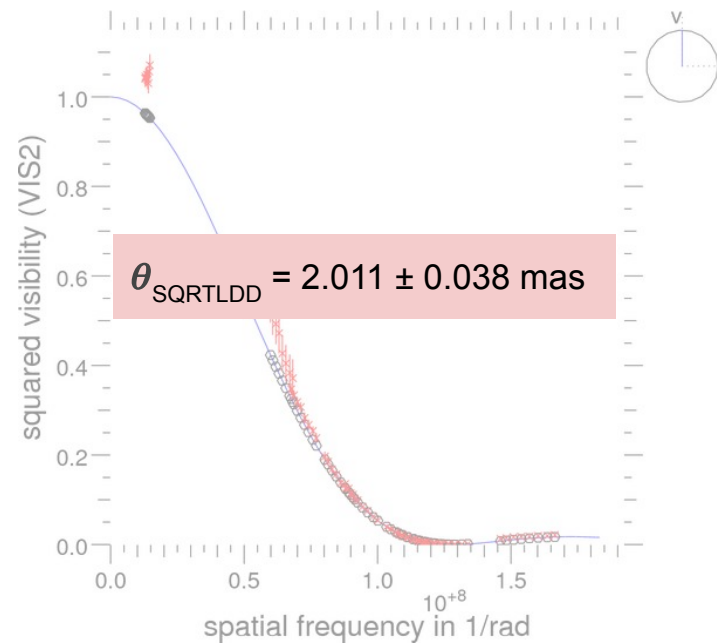
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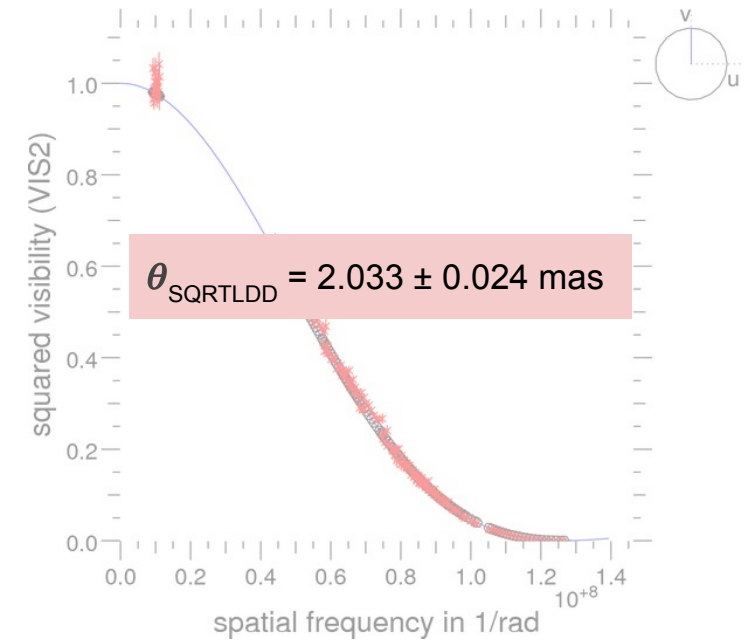
HD 10700, G8V, Aug. 18th 2024



PIONIER



MIRCX



MYSTIC

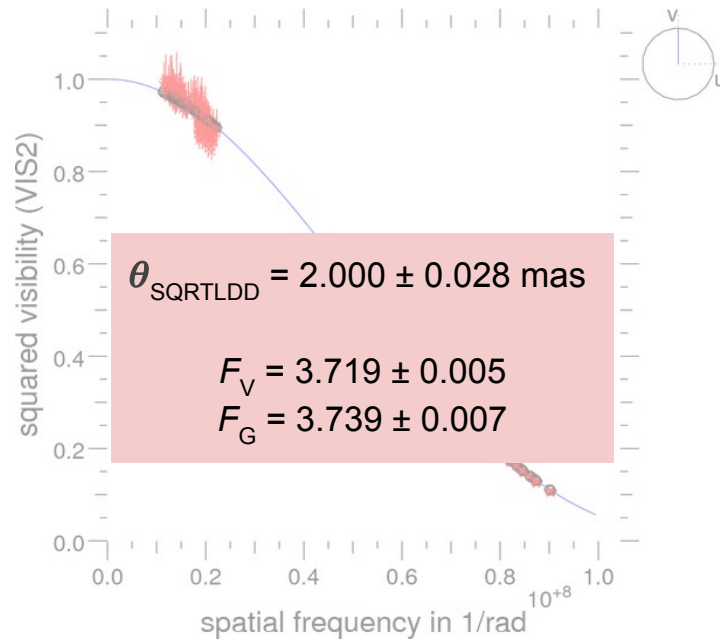
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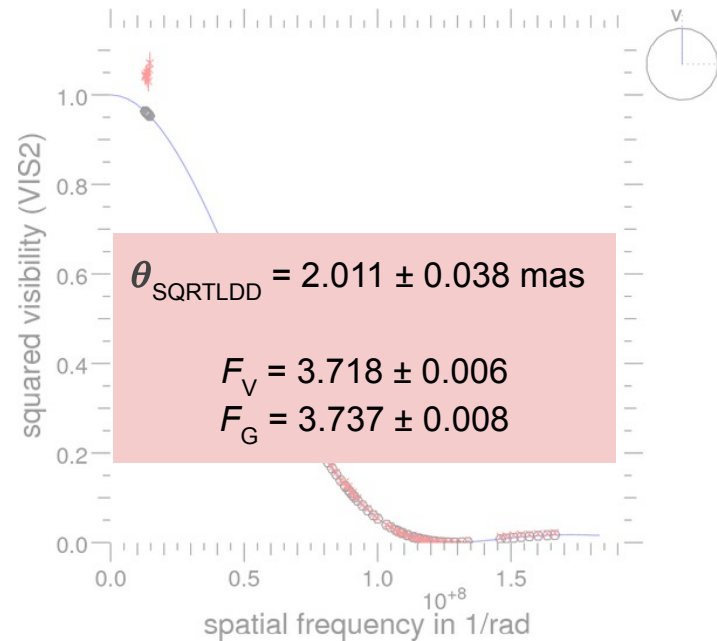
INTERFEROMETRY: θ_{LD}

HD 10700, G8V, Aug. 18th 2024

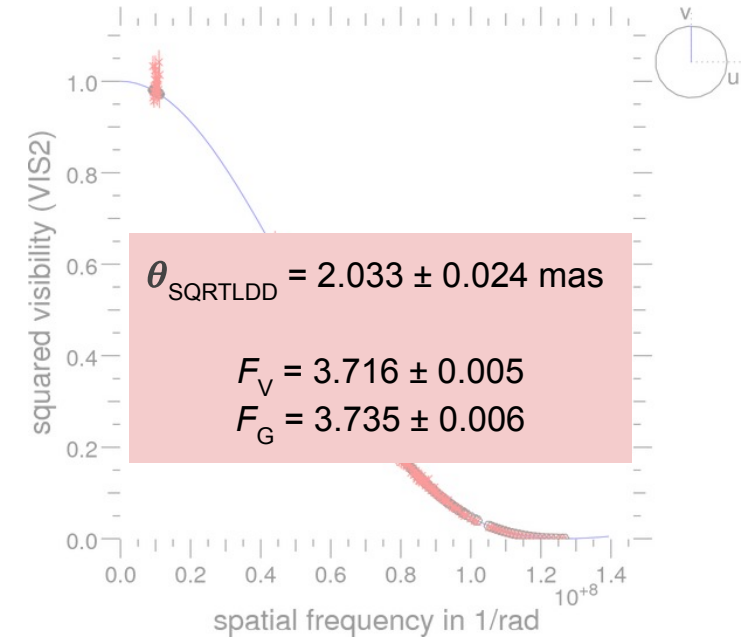
$$F_{\lambda} = 4.2196 - 0.1 m_{\lambda 0} - 0.5 \log \theta_{LD}$$



PIONIER



MIRCX



MYSTIC



CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

SPECTROSCOPY: T_{eff} , $\log g$

HARPS, HARPS-N, FEROS, SOPHIE, ELODIE

943 spectra were used.

iSpec (Blanco-Cuaresma et al. 2014, 2019)

Model atmosphere: MARCS Gaia-ESO Survey (GES) / APOGEE (Gustafsson et al. 2008)

$T_{\text{eff}} = [2500; 8000] \text{ K}$

$\log g = [-1.0; 5.0] \text{ dex}$

$[M/H] = [-5.0; 1.0] \text{ dex}$

Solar abundances: Grevesse 2007

Atomic line list: GES line list (V6, hfs, iso, 420 - 920 nm)

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

SPECTROSCOPY: T_{eff} , $\log g$

HD 142860, F6V

160 HARPS spectra

Input parameters:
(Gaia DR3) $T_{\text{eff}} = 6183 \pm 2 \text{ K}$
 $\log g = 4.079 \pm 0.004 \text{ dex}$

HD 10700, G8V

171 HARPS spectra

Input parameters:
(Soubiran+2024) $T_{\text{eff}} = 5397 \pm 15 \text{ K}$
 $\log g = 4.50 \pm 0.01 \text{ dex}$

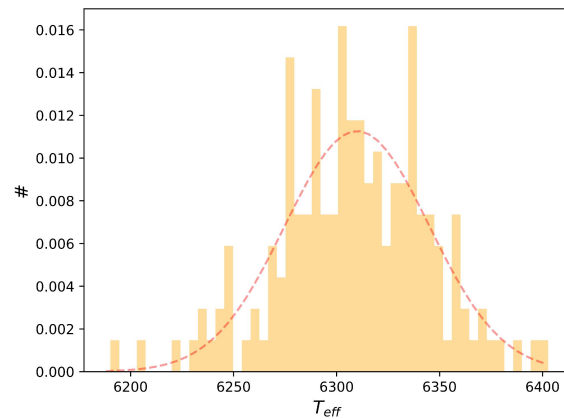
CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

SPECTROSCOPY: T_{eff} , $\log g$

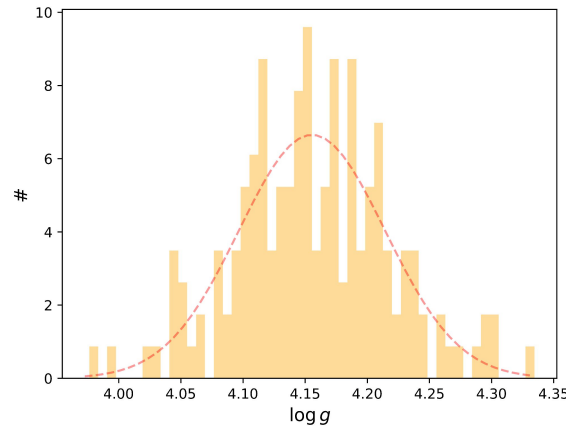
HD 142860, F6V

160 HARPS spectra

Input parameters:
(Gaia DR3) $T_{\text{eff}} = 6183 \pm 2$ K
 $\log g = 4.079 \pm 0.004$ dex



$T_{\text{eff}} = 6310 \pm 35$ K

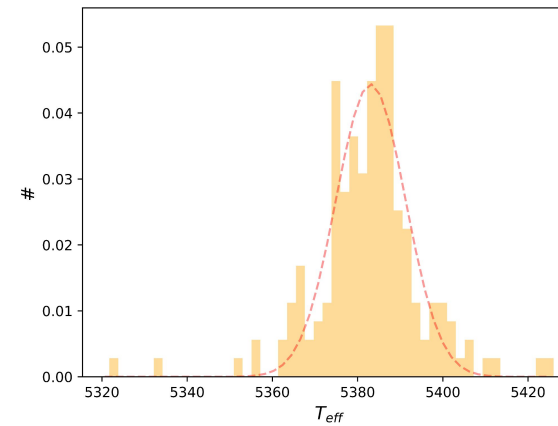


$\log g = 4.16 \pm 0.06$ dex

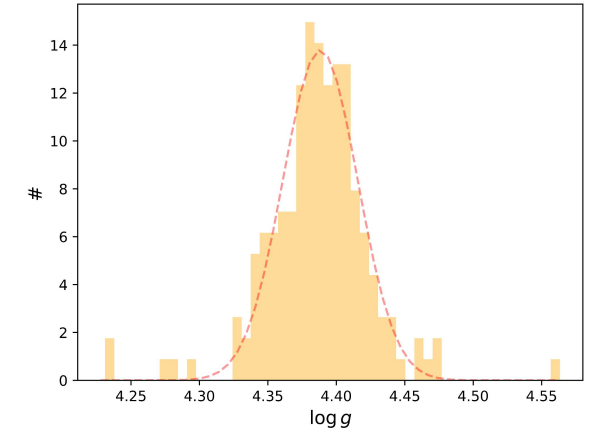
HD 10700, G8V

171 HARPS spectra

Input parameters:
(Soubiran+2024) $T_{\text{eff}} = 5397 \pm 15$ K
 $\log g = 4.50 \pm 0.01$ dex



$T_{\text{eff}} = 5383 \pm 8$ K



$\log g = 4.39 \pm 0.03$ dex

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

INTERFEROMETRY: θ_{LD} SPECTROSCOPY: T_{eff} , $\log g$

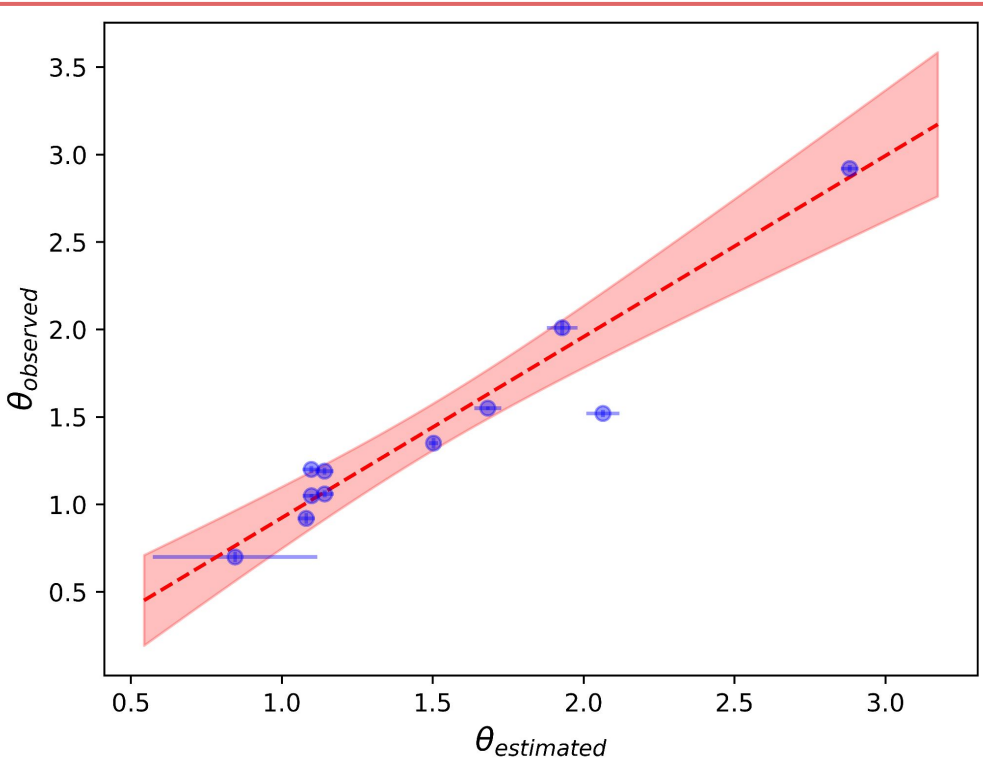
Star	SpT	θ_{LD}	F_V	F_G	# spectra	Teff	$\log g$
HD 148112	A2VpCrSr	0.33 ± 0.07	4.009 ± 0.049	4.008 ± 0.051	--	--	--
HD 97633	A2IV	0.70 ± 0.03	3.967 ± 0.012	3.964 ± 0.013	--	--	--
HD 142860	F6V	1.19 ± 0.02	3.798 ± 0.006	3.813 ± 0.007	160	6310 ± 35	4.16 ± 0.06
HD 30652	F6V	1.52 ± 0.02	3.810 ± 0.005	3.820 ± 0.007	56	6983 ± 96	4.81 ± 0.11
HD 4614	F9V	1.55 ± 0.01	3.781 ± 0.004	3.792 ± 0.005	189	5876 ± 27	4.22 ± 0.08
HD 22484	F9IV-V	1.06 ± 0.02	3.779 ± 0.006	3.793 ± 0.008	24	5882 ± 14	3.92 ± 0.04
HD 19373	G0V	1.20 ± 0.02	3.774 ± 0.006	3.790 ± 0.007	1	5849 ± 72	4.05 ± 0.09
HD 34411	G1.5IV-V	0.92 ± 0.03	3.768 ± 0.009	3.785 ± 0.010	1	5936 ± 65	4.35 ± 0.08
HD 10700	G8V	2.01 ± 0.04	3.716 ± 0.005	3.735 ± 0.006	171	5383 ± 8	4.39 ± 0.03
HD 219134	K3V	1.05 ± 0.01	3.652 ± 0.004	3.686 ± 0.006	341	4878 ± 17	4.34 ± 0.02
HD 17824	K0III	1.35 ± 0.03	3.680 ± 0.008	3.703 ± 0.009	--	--	--
HD 168723	K0III-IV	2.92 ± 0.02	3.664 ± 0.003	3.689 ± 0.005	--	--	--

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

INTERFEROMETRY: θ_{LD}

SPECTROSCOPY: $T_{eff}, \log g$

Star	SpT
HD 148112	A2VpCrSr
HD 97633	A2IV
HD 142860	F6V
HD 30652	F6V
HD 4614	F9V
HD 22484	F9IV-V
HD 19373	G0V
HD 34411	G1.5IV-V
HD 10700	G8V
HD 219134	K3V
HD 17824	K0III
HD 168723	K0III-IV



$\log g$
--
--
4.16 ± 0.06
4.81 ± 0.11
4.22 ± 0.08
3.92 ± 0.04
4.05 ± 0.09
4.35 ± 0.08
4.39 ± 0.03
4.34 ± 0.02
--
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$$\theta_{LD-observed} = 1.03_{(\pm 0.08)} \theta_{LD-estimated} - 0.11_{(\pm 0.13)}$$

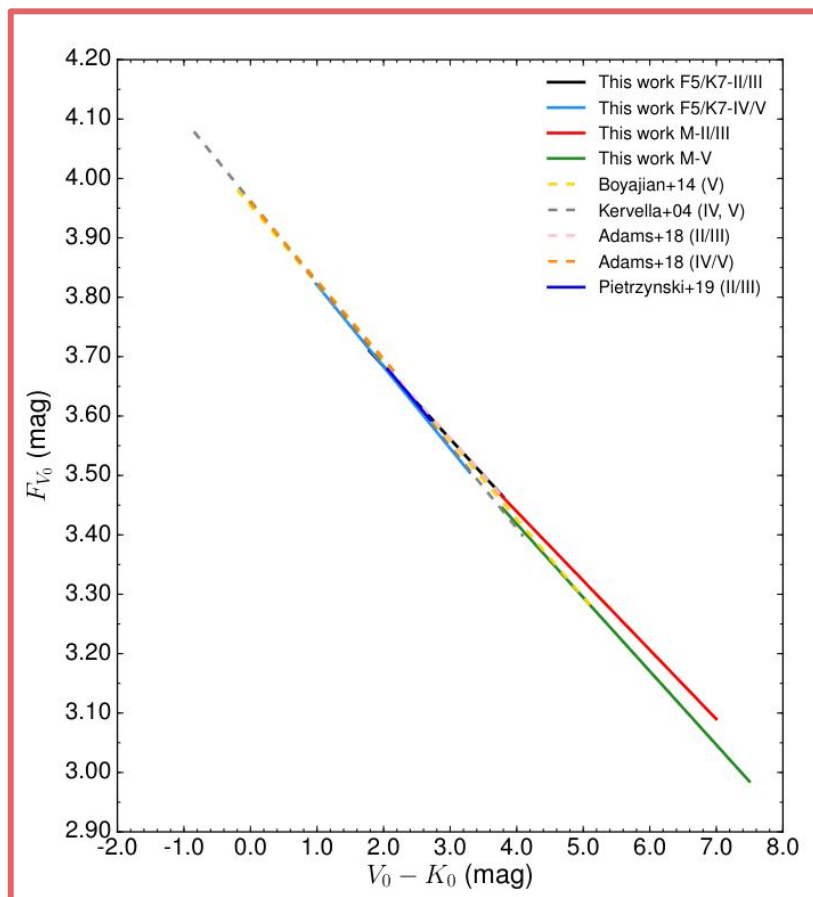
corr = 93%



CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

INTERFEROMETRY: θ_{LD}

SPECTROSCOPY: T_{eff} , $\log g$



S06
Binaries

S07
Rotation

S08
Winds &
environments



Juraj Jonák

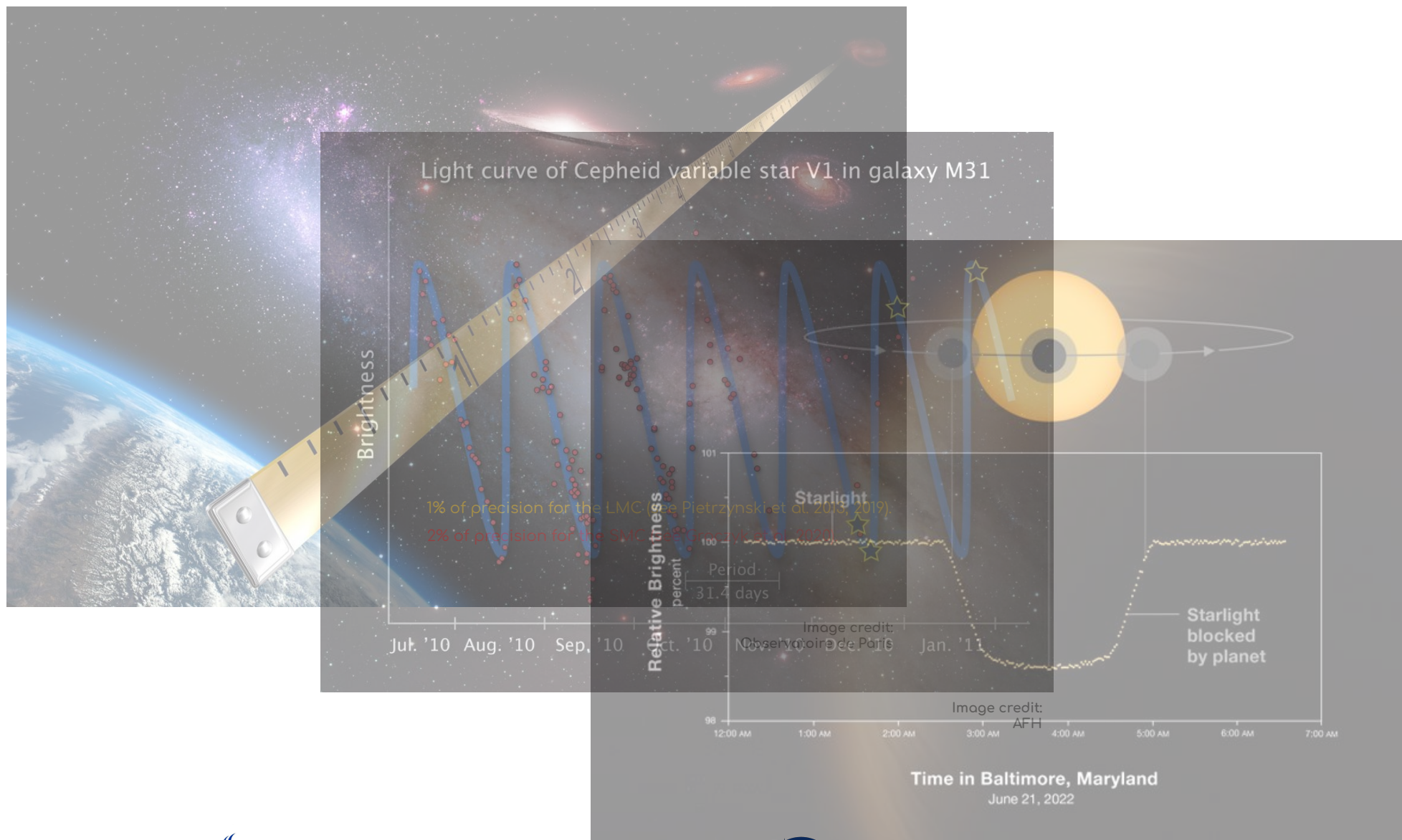


Armando
Domiciano



Markus Wittowski

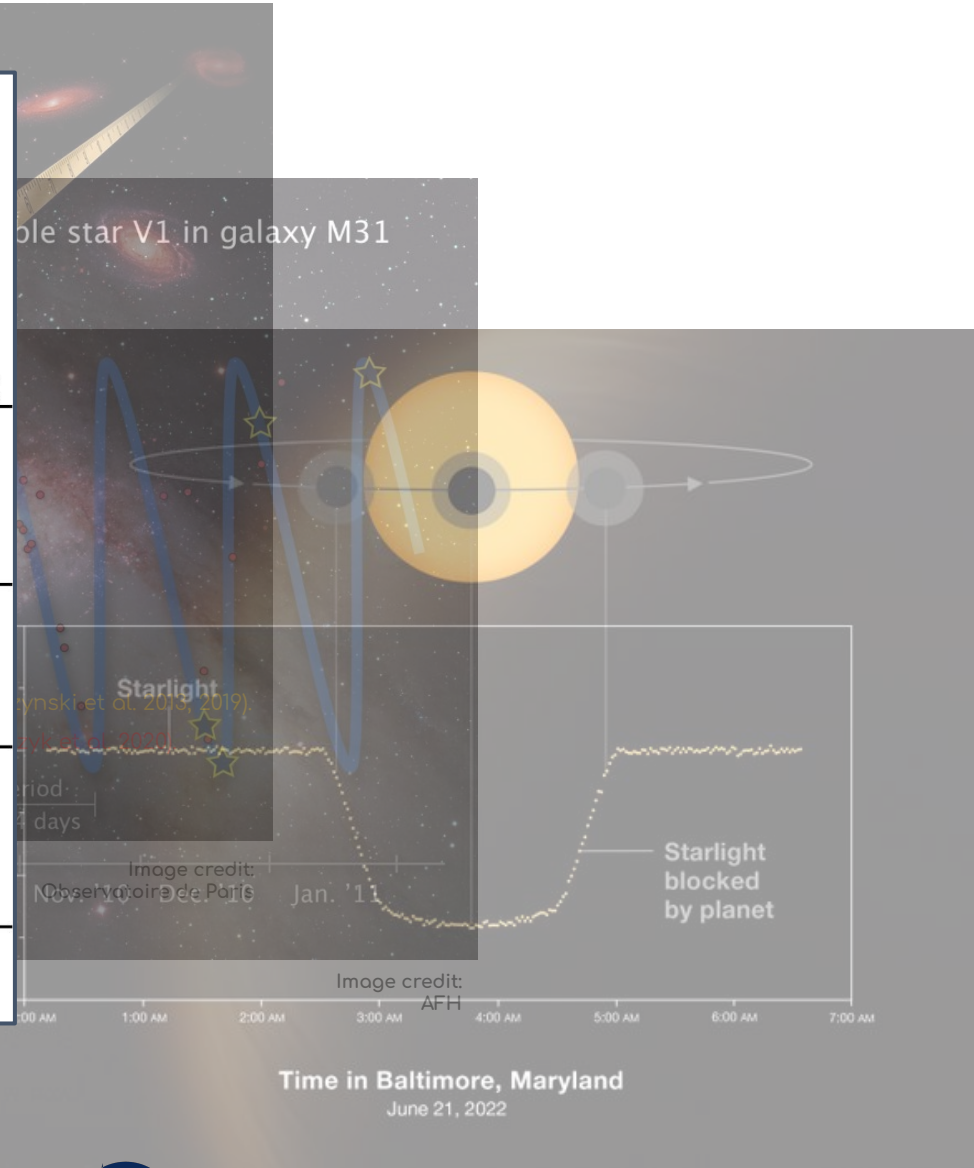
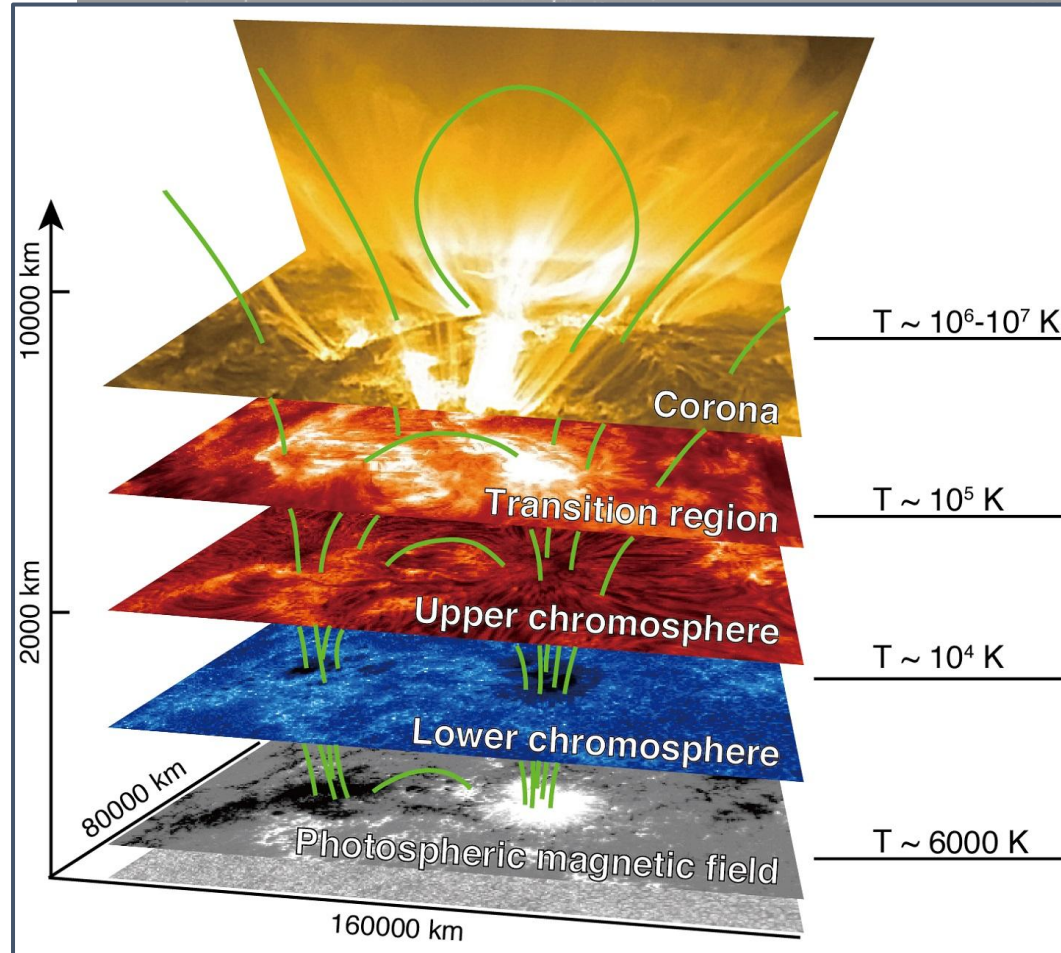
CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



The radius of the planet can be derived from the stellar radius through the transit (see Ligi et al. 2016).

Image credit:
NASA, ESA, CSA, STScI

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



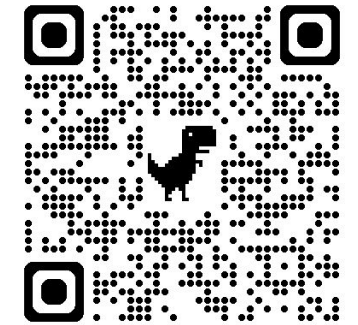
The radius of the planet can be derived from the stellar radius through the transit (see Ligi et al. 2016).

Image credit: NASA, ESA, CSA, STScI

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

Ibañez Bustos, R. V. ; Buccino, A. P. ; Nardetto, N. ; Mourard, D. ; Flores, M. ; Mauas, P. J. D. 2025, A&A.

Go to read it!



*if you can read it,
you can cite it ;)*

We studied 35 inactive M dwarfs...

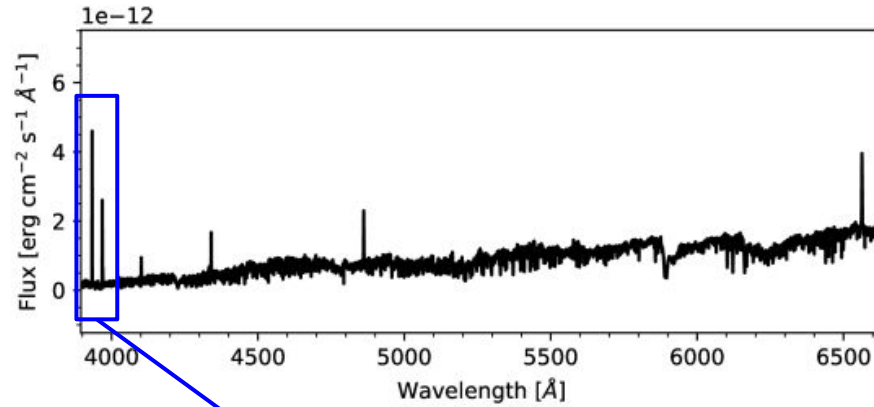
we used 2965 spectra in the optical range to build time series with extensions of up to 21 years.

Using the color index (V-Ks), we have computed the chromospheric emission levels.

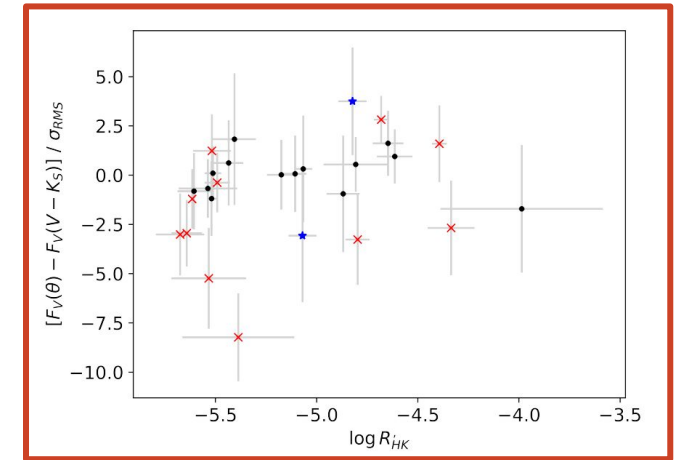
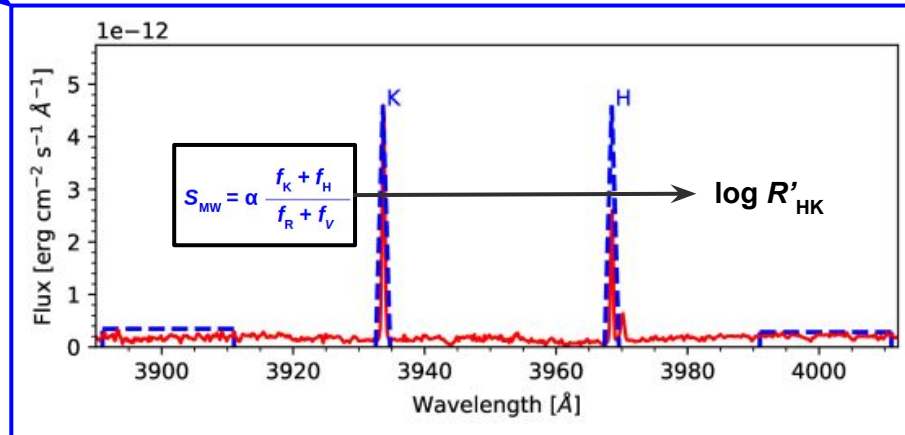
+ ideas from Salsi et al. (2021)...

we studied the possible impact of the chromospheric activity on the surface brightness.

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)



+ ideas from Salsi et al. (2021)...



Ibañez Bustos et al. (2025)

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

Main conclusion

<< If one is to understand the great mystery of the Force...

one must study all its aspects >>

Palpatine

CHARA/SPICA ISSP Project S04: Surface Brightness - Color Relation (SBCR)

Main conclusion

<< If one is to understand the great mystery of the Force...

SBCR

one must study all its (aspects) >>

(Teff, log g, stellar activity, magnetic activity ...)

Palpatine