# Searching for new solar twins: The Inti survey for the Northern Sky

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# ABSTRACT

Solar twins are key in different areas of astrophysics, however only just over a hundred were identified and well-studied in the last two decades. In this work, we take advantage of the very precise *Gaia* (DR2/EDR3), Tycho and 2MASS photometric systems to create the **Inti** survey of new solar twins in the Northern Hemisphere. The spectra of our targets were initially obtained with spectrographs of moderate resolution (ARCES and Goodman spectrographs with R = 31500 and 11930, respectively) to find the best solar twin candidates and then observed at McDonald Observatory with higher resolving power (TS23, R = 60000) and signal-to-noise ratio (SNR ~ 300-500). The stellar parameters were estimated through the differential spectroscopic equilibrium relative to the Sun, which allow us to achieve a high internal precision ( $\sigma(T_{eff}) = 15$  K,  $\sigma(\log g) = 0.03$  dex,  $\sigma([Fe/H]) = 0.01$  dex, and  $\sigma(v_t) = 0.03$  km s<sup>-1</sup>). We propose a new class of stars with evolution similar to the Sun: *solar proxy*, which is useful to perform studies related to the evolution of the Sun, such as its rotational and magnetic evolution. Its definition is based on metallicity (-0.15 dex  $\leq [Fe/H] \leq +0.15$  dex) and mass ( $0.95 M_{\odot} \leq M \leq 1.05 M_{\odot}$ ) constraints, thus assuring that the star follows a similar evolutionary path as the Sun along the main sequence. Based on this new definition, we report 70 newly identified solar proxies, 46 solar analogs and 13 solar-type stars. In addition, we identified 9 *close solar twins* whose stellar parameters are the most similar to those of the Sun.

**Key words:** stars: solar-type – stars: abundances – stars: activity – stars: atmospheres – stars: fundamental parameters – techniques: spectroscopic

#### **1 INTRODUCTION**

Since the 1980s, the astronomical community was interested in finding stars with physical parameters similar to those of the Sun, i.e., solar twins. However, a crucial question arose: *which parameters should be considered to define an object as solar twin?*. Cayrel de Strobel et al. (1981); Cayrel de Strobel & Bentolila (1989); Cayrel de Strobel (1996) defined these objects as stars whose effective temperature ( $T_{eff}$ ), surface gravity (log g), metallicity ([Fe/H]), microturbulence ( $v_t$ ), photometric properties, chemical composition, age, luminosity, rotation, and magnetic fields are similar, if not identical, to those of the Sun. These authors performed the first attempts to find *real solar twins* exploiting a list of 78 solar analogs obtained by Hardorp (1978) through spectrophotometric observations. However,

with these constraints, it was almost impossible to find a real solar twin. A less rigorous definition was carried out by Friel et al. (1993): "every observable and derivable physical quantity must be identical within observational errors to that of the Sun". Porto de Mello & da Silva (1997), using the Cayrel de Strobel's definition (Cayrel de Strobel & Bentolila 1989), were able to find the first closest solar twin: 18 Sco. Years later, other authors also claimed to have identified solar twins based on photometric and spectroscopic parameters constraints: HD 143436 (King et al. 2005), HD 98618 (Meléndez et al. 2006), HD 10307 and HD 34411 (Galeev et al. 2004), and finally HD 101364 and HD 133600 (Meléndez & Ramírez 2007), the latter ones not only reproduce the solar fundamental parameters but also a low lithium abundance. On the other hand, Ramírez et al. (2009) introduced a concept of solar twin based only on spectroscopic stellar parameters constraints (i.e., only  $T_{\text{eff}}$ , log g, and [Fe/H]), which is useful for achieving high precision differential abundances relative

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to the Sun; however, this definition introduces a slight bias in the mass-age-[Fe/H] space that will be discussed later. One of the last definitions comes from Datson et al. (2012, 2014, 2015), where a solar twin is defined as a star whose stellar parameters (estimated only with high resolution spectrographs) are indistinguishable from solar within the errors. A very comprehensive discussion about the concept of solar twins and solar analogs is given in Porto de Mello et al. (2014). These authors suggest that solar twins should not be only indistinguishably from the Sun, but also follow a similar evolutionary history. In brief, the literature is full of different definitions of solar twins, but until now it is not yet clear which parameters should define a *real solar twin*, thus hindering the efforts for finding these objects as well as studies such as gyrochronology and magnetic activity evolution (e.g., Lorenzo-Oliveira et al. 2018).

To date, despite different definitions in the literature, approximately 100 solar twins have been identified by different authors (e.g., Pasquini et al. 2008; Meléndez et al. 2009, 2014a; Ramírez et al. 2009; do Nascimento et al. 2013a; Ramírez et al. 2014; Takeda & Tajitsu 2009; Baumann et al. 2010; Önehag et al. 2011; Sousa et al. 2011; González Hernández et al. 2010; Datson et al. 2012; Porto de Mello et al. 2014; Galarza et al. 2016; Giribaldi et al. 2019) and their applications in different astrophysical fields have had significant impacts on our knowledge about stars and the Sun. For example, they are useful for setting the zero point of fundamental photometric calibrations (Holmberg et al. 2006; Casagrande et al. 2010; Ramírez et al. 2012; Datson et al. 2014; Casagrande et al. 2020), studying the mineralogy of asteroids by subtracting the Sun's reflected light on them (e.g., Lazzaro et al. 2004; Jasmim et al. 2013), testing stellar interiors through asteroseismology (Chaplin et al. 2011; Bazot et al. 2012, 2018), measuring distances (Jofré et al. 2015), and even improving spectroscopic methods for stellar parameters determination (Saffe et al. 2018). More recently, Yana Galarza et al. (2021) detected for the first time a differential odd-even effect in a solar twin, providing new insights to understand the supernova nucleosynthesis history.

The study of solar twins has also contributed to the understanding of the chemical evolution of the Galactic disk (da Silva et al. 2012; Nissen 2015; Spina et al. 2016b, 2018; Bedell et al. 2018; Nissen et al. 2020; Botelho et al. 2020), and the study of the neutron-capture elements (Meléndez et al. 2014b; Yana Galarza et al. 2016). As a result, new chemical clocks as the [Y/Mg]-age correlation initially proposed by da Silva et al. (2012) and improved by several authors (e.g., Nissen 2015; Tucci Maia et al. 2016; Feltzing et al. 2017; Spina et al. 2018; Jofré et al. 2020; Nissen et al. 2020) and the Li-age correlation (Baumann et al. 2010; Carlos et al. 2016, 2019) have been established. Biology principles (Phylogenetics of solar twins) have also been applied to investigate the chemical evolution of the Milky Way (Jofré et al. 2017; Jackson et al. 2020).

Significant contributions come from the works of do Nascimento et al. (2013b, 2020) and Lorenzo-Oliveira et al. (2019, 2020) in the field of gyrochronology using solar twins, giving important clues to understand the rotational evolution of the Sun. A controversial diagnostic of stellar ages is the age-chromospheric activity relation (Mamajek & Hillenbrand 2008; Pace 2013), whose applicability is extended for stars with ~6-7 Gyr (Lorenzo-Oliveira et al. 2016). Besides, the analysis of solar twins could help us to place the ~11 yr solar cycle in context (Hall et al. 2007, 2009; Flores et al. 2018). Meléndez et al. (2009) reported chemical anomalies in the Sun when it is compared to solar twins, thereby establishing the basis for studying the planet-stellar chemical composition connection (e.g., Ramírez et al. 2009; González Hernández et al. 2010, 2013; Schuler et al. 2011; Adibekyan et al. 2014; Maldonado et al. 2015; Spina et al. 2016b;

**Table 1.** *Gaia* Absolute Magnitude  $(M_G)$  and Photometric color constraints established using known solar twins (Ramírez et al. 2014).  $V_{TG}$  is the V magnitude based on Eq. (1), while  $B_T$  represent the Tycho B magnitude,  $G_{\rm BP}$  and  $G_{\rm RP}$  are *Gaia* EDR3 magnitudes in the BP and RP passbands, and  $J, H, K_S$  are 2MASS magnitudes.

Gaia Absolute Magnitude & color constraints
$3.755 \le M_G \le 5.331$
$0.254 \le G_{\rm BP} - G \le 0.377$
$0.455 \le G - G_{\rm RP} \le 0.589$
$0.761 \le G_{\rm BP} - G_{\rm RP} \le 0.907$
$0.960 \le G - J \le 1.315$
$1.207 \le G - H \le 1.708$
$1.284 \le G - K_S \le 1.791$
$0.166 \le J - H \le 0.506$
$0.281 \le J - K_S \le 0.550$
$-0.002 \le H - K_S \le 0.180$
$0.473 \le B_T - V_{TG} \le 0.947$

Nissen 2015; Nissen et al. 2017; Liu et al. 2016; Bedell et al. 2018; Maia et al. 2019; Cowley et al. 2020). Finally, the study of solar twins is also expanded to the field of exoplanets. For instance, Bedell et al. (2015, 2017) and Meléndez et al. (2017) have demonstrated that with the high precision achieved in stellar parameters in solar twins, it is possible to get very precise exoplanet properties (mass and radius). Additionally, it is also feasible to study habitability and evolution of exoplanets through radioactive elements such as thorium (e.g., Unterborn et al. 2015; Botelho et al. 2019).

As widely discussed above, the identification of new solar twins is essential to the advancement of diverse astronomical fields. Therefore, in this work we present the **Inti**<sup>1</sup> catalog of new solar twins, solar analogs, and solar-type stars identified in the Northern Hemisphere. The **Inti** survey provides reliable and precise spectroscopic stellar parameters, chromospheric activity levels, and photometric rotational periods when its determinations through high-precision light curves are possible.

#### **2** SAMPLE SELECTION

Inspired by seminal works for searching solar twins (e.g., Hardorp 1978; Cayrel de Strobel et al. 1981; Meléndez & Ramírez 2007; Ramírez et al. 2009; Porto de Mello et al. 2014), in this era of large surveys, we take advantage of the precise photometric systems of Gaia DR2/EDR3 (Gaia Collaboration et al. 2018, 2020), Tycho (Høg et al. 2000), and 2MASS (Skrutskie et al. 2006) to search these stellar objects. However, unlike these initial studies mainly based on photometric comparisons with the Sun, our methodology consist in performing color constraints from the well characterized solar twins of Ramírez et al. (2014). To do so, we cross-matched the solar twin sample with the TGAS (Tycho-Gaia Astrometric Solution, Marrese et al. 2017) catalog updated with the Gaia EDR3 magnitudes, resulting in 63 common objects. In our study we also found a simple photometric relationship from Gaia EDR3 G (updated from our initial relations using DR2) to Tycho V and Johnson V (Kharchenko 2001):

 $V_{TG} = G \times 0.9942(\pm 0.0021) + 0.2657(\pm 0.0156)$ (1)

$$W_G = G \times 0.9940(\pm 0.0014) + 0.1929(\pm 0.0097),$$
 (2)

<sup>1</sup> Inti means Sun in the Inca-Andean-Quechua cosmovision.



Figure 1. Photometric relationship between Johnson/Tycho V vs. *Gaia* EDR3 G magnitudes, which are valid only for solar twins. Both the red line and the red dashed lines represent the linear fit to the data considering errors in both axis, while the black line is the 1:1 relation. Error bars are smaller than the symbols.

where  $V_{TG}$  is the transformation between *G* and Tycho V, while  $V_G$  is the conversion between *G* and Johnson *V* (see Figure 1). The dispersion and the reduced chi-squared  $(\chi^2_{red})$  of the linear fit are 0.018 mag and 1.608 for Eq. (1), and 0.014 mag and 1.554 for Eq. (2), respectively. It is important to highlight that these relationships are valid only for solar twins<sup>2</sup>. Besides,  $V_{TG}$  is used only to establish the color constraints showed in Table 1, while  $V_G$  is useful to estimate isochronal ages as it will be discussed later. In this way, we established the bounds of our color constraints, which are shown in Table 1.

The sample selection technique consists in first cross-matching the Gaia DR2 (updated to EDR3 in Table 1) with the 2MASS and Tycho catalogs within a region of 100 pc from Earth and with Gvalues ranging from 5 to 9 mag. Then, we applied our color constraints in the cross-matched sample and found 3100 objects. These objects compose our preliminary sample of solar twin candidates and are plotted as red circles in the Gaia EDR3 Hertzsprung-Russell diagram<sup>3</sup> of Figure 2. We did not apply reddening corrections for our sample, since it is within 100 pc and thus has negligible reddening. This is supported by Vergely et al. (2010) and Lallement et al. (2014), who found a gradient of d E(B-V)/dr = 0.0002 mag per pc (see Figure 2 in Lallement et al. 2014). A similar result is found by Green et al. (2019), who created a precise dust map using the Pan-STARRS1, 2MASS, and Gaia DR2 (including its parallaxes) photometric bands. On the other hand, Reis et al. (2011) reported interstellar absorption (E(B-V) > 0.056) in the local bubble for regions on the Galactic plane (d > 60 pc) with latitudes from  $l \ge 270^{\circ}$  up to  $l \leq 45^{\circ}$ . However, the stars of the **Inti** survey that fall in this region have d < 50 pc and thus E(B-V) = 0.

Finally, as our photometric methodology (see Table 1) for searching solar twins is based only on stellar parameter constraints (Ramírez



**Figure 2.** Gaia EDR3 HR diagram of ~1.4 million stars within 200 pc from the Solar System (the data were obtained using the astroquery package). The colormap represents the stellar density distribution created from the 2D-histogram function of the matplotlib library. The red circles are the solar twin candidates found after applying our color constraints. The Sun is plotted as a yellow solar standard symbol.

et al. 2009), it is expected to have a bias in our results (see the irregular polygon in Figure 2), as our criteria are not symmetric relative to the main sequence evolution of a one-solar-mass solar-metallicity star. This will be discussed more extensively in the subsection 4.2.

## 3 SPECTROSCOPIC OBSERVATIONS AND DATA REDUCTION

We obtained spectra of high signal-to-noise ratio (SNR ~ 400) of our candidates with the Goodman High Throughput Spectrograph (Clemens et al. 2004), on the SOAR Telescope. From these spectra, we could retrieve a reliable initial guess of the spectroscopic parameters. The methodology consists in estimating [Fe/H] through spectral synthesis with the SP\_ACE spectral analysis tool<sup>4</sup>,  $T_{\rm eff}$  by using the colour-temperature-metallicity calibrations established by Casagrande et al. (2010), and trigonometric log g from Gaia EDR3 parallaxes with bolometric corrections given in Meléndez et al. (2006). Our technique was tested using several known solar twins and the results are consistent (within the uncertainties) with those estimated with high precision spectra (e.g., Spina et al. 2018). We also used the ARC Echelle Spectrograph (ARCES) on the 3.5-meter Apache Point Observatory telescope to explore the northern sky since the observations with the SOAR telescope are inaccessible to DEC  $\gtrsim$  +25°. Thanks to these initial observations, we created a sample of 150 objects with the best solar twin candidates which were later observed with the Robert G. Tull Coudé Spectrograph (hereafter TS23, Tull et al. 1995) on the McDonald Observatory. The number of stars

<sup>&</sup>lt;sup>2</sup> A similar relationship was found between *Gaia* DR2 *G* and Johnson *V*:  $V_G = G \times 0.9901(\pm 0.0014) + 0.2346(\pm 0.0097)$ 

<sup>&</sup>lt;sup>3</sup> Our HR diagram is based on https://vlas.dev/post/gaia-dr2-hrd/

<sup>&</sup>lt;sup>4</sup> http://dc.g-vo.org/SP\_ACE

observed with each instrument and the internal precision achieved in stellar parameters are summarized in Table 2. In the following are detailed the spectroscopic observations performed in each observatory.

# 3.1 SOAR Telescope at Cerro Pachon

The spectra of the first potential solar twin candidates were obtained using the Goodman spectrograph on the 4.1-meter SOAR Telescope under the programs SO2017B-004, SO2018A-005, SO2019A-007, and SO2019B-005 from 2017 to 2019. The solar spectrum was obtained after a short exposure of the Moon. The instrument was configured to use the red camera and the grating of 2100 lines/mm, resulting in a moderate resolving power  $R = \lambda/\Delta\lambda = 12000$  and wavelength coverage of 630 Å centered at H $\alpha$ . The Goodman spectra were reduced using IRAF<sup>5</sup> following the standard procedure, i.e., creation of the master flat, flat field correction, sky subtraction, order extraction, etc. The radial velocity correction was performed using the rvidlines and dopcor task of IRAF. The obtained spectra were also normalized using IRAF's continuum task with orders ranging from two to five.

#### 3.2 Apache Point Observatory

We also obtained the spectra of the solar twin candidates using the ARCES on the 3.5-meter telescope at the Apache Point Observatory. The observations were carried out from 2019 to 2020. The solar spectra were obtained by observing the sky at twilight time. We used the CERES<sup>6</sup> pipeline in order to perform the standard reduction of the ARCES spectra. The ARCES spectrograph provides spectra of  $R \sim 31500$  and covers the entire visible wavelength (from 3200-10000 Å). The SNR achieved ranges from 200 to 300 at ~6000 Å.

#### 3.3 McDonald Observatory

All the observations were taken during the years of 2018-2020 using the TS23 configured in its high resolution mode on the 2.7-meter Harlan J. Smith Telescope at McDonald Observatory. The spectra of the Sun were obtained through the reflected light from the Moon. As the McDonald Observatory does not have an official pipeline to reduce the TS23 spectra, we have developed our own scripts<sup>7</sup> based on the practical reduction notes of the Dr. Chris Sneeden, Dr. Ivan Ramírez, and Dr. Diego Lorenzo-Oliveira. The code consists of a number of semi-automatic python scripts that performs bias subtraction, flat fielding, order extraction, and wavelength calibration using PyRAF (Science Software Branch at STSCI 2012). The resulting spectra are free of fringing defects and have R = 60000, SNR ~300-500 at ~6500 Å, and cover a wide spectral range (from 3750-9900 Å).

<sup>6</sup> https://github.com/rabrahm/ceres

**Table 2.** Number of stars observed with each instrument and the internal precision achieved in stellar parameters. ( $\star$ ) Number of stars observed in the Northern Hemisphere with -18°  $\leq$  DEC  $\leq$  +25°.

Instrument	Observed stars	$\sigma(T_{\rm eff})$ (K)	$\sigma(\log g)$ (dex)	σ([Fe/H]) (dex)
Goodman	160*	190	0.20	0.15
ARCES	20	100	0.11	0.08
TS23	147	15	0.03	0.01

#### **4 FUNDAMENTAL PARAMETERS**

#### 4.1 Equivalent Widths and Stellar Parameters

In order to perform the standard treatment and analysis of the TS23 spectra, we have developed semi-automatic python scripts<sup>7</sup>, whose structure is a combination of two tools: iSpec<sup>8</sup> and IRAF. In summary, the scripts use the iSpec tool to perform the radial/barycentric velocity correction, and the continuum and scombine tasks of IRAF to normalize and combine the TS23 spectra. All the processes mentioned above are automatic resulting in spectra of high quality and SNR (~300-500 at 6500 Å). The scripts are also capable of measuring Equivalent Widths (EWs) through Gaussian fits to the line profile using the Kapteyn kmpfit Package<sup>9</sup> in windows of 6 Å; however, this process is manually performed in order to achieve a higher precision. The method is based on line-by-line equivalent width measurements between the Sun and the object of interest, choosing consistent pseudo-continuum regions for both objects (e.g., Meléndez et al. 2009; Bedell et al. 2014; Yana Galarza et al. 2016; Spina et al. 2018). Besides, the script generates an output file containing information about the local continuum, limits of the Gaussian fits,  $\chi^2$ test, excitation potential, oscillator strength, and laboratory log(gf)values (see Meléndez et al. 2014b). On the other hand, as the ARCES spectra are already corrected by radial velocity shifts, we used our python scripts only to measure the EWs, rigorously following the same procedure already explained above.

As in our previous works (e.g., Ramírez et al. 2014; Yana Galarza et al. 2019), we employed the automatic  $q^2$  (qoyllur-quipu)<sup>10</sup> python code to determine the spectroscopic stellar parameters ( $T_{\text{eff}}$ , log g, [Fe/H],  $v_t$ ) for our sample. In short, the code estimates the iron abundances using the line list from Meléndez et al. (2014b) and the 2019 version of the local thermodynamic equilibrium (LTE) code MOOG (Sneden 1973) with the Kurucz ODFNEW model atmospheres (Castelli & Kurucz 2003). Then, the q<sup>2</sup> employs the spectroscopic equilibrium, which is a standard technique of iron line excitation and ionization equilibrium. As a result, we obtain very reliable stellar parameters with high internal precision  $\sigma(T_{\text{eff}}) = 15 \text{ K}$ ,  $\sigma(\log g) = 0.03 \text{ dex}, \sigma([\text{Fe/H}]) = 0.01 \text{ dex}, \text{ and } \sigma(v_t) = 0.03 \text{ kms}^{-1}.$ The masses were inferred from an isochrone analysis, which is described in detail in subsection 4.3. Our inferred stellar parameters can be found in Table A1. In order to test the precision of the scripts and the reliability of the results, we compared our stellar parameters with those from Ramírez et al. (2013, 2014) and Spina et al. (2016a, 2018). As shown in Figure 3, there is a good agreement between our results and those obtained using spectrographs of even higher resolution (e.g., HARPS spectrograph with  $R \sim 115000$  in Spina et al. (2018)) than the TS23.

<sup>10</sup> https://github.com/astroChasqui/q2

<sup>&</sup>lt;sup>5</sup> IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of the Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation.

<sup>&</sup>lt;sup>7</sup> https://github.com/ramstojh

<sup>8</sup> https://www.blancocuaresma.com/s/iSpec

<sup>9</sup> https://www.astro.rug.nl/software/kapteyn/



**Figure 3.** Comparison between our stellar parameters and those obtained by Ramírez et al. (2013, 2014) (squares and triangles) and Spina et al. (2016a, 2018) (stars and circles). The dashed lines represent the 1:1 ratio, while the green lines are the linear fits for  $T_{\text{eff}}$  (left panel, rms = 12 K), log g (middle panel, rms = 0.03 dex), and [Fe/H] (right panel, rms = 0.02 dex).

#### 4.2 New solar twins

As discussed earlier, the concept of solar twins changed over time (e.g., Cayrel de Strobel et al. 1981; Friel et al. 1993; Datson et al. 2012; Ramírez et al. 2014), and most of them are generally based on photometric and spectroscopic stellar parameters constraints but not on fundamental parameters that drive evolutionary states. The lack of the latter introduces a bias in the mass of the known solar twins, i.e., most of them are slightly more massive (~ 0.03  $M_{\odot}$ ) than the Sun (Ramírez et al. 2014: Spina et al. 2018). Thus, hampering the sample selection for studies such as gyrochronology and magnetic activity evolution (e.g., Lorenzo-Oliveira et al. 2018, 2019). It is expected that our sample also has the same bias because we used the stellar parameters constraints given by Ramírez et al. (2014) (i.e., all stars with stellar parameters into  $T_{\text{eff}} = 5777 \pm 100 \text{ K}$ ,  $\log g = 4.44 \pm 0.10$ dex,  $[Fe/H] = 0.00 \pm 0.10$  dex) in our solar twin hunting program. Figure 2 clearly shows that these constrains (in shape of an irregular polygon) do not follow the evolutionary tracks of main sequence stars, thereby introducing a slight bias in mass and removing several solar twin candidates with  $M < 1.0 M_{\odot}$  in our sample.

In order to address this issue for studies of the Sun's evolution along the main sequence, such as rotational and magnetic evolutionary studies, we propose a new class of star like the Sun<sup>11</sup>: solar proxy stars. Its definition is based on spectroscopic stellar parameter constraints ensuring that the star follows an evolutionary path similar to the Sun on the main sequence. Such constraints are: 1) [Fe/H] and mass values within  $\pm 0.15$  dex and  $\pm 5\%$  of the Sun's, respectively. Stars with these values roughly follow a similar evolutionary path as the Sun; 2) the  $\log g$  is only constrained to verify if the star is on the main sequence and its bounds depend on the mass isochrone model (e.g.,  $\log g$  can takes values from ~4.1 dex to 4.6 dex for a solar-mass star); 3) as a result of the above constraints, the  $T_{\rm eff}$  takes larger values ranging from ~5320 K to ~6050 K, nonetheless to achieve a high precision in stellar parameters we recommend to use  $T_{\rm eff}$  values within 150-200 K of the solar value (e.g., to avoid differential 3D and non-LTE effects). All these constraints are very well represented in Figure 4, where the dashed lines are the evolutionary tracks taken from Yonsei-Yale  $(Y^2)$  isochrones (Yi et al. 2001; Demarque et al. 2004) for masses between 0.95  $M_{\odot}$  and 1.05  $M_{\odot},$  in steps of 0.05 dex in [Fe/H]. Solar analog and solar-type stars keep the same definition, i.e., solar analogs are objects with [Fe/H] within a factor of two of solar (Soderblom & King 1998), while solar-type stars are main sequence or subgiant stars with 5000 K <  $T_{\rm eff}$  < 6500 K or spectral type ranging from F8V to K2V as is defined in the literature (e.g., see Soderblom & King 1998; Adibekyan et al. 2017).

Applying the above definitions in our sample, we identified 70 solar proxies (from which 42 are solar twins according to the definition of Ramírez et al. 2014), 46 solar analogs, and 13 solar-type stars, which are represented by circles (solar twins and proxies), diamonds, and squares, respectively in Figure 4. It is important to mention that we consider as solar twin/proxy/analog star to those whose uncertainties in fundamental parameters fall into our definition criteria, since our precision is limited by the resolving power. In addition, there are 23 wide binaries (Tokovinin 2014a,b) from which 14 are solar proxies, 7 are solar analogs and 2 are solar-type stars. The spectra of these binaries are not contaminated by their companions. We also identified four new spectroscopic binaries which are not analyzed in this work, however they are summarized in Table A4. Despite some stars of our sample have been already analyzed by other authors, their stellar parameters were estimated using methods that are different from ours, and with lower SNR or resolving power, or different spectral coverage. In order to identify the closest solar twin in our sample, we have narrowed down the [Fe/H],  $T_{eff}$ , log g, and mass to be within of 0.05 dex, 50 K, 0.05 dex, and 0.03  $M_{\odot}$  of the solar values. As a result, 9 stars (HIP 49580, HIP 20218, HIP 11253, HIP 7244, HD 105590A, HD 49425, HD 22875, HD 9201, TYC 1678-109-1) met these strict criteria, whose solar masses and [Fe/H] make them useful for obtaining precise chemical abundances differentially to the Sun. These few objects represent 7% from the total of stars analyzed in this work, thus showing how hard they are to find.

#### 4.3 Age and Mass

Isochronal mass and age determinations helped us to better understand the evolution of stars, calibrate age correlations as gyrochronology and magnetic activity evolution, as well as to understand the Chemical Evolution of the Galaxy. However, this method relies on isochrones of stellar evolution models and input stellar parameters ( $T_{\text{eff}}$ , absolute magnitude ( $M_V$ ) and [Fe/H]) (e.g., Lachaume et al. 1999; Takeda et al. 2007) that usually give large uncertainties (~3-4 Gyr), biases, or sometimes serious spurious age results because

<sup>&</sup>lt;sup>11</sup> Historically there are three classes of stars like the Sun: solar twins, solar analog stars, and solar-type stars (Cayrel de Strobel 1996).



**Figure 4.** Hertzsprung-Russell diagram plotted using the evolutionary tracks of  $Y^2$  (Yi et al. 2001; Demarque et al. 2004). The left dashed lines represent the evolutionary tracks for 1.05 M<sub> $\odot$ </sub> with [Fe/H] from 0.00 to -0.15 dex, while the right dashed lines for 0.95 M<sub> $\odot$ </sub> with [Fe/H] from 0.00 to 0.15 dex. The new solar twins and solar proxies are plotted as circles. To differentiate solar twins from solar proxies we also plotted the Ramirez's solar twin definition in blue dashed lines, i.e., all the circles plus their error bars that fall within this region are considered as solar twins. The

solar analogs and the solar-type stars are shown in diamonds and squares, respectively. The colormap represents the [Fe/H] for all the stars. The Sun's data is plotted as reference (green solar standard symbol) with its evolutionary track (i.e., dashed line for  $1.0 M_{\odot}$  and [Fe/H] = 0.0 dex).

the  $M_V$  is generally estimated from photometry of moderate precision. In order to increase the precision in the method, Ramírez et al. (2013, 2014) replaced the  $M_V$  by the spectroscopic log g. Using the  $q^2$  code, that performs probability distribution functions of ages and masses from the  $Y^2$  isochrones, these authors not only were able to achieve precise age values, but also greatly reduce their uncertainties to ~1-2 Gyr (e.g., see the compelling example of HIP 56948 in Meléndez et al. 2012). Spina et al. (2018) improved the  $q^2$  interpolation method by including  $\alpha$ -enhancements, spectroscopic log g, and  $M_V$  (estimated through Hipparcos/Gaia parallaxes) as input parameters (see their Eq. 3). As a result, these authors further reduce the uncertainties to ~1.0 Gyr (~0.5 Gyr using Gaia DR2 parallaxes). Despite the improvements performed by Ramírez et al. (2014) and Spina et al. (2018) to the isochronal age estimator, there is still a strong dependency on the precision of the spectroscopic  $\log g$  which at the same time is sensitive to EWs measurements and therefore also to the ionization balance.

In this work, we estimate isochronal ages using both the improved  $q^2$  and the Bayesian inference. The improved  $q^2$  uses stellar parameters, parallaxes and Johnson V magnitudes as input parameters. In our age estimations we use the precise Gaia EDR3 parallaxes, which are corrected by subtracting  $-15 \pm 18 \,\mu$ as as suggested by Stassun & Torres (2021). Besides, as the Johnson V is not as precise as Gaia G, we used the  $V_G$  (estimated from Eq. (2) and with  $\sigma(V_G) \sim 0.015$ ) when the uncertainties of Johnson V are greater than 0.015. It helps us to improve the q2 age estimations and it is also useful when Johnson V is not available. We found a dispersion of only  $\sim 0.04$ Gyr between the q<sup>2</sup> ages estimated using Johnson V and  $V_G$ . On the other hand, the Bayesian inference method (Grieves et al. 2018) employs the Y<sup>2</sup> evolutionary tracks adopting steps of 0.01 M/M $_{\odot}$  in mass, 0.05 dex in metallicity, and 0.05 dex in  $[\alpha/\text{Fe}]$ . Posterior distributions of ages and other evolutionary parameters are estimated through the proper marginalization of the likelihood as a function of  $T_{\rm eff}$ , [Fe/H]<sup>12</sup>, log g, Gaia EDR3 parallaxes (already offset by -15  $\mu$ as) and *Gaia* DR2 *G* band photometry. We emphasize that we did not use Gaia EDR3 G band in the Bayesian method as there are not yet bolometric corrections (BC) for it. For the brightest stars (G < 6mag), we corrected the Gaia DR2 G band systematics and applied the BC of Casagrande & VandenBerg (2018) to estimate luminosities. The resulting photometric errors are composed by the quadratic propagation of the nominal G band errors reported by Gaia DR2 and a conservative lower limit of 0.01 mag. The likelihood function is evaluated along each possible evolutionary step (within  $\pm 10\sigma$  of the input parameter space) and simultaneously weighted by metallicity and mass inputs, which are based on the solar neighborhood metallicity distribution (Casagrande 2018) and Salpeter initial mass function, respectively. The values adopted for each one of the evolutionary parameters result from the median (50% percentile) and  $\pm 1\sigma$  intervals (16-84% percentile) yielded by its posterior cumulative distributions.

The left panel of Figure 5 shows the q<sup>2</sup> ages estimated for our sample using spectroscopic stellar parameters and parallaxes as input parameters (hereafter log g & plx) versus the Bayesian inference ages. There is a good agreement between methods with a dispersion of only ~0.48 Gyr. This dispersion is estimated removing the most prominent outlier, which is a star with [Fe/H] = -0.5 dex and M = 0.85 M<sub> $\odot$ </sub>. In the middle panel of Figure 5, we compare the masses and it is shows good agreement with a dispersion of only 0.01 M<sub> $\odot$ </sub>. As the spectroscopic log g is a fundamental observable for estimating isochronal ages, it is important to make a comparison with the trigonometric gravity. It is estimated from the luminosity ( $\propto R^2 T_{eff}^4$ )

<sup>&</sup>lt;sup>12</sup> In this work, we adopted  $[\alpha/Fe] = 0$  as we did not determine the abundance of  $\alpha$ -enhancement elements.



**Figure 5. Left panel:** Comparison between the  $q^2$  ages estimated using  $\log g$  & parallaxes as input parameters versus the Bayesian ages. The latter includes *Gaia* DR2 *G* magnitudes in its calculations. **Middle panel:**  $q^2$  (log g & parallaxes) masses versus Bayesian masses. **Right panel:** Comparison between the spectroscopic and the trigonometric log g (Eq. (3)). In all panels, the dashed red lines represent the 1:1 ratio, while the yellow triangles the binary stars.

and gravity ( $\propto$  M/R<sup>2</sup>) relations to arrive to the following expression:

$$\log g(Trig) = \log \left(\frac{M}{M_{\odot}}\right) + 4 \log \left(\frac{T_{\text{eff}}}{T_{\odot}}\right) + 0.4V + 0.4BC + 2 \log \left(\frac{plx}{1000}\right) + 0.104,$$
(3)

where V is the unreddened visual magnitude, plx the parallax in milliarcsecond, and BC the bolometric correction. The latter is taken from Meléndez et al. (2006). The last term of Eq. (3) is somewhat different from the literature (e.g., Nissen et al. 1997) because we adopted a slightly different absolute bolometric magnitude value for the Sun ( $M_{bol,\odot}$  = 4.74; Bessell et al. 1998). As can be seen in the right panel of Figure 5, there is generally good agreement between the spectroscopic and trigonometric log  $g(\text{almost within } 2\sigma)$  with a dispersion of 0.035 dex. Binary stars (represented by yellow triangles) are not considered into the dispersion estimation in all panels of Figure 5. Therefore, with the above results, we can conclude that the ages determined using q<sup>2</sup> are as precise as those from the Bayesian inference. This is somewhat expected since the errors derived in this work are small enough to reduce the importance of the prior probability assumptions present in Bayesian models. However, particular attention is paid in this point because age determination techniques must be also tested with other methods as for instance gyrochronology, asteroseismology, chemical clocks, etc. In this paper, we adopted the ages estimated using the  $q^2$  since it is shown that this method gives reliable ages as the Bayesian inference. Therefore, the  $q^2$  ages will be used in the figures of the next sections. All our age, mass, and radius results using both methods are summarized in Table A2.

## **5 STELLAR ROTATION WITH KEPLER & TESS**

It is well-known that late-type stars inherit part of the original molecular cloud angular momentum as they are born. Therefore, a large spread in their initial rotational velocities is observed among young open cluster and stellar associations (Bouvier et al. 1997). As the stars arrive at the main sequence, it is expected that magnetized stellar winds, powered by stellar dynamo, drive the angular momentum evolution throughout their evolutionary history, gradually forgetting the initial rotational conditions. Therefore, after a given age, latetype stars tend to converge into well-behaved rotational sequence as a function of mass and age, enabling the calibration of empirical rotation-age-mass relations (Skumanich 1972; Barnes 2003). This age-dating technique is known as gyrochronology and establish a precise rotational clock where stellar ages are estimated from rotational period measurements (Barnes 2003; Meibom et al. 2011, 2015).

In the last decade, a new era for astronomy began with the successful Kepler (Borucki et al. 2010), K2 (Howell et al. 2014), and TESS (Ricker et al. 2015) missions. In this paper, we take advantage of the large public database of these surveys to measure rotation periods  $(P_{rot})$  for our sample. We found 31 precise light curves (one in Kepler, two in K2, and 28 in TESS) where several of them belong to the short and long cadence (e.g., 2-minute and 30-minute cadence observation in TESS). To extract TESS and Kepler light curves, we repeated the same procedure adopted in Lorenzo-Oliveira et al. (2020). The light curves were obtained from target pixel files using pixel level decorrelation technique through the *lightkurve*<sup>13</sup> python package (Lightkurve Collaboration et al. 2018). For each target, we remove surrounding pixels eventually contaminated by nearby stars. The resulting light curves are cleaned from outliers beyond  $\pm 3\sigma$ and in some cases binned in steps of 0.5 h to enhance the signal-tonoise ratio and also mitigate short-term variability (e.g., oscillations, spacecraft pointing jitter).

Prot were initially measured through Generalized Lomb-Scargle analysis. Since most of our stars shows moderate to low level of activity, we restricted our search for rotational periods within a reasonable window between 1 and 50 days. Detected rotation periods are defined by signals in the periodograms with false alarm probability bellow 1%. In the cases where aliases of the strongest detection are also present and statistically significant, we choose to report the secondary detection together with the strongest one. For a sanity test, the Prot were also estimated through Gaussian Process (GP) that uses a kernel developed from a mixture of two harmonic oscillators (for a complete description see Foreman-Mackey et al. 2020). Figure 6 shows the reduced light curve of HIP 17936 with the GP model plotted in black solid line and its  $2\sigma$  model prediction in red shaded region. The  $P_{\rm rot}$  estimated with both methods are in a very good agreement and we use the median of them as the adopted rotational period value (see Table A1).

In Figure 7 are displayed the rotational evolution of our sample

<sup>13</sup> https://docs.lightkurve.org/index.html



Figure 6. TESS light curve (filled circles) of the new solar proxy HIP 17936 observed in one sector. The black line represents the GP model, while the red shaded region its  $2\sigma$  rotation prediction model.



**Figure 7.** Age-Rotation diagram for our solar twins and proxies using model predictions from Barnes (2010) calibrated to the Sun (green solar standard symbol) and with variations of  $\pm 0.05 M_{\odot}$  (shaded region). The red dashed line represents the rotational evolution of the Sun.

of solar proxies (green circles), solar analogs (blue triangles) and the Sun (green solar standard symbol). The shaded region represents the rotational evolution model with solar metallicity and mass within  $\pm 5\%$  of the Sun. The model is based on the *period evolution equation* established by Barnes (2010) (see Equation (32) therein) that includes the convective turnover timescale (Table 1, Barnes & Kim 2010). We found a good agreement between the isochronal q<sup>2</sup> ages and the rotational evolution model, almost within the uncertainties.

#### 6 CHROMOSPHERIC ACTIVITY

Thanks to the very good performance of the TS23 spectrograph in the blue part of the spectra, we estimated the activity indices for our sample by measuring the Ca II H&K emission line fluxes (3933.664 Å and 3968.470 Å). The normalization of the spectral region brack-

eting the Ca II lines demands a different normalization procedure. In order to ensure the overall consistency of activity measurements, for each star, we performed a differential normalization procedure of the echelle spectral orders that surround the Ca II lines. As a template to guide the normalization procedure of a given star, we build a high SNR master spectrum from the large HARPS (R = 115000) time series and thus degraded the resolving power to match with TS23 observations (R = 60000). In the cases where no HARPS observations were performed for a given TS23 solar twin candidate, we choose another HARPS star with similar  $T_{eff}$  and [Fe/H] as a template. The S<sub>HK</sub> index was calculated following the prescription given in Wright et al. (2004). In order to perform a reliable calibration of our S<sub>HK,TS23</sub> indices into the Mount Wilson system (MW), we first selected a subsample of 10 stars whose S<sub>MW</sub> are very well estimated by Lorenzo-Oliveira et al. (2018) and then complemented with 5 new solar-type stars found in the European Southern Observatory (ESO) archive<sup>14</sup> also with common observations between HARPS and TS23. This sample of 15 stars is distributed between active and inactive regimes (Table A3). As a result, we obtain the following calibration equation:

$$S_{\rm MW} = 0.038(\pm 0.015) + 1.048(\pm 0.125) \times S_{\rm HK, TS23},\tag{4}$$

where the typical standard deviation of the linear fit is 0.0073 (see Figure 8), comparable with calibrations carried out using spectrographs of higher resolving power and stability than TS23 (e.g, HARPS). The converted  $S_{MW}$  values and their respective errors taking into account photometric and repeatability measurement errors are given in Table A1 for the **Inti** sample. However, we excluded from our sample stars with  $S_{MW}$  values estimated in a single patch epoch.

Activity levels were estimated using log  $R'_{\rm HK}(T_{\rm eff})$  index following the procedure given by Lorenzo-Oliveira et al. (2018). We emphasize that log  $R'_{\rm HK}(T_{\rm eff})$  should not be confused with the usual log  $R'_{\rm HK}$ based on photometric colors (Noyes et al. 1984). For the most active stars, the difference between both indices is negligible, however substantial differences arise after log  $R'_{\rm HK} \sim -4.8$  towards the lowest activity levels. Besides, the updated Ca II index log  $R'_{\rm HK}(T_{\rm eff})$ shows improved activity-age correlation for inactive stars. To build this index, Lorenzo-Oliveira et al. (2018) removed the photospheric

14 http://archive.eso.org/wdb/wdb/adp/phase3\_spectral/ form?phase3\_collection=HARPS



**Figure 8.** Mount Wilson system calibration using  $S_{HK,TS23}$  versus  $S_{HK,MW}$ . The red dashed line and the blue shaded region represent the linear fit (considering the errors in both axes) and the 95% confidence interval, respectively.

contribution of the  $R'_{\rm HK}$  by using an improved photospheric correction as a function of  $T_{\rm eff}$  (Equation (7) therein) instead of the standard photometric color (B - V) (Wright et al. 2004). The uncertainties are estimated through random samples from a Gaussian distribution that takes into account the  $\sigma(S_{\rm HK,MW})$ . As a result, we obtained updated chromospheric indices log  $R'_{\rm HK}(T_{\rm eff})$  for our sample and they can be also found in Table A1.

In Figure 9 are shown the chromospheric indices versus the ages for our solar proxy sample. The activity-age relation found by Lorenzo-Oliveira et al. (2018) is also plotted as red dashed lines with its  $2\sigma$ activity variability prediction band (shaded region). We can clearly see that our new sample of solar twins/proxies also follows this correlation, thereby favouring the chromospheric activity as a useful clock even for stars older than the Sun. However, notice that the activity-age relation in Lorenzo-Oliveira et al. (2018) was derived using high resolving power (R = 115000) time-series of Ca II H&K measurements. Besides, the typical [Fe/H] values of their sample are more narrowed around the solar metallicity ( $\pm 0.05$  dex of the solar value) in comparison to our sample. The latter explains the presence of some outliers in our activity-age diagram. The solar analog stars and solar-type stars are not included in Figure 9 as their mass and [Fe/H] regime are different to the solar proxies.

#### 7 SUMMARY AND CONCLUSIONS

Thanks to the *Gaia* mission, we found a large sample of solar twins candidates through constraints on color (using Tycho, 2MASS and *Gaia* EDR3 catalogs) and absolute magnitude (employing *Gaia* EDR3 parallaxes). As our sample is within 100 pc from Earth, reddening corrections are negligible. The definitive color constraints used for our solar twin hunting program are shown in Table 1 and were established following the spectroscopic solar twin definition given by Ramírez et al. (2014). However, this definition does not consider the evolutionary state of the star, thus introducing a slight bias in the mass distribution in the sample of known solar twins (see



**Figure 9.** Activity-age diagram for our solar twins and solar proxies. The red dashed line represents the activity-age relation  $(R'_{HK}(T_{eff}) \propto Age^{-0.52})$  and the shaded region its  $2\sigma$  activity prediction band found by Lorenzo-Oliveira et al. (2018). The Sun is represented by the green solar standard symbol, while the colormap shows the metallicity distribution.

Ramírez et al. 2014; Spina et al. 2018). Although the selection criteria of Ramírez et al. (2009) is useful for obtaining precise chemical abundances differentially to the Sun (due to a narrow range in stellar parameters relative to the Sun), that criteria hampers studies dedicated to understand the rotational and magnetic evolution of the Sun. To address this issue for future works, we propose a new class of star like the Sun: solar proxy, whose definition is based not only on stellar parameters constraints, but also on its evolutionary track during the main sequence. In this new definition, the metallicity and the mass define whether a star is a solar proxy or not. These parameters are constrained to be within  $\pm 0.15$  dex and 5% to the solar values, thereby assuring that the star follows a similar evolution as the Sun. The log g is assumed to be from  $\sim 4.1$  to 4.6 dex since this constraint is used only to verify if the star is on the main sequence. As is shown in Figure 4, the  $T_{\rm eff}$  of solar proxies can take values ranging from ~5310-6050 K, however, for precise abundances, it is recommended to work with stars with  $T_{\rm eff}$  within 150-200 K of the solar value in order to avoid 3D and non-LTE effects. Note that the solar proxy limits are not defined by an irregular polygon region, but instead by evolutionary tracks.

Applying all the definitions discussed above, we identified 70 solar proxies, 46 solar analogs and 13 solar-like stars. Their stellar parameters were estimated through the differential analysis and the spectroscopic equilibrium technique. As a result, we obtained a high internal precision ( $\sigma(T_{\text{eff}}) = 15 \text{ K}$ ,  $\sigma(\log g) = 0.03 \text{ dex}$ ,  $\sigma([\text{Fe/H}]) = 0.01 \text{ dex}$ , and  $\sigma(v_t) = 0.03 \text{ km s}^{-1}$ ). We also search the *close solar twin* within our **Inti** sample by narrowing down the mass,  $T_{\text{eff}}$ ,  $\log g$ , and [Fe/H] values to  $0.03 \text{ M}_{\odot}$ , 50 K, 0.05 dex, and 0.05 dex relative to the solar values, respectively. We found 9 potential candidates that meet these rigorous criteria. However, further studies should be performed to confirm these stars as close solar twins (e.g., chemical composition, Li abundances, etc).

Isochronal ages were estimated trough the Yonsei-Yale ischrones models (Yi et al. 2001) and employing two algorithms that use spectroscopic stellar parameters and precise *Gaia* EDR3 parallaxes as input parameters. The ages and masses show a good agreement between the methods within the uncertainties. We also estimated the trigonometric gravity to compare with the spectroscopic gravity and we found relatively good agreement between them, thus validating our age results. However, this is not the case for some binary stars, and it is necessary to use other age determinations such as gyrochronology, asteroseismology, chromospheric-age relations, etc., in order to evaluate the reliability of the results. We also determine a precise Mount Wilson system calibration for the activity indices ( $S_{HK,TS23}$ ) taken with the TS23 spectrograph at McDonald Observatory (see Eq. 4 and Figure 8). With this new calibration, we obtained improved chromospheric indices (log  $R'_{HK}(T_{eff})$ ; Lorenzo-Oliveira et al. 2018). Our new sample of solar twins/proxies also follow the activity-age correlation, thereby reinforcing the scenario where stars older than the Sun continue to decrease their chromospheric activity (see Figure 9). Rotational periods were estimated using precise TESS, Kepler, and K2 light curves after applying the Generalized Lomb-Scargle and Gaussian Process methods.

In this work, we provide to the community precise stellar parameters, ages, chromospheric indices and rotational periods (albeit we were not able to detect rotational periods in stars older than the Sun; Figure 7). Finally, the **Inti** survey is ideal for exoplanet searches around stars like the Sun (e.g., Bedell et al. 2015), in the quest for Solar System analogs.

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*Dedication:* This work is dedicated to the memory of Giusa Cayrel de Strobel, who had tremendous influence and contribution to the stellar astrophysics that we know today. This paper is purely inspired in Cayrel de Strobel's work who initiated the search for *real solar twins* in 1981. This work is also dedicated to Peru's Bicentennial Generation (*Generación del Bicentenario*) and overall to Brian Pintado Sánches and Inti Sotelo Camargo, who lost their lives defending the Peruvian democracy on November 14th, 2020.

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Softwares: numpy (van der Walt et al. 2011), matplotlib (Hunter 2007), pandas (McKinney 2010), astroquery (Ginsburg et al. 2019), IRAF (Tody 1986), iSpec (Blanco-Cuaresma et al. 2014;

Blanco-Cuaresma 2019), **Kapteyn Package** (Terlouw & Vogelaar 2015), **MOOG** (Sneden 1973), **q<sup>2</sup>** (Ramírez et al. 2014), **CERES** (Brahm et al. 2017), **SP\_ACE** (Boeche & Grebel 2016).

#### DATA AVAILABILITY

The **Inti** survey is available through MNRAS in its online supplementary material, and its spectra can be shared on request to the corresponding author.

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# **APPENDIX A: TABLES**

Table A1. Stellar parameters for the **futi** survey. This table is available in its entirety in machine readable format at the CDS.

$T_{eff}$ (K)         log g (dex)         log g Trigonometric (dex)         [Fe/H] (dex) $v_t$ (km s <sup>-1</sup> )           -1         5722 ± 8         4.350 ± 0.025         4.380 ± 0.023         -0.040 ± 0.007         1.03 ± 0.02
$5727 \pm 13 + 520 \pm 0.026 + 543 \pm 0.023 - 0.017 \pm 0.010   1.11 = 0.011 + 0.010   1.11 = 0.011 + 0.010   1.11 = 0.011 + 0.010   1.11 = 0.011 + 0.010   1.11 = 0.011 + 0.010   1.11 = 0.011 + 0.010   1.11 = 0.011 + 0.010   1.11 = 0.011 + 0.010   1.11 = 0.011 + 0.010   1.11 = 0.010   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.011 + 0.000   1.000 $
$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$
$5779 \pm 9$ 4.430 $\pm$ 0.026 4.429 $\pm$ 0.023 -0.026 $\pm$ 0.008
$5840 \pm 8$ 4.480 $\pm$ 0.028 4.495 $\pm$ 0.025 0.092 $\pm$ 0.00 $5801 \pm 10$ 4.470 $\pm$ 0.033 4.487 $\pm$ 0.023 $\pm$ 0.00
$5856 \pm 11  4.320 \pm 0.032 \qquad 4.322 \pm 0.023  -0.007 \pm 0.0$
5672 ± 8 4.440 ± 0.027 4.463 ± 0.023 -0.044 ± 0
$5827 \pm 10$ 4.470 $\pm 0.034$ 4.497 $\pm 0.023$ 0.083 $\pm$
$5794 \pm 16$ $4.560 \pm 0.030$ $4.533 \pm 0.023$ $0.031 \pm 0.031$
$5766 \pm 11$ 4.470 $\pm 0.030$ 4.509 $\pm 0.023$ -0.076
$5755 \pm 9$ $4.450 \pm 0.030$ $4.500 \pm 0.023$ -0.015
$5874 \pm 7$ 4.480 $\pm 0.022$ 4.492 $\pm 0.023$ 0.084
$5767 \pm 15$ $4.510 \pm 0.026$ $4.517 \pm 0.023$ $-0.006$
$5766 \pm 10$ $4.490 \pm 0.024$ $4.519 \pm 0.023$ $-0.028$
$5725 \pm 10$ $4.510 \pm 0.022$ $4.523 \pm 0.023$ $-0.020$
501.0 5279 + 0 4445 + 0.028 4.307 ± 0.023 0.097 5879 + 9 4445 + 0.078 4.476 + 0.073
$\begin{array}{cccccccccccccccccccccccccccccccccccc$
$5667 \pm 10$ $4.470 \pm 0.034$ $4.524 \pm 0.023$ $0.060$
$5729 \pm 11$ 4.510 $\pm$ 0.026 4.514 $\pm$ 0.023 0.05
$5689 \pm 9$ $4.465 \pm 0.031$ $4.533 \pm 0.023$ $-0.00$
$-1  5747 \pm 8  4.480 \pm 0.033  4.493 \pm 0.023  0.097$
-1 $5769 \pm 11$ $4.460 \pm 0.033$ $4.499 \pm 0.023$ -0.00
$-1  5742 \pm 11  4.500 \pm 0.030  4.508 \pm 0.023  0.08($
$5008 \pm 23 + 350 \pm 0.040 + 3505 \pm 0.023 - 0.000 \pm 125 \pm 0.023 + 0.026 + 2475 \pm 0.023 + 0.026 + 2477 \pm 0.023 + 0.026 + 0.023 + 0.026 +$
-1 5675 ± 8 4.433 ± 0.027 4.512 ± 0.023 0.09
$5707 \pm 10$ 4.320 $\pm$ 0.029 4.375 $\pm$ 0.023 -0.02
$5732 \pm 9$ $4.485 \pm 0.034$ $4.513 \pm 0.023$ $0.018$
$5872 \pm 10$ 4.390 $\pm$ 0.029 4.403 $\pm$ 0.023 0.109
$5786 \pm 11$ 4.440 $\pm 0.028$ 4.466 $\pm 0.023$ 0.035
$5812 \pm 15$ $4.430 \pm 0.041$ $4.328 \pm 0.023$ $-0.006$
$5890 \pm 16$ 4.540 $\pm$ 0.024 4.527 $\pm$ 0.023 -0.016
$5869 \pm 8$ $4.480 \pm 0.029$ $4.488 \pm 0.023$ $0.029$
$5884 \pm 9$ $4.430 \pm 0.025$ $4.410 \pm 0.023$ $-0.010$
$5727 \pm 9$ $4.510 \pm 0.019$ $4.505 \pm 0.023$ -0.079
$5759 \pm 8$ $4.470 \pm 0.026$ $4.439 \pm 0.023$ $0.010$
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Notes.(1) Solar twins, (2) Solar proxies, (3) Solar analogs, (4) Solar-type stars, ( $\ddagger$ ) Binary star.

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211726/079903573504 $TYC3130-2191-1$ $8.10 (+0.52)(-0.29)$ $0.909$ $297548019938221056$ $HD168069$ $2.20 (+1.01)(-0.48)$ $1.050$ $452963441760144866$ $HD168069$ $2.20 (+1.01)(-0.48)$ $1.050$ $1761984258439478744$ $HD193025$ $6.30 (+0.82)(-0.27)$ $1.000$ $900844114760515840$ $HD20722$ $1.010 (+0.657) (-0.77)$ $1.070$ $74073586325683268326833068HDP492585.30 (+0.82)(-0.27)1.0007407358632568326849062080HD9492586.90 (+1.01)(-0.67)1.0107407358632568326849062080HD94052301.00 (+0.657)(-0.79)1.0003557158857582834042080HDP4052301.00 (+0.657)(-0.79)1.0003557158857582834745083HDP60762.80 (+1.18)(-0.74)1.0003557158857582834745083HDP60762.80 (+1.08)(-0.57)1.000355715885758283474508HDP60762.10 (+1.08)(-0.57)1.000355715885758289143768HDP60762.10 (+1.08)(-0.53)1.00035571587558891374712HD91721.00 (+0.75)(-0.47)1.000357715875288407647HD722184591.00 (+0.75)(-0.47)1.0003577158752833255440HD722184591.000 (+0.75)(-0.47)1.0003577156551891443968HD72211032.20 (+0.91)(-0.67)1.0003577150551891441594HD72211039221068644060601.00 (+1.00)(-0.75)1.000357712052511977360525189479HD7221103922106841826854741.000 (+0.75)(-0.37)1.$	$\begin{array}{c} 0.960 \ (+0.014) (-0.007) \\ 0.999 \ (+0.008) (-0.008) \\ 1.050 \ (+0.008) (-0.008) \\ 1.020 \ (+0.009) (-0.008) \\ 0.990 \ (+0.009) (-0.009) \\ 1.010 \ (+0.014) (-0.007) \\ 1.030 \ (+0.010) (-0.009) \\ 1.010 \ (+0.012) \ (-0.009) \\ 1.000 \ (+0.010) (-0.009) \\ 1.000 \ (+0.008) (-0.009) \\ 1.000 \ (+0.010) (-0.009) \\ 1.000 \ (+0.0117) (-0.012) \\ 0.960 \ (+0.010) (-0.009) \\ 1.000 \ (+0.0012) \ (-0.008) \\ 1.000 \ (+0.0012) \ (-0.008) \\ 1.000 \ (+0.0013) (-0.008) \\ 1.000 \ (+0.0013) (-0.008) \\ 1.000 \ (+0.0013) (-0.008) \\ 1.000 \ (+0.0013) (-0.008) \\ 1.000 \ (+0.009) (-0.008) \\ 1.000 \ (+0.009) (-0.008) \\ 1.000 \ (+0.009) (-0.008) \\ 1.040 \ (+0.009) (-0.015) \\ 1.040 \ (+0.0015) \\ 1.040 \ (+0.00$	$\begin{array}{l} 1.060\ (\pm 0.014)(-0.008)\\ 0.902\ (\pm 0.004)(-0.004)\\ 1.000\ (\pm 0.010)(-0.009)\\ 1.130\ (\pm 0.009)(-0.009)\\ 1.010\ (\pm 0.007)(-0.009)\\ 0.980\ (\pm 0.016)(-0.008)\\ 0.970\ (\pm 0.016)(-0.015)\\ 1.180\ (\pm 0.016)(-0.015)\\ 1.120\ (\pm 0.005)(-0.008)\\ 0.900\ (\pm 0.008)(-0.007)\\ 0.920\ (\pm 0.001)(-0.007)\\ 0.920\ (\pm 0.003)(-0.007)\\ 0.920\ (\pm 0.003)(-0.007)\\ 0.920\ (\pm 0.003)(-0.007)\\ 0.920\ (\pm 0.002)(-0.007)\\ 0.920\ (\pm 0$	8.60 (+0.40)(-0.60) 0.60 (+0.50)(-0.40) 2.20 (+0.50)(-0.40) 7.10 (+0.30)(-0.40) 5.60 (+0.40)(-0.60) 0.90 (+0.50)(-0.40) 2.80 (+0.50)(-0.40) 7.80 (+0.40)(-0.50) 6.80 (+0.60)(-0.60) 7.80 (+0.40)(-0.30) 7.80 (+0.40)(-0.30) 0.70 (+0.40)(-0.30) 0.70 (+0.40)(-0.60) 0.70 (+0.40)(-0.60) 0.70 (+0.40)(-0.60) 0.70 (+0.40)(-0.60) 0.70 (+0.60)(-0.60) 0.240 (+0.70)(-0.50) 0.20 (+0.70)(-0.50) 0.20 (+0.70)(-0.60) 1.20 (+0.70)(-0.60)	$\begin{array}{c} 0.940 \ (+0.010)(-0.008) \\ 0.998 \ (+0.008)(-0.008) \\ 1.050 \ (+0.008)(-0.010) \\ 1.000 \ (+0.008)(-0.010) \\ 0.973 \ (+0.018)(-0.010) \\ 1.008 \ (+0.010)(-0.013) \\ 1.018 \ (+0.008)(-0.010) \\ 0.978 \ (+0.008)(-0.010) \\ 0.978 \ (+0.008)(-0.010) \\ 0.978 \ (+0.008)(-0.010) \\ 0.978 \ (+0.008)(-0.010) \\ 0.968 \ (+0.010)(-0.010) \\ 1.008 \ (+0.010)(-0.010) \\ 0.968 \ (+0.010)(-0.010) \\ 1.008 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \\ 0.910 \ (+0.010)(-0.010)(-0.010) \\ 0.910 \ (+0.010)(-0.010) \\ 0.910 \ (+0.010)(-0.010) \\ 0.910 $	$\begin{array}{c} 1.045 \ (+0.010)(-0.013) \\ 0.893 \ (+0.008)(-0.010) \\ 0.993 \ (+0.008)(-0.010) \\ 0.993 \ (+0.008)(-0.010) \\ 0.998 \ (+0.008)(-0.008) \\ 0.973 \ (+0.008)(-0.008) \\ 0.973 \ (+0.008)(-0.010) \\ 0.955 \ (+0.010)(-0.010) \\ 1.115 \ (+0.010)(-0.010) \\ 0.925 \ (+0.008)(-0.008) \\ 0.922 \ (+0.010)(-0.010) \\ 0.922 \ (+0.010)(-0.010) \\ 0.922 \ (+0.010)(-0.010) \\ 0.922 \ (+0.008)(-0.008) \\ 0.922 \ (+0.010)(-0.010) \\ 0.922 \ (+0.008)(-0.008) \\ 0.922 \ (+0.008)(-0.008) \\ 0.922 \ (+0.008)(-0.008) \\ 0.922 \ (+0.008)(-0.008) \\ 0.922 \ (+0.008)(-0.008) \\ 0.922 \ (+0.008)(-0.008) \\ 0.922 \ (+0.008)(-0.008) \\ 0.922 \ (+0.008)(-0.008) \\ 0.921 \ (+0.008)(-0.008) \\ 0.922 \ (+0.008)(-0.008) \\ 0.921 \ (+0.008)(-0.008)(-0.008) \\ 0.921 \ (+0.008)(-0.008)(-0.008) \\ 0.921 \ (+0.008)(-0.008)(-0.008) \\ 0.921 \ (+0.008)(-0.008)(-0.008) \\ 0.921 \ (+0.008)(-0.008)(-0.008)(-0.008) \\ 0.921 \ (+0.008)(-0.008)(-0.008)(-0.008) \\ 0.921 \ (+0.008)(-0.008)(-0.008)(-0.008) \\ 0.921 \ (+0.008)(-0.008)(-0.008)(-0.008)(-0.008) \\ 0.921 \ (+0.008)(-0.008)(-0.008)(-0.008)(-0.0$	
297548019938221056HIP8522 $0.70 (+0.97)(-0.49)$ $0.999$ 452963441760144896HIP103025 $6.30 (+0.82)(-0.29)$ $1.050$ 990844114760515840HIP03025 $5.30 (+0.82)(-0.29)$ $1.000$ 990844114760515840HIP20722 $1.00 (+0.62)(-0.27)$ $1.070$ 740735868326833368HIP20722 $1.00 (+0.62)(-0.27)$ $1.070$ 74073586832683368HIP69709 $5.90 (+1.01)(-0.67)$ $1.070$ 74073586832684062080HIP52649 $5.90 (+1.14)(-0.79)$ $1.010$ 3557158782894062080HIP52649 $5.90 (+1.18)(-0.48)$ $1.000$ 3557158782894062080HIP52649 $5.90 (+1.18)(-0.48)$ $1.000$ 3557158782894062080HIP52649 $5.90 (+1.18)(-0.48)$ $1.000$ 3557158782894062083HIP9172 $1.000 (+0.75)(-0.19)$ $1.000$ 355715878289406205824HIP9172 $1.00 (+0.75)(-0.19)$ $1.000$ 3576551891443968HIP9172 $1.00 (+0.75)(-0.19)$ $1.000$ 3576551891443968HIP920218 $2.50 (+0.91)(-0.44)$ $1.000$ 3732065418561000HIP72048 $1.00 (+1.07)(-0.47)$ $1.000$ 333106054183616000HIP10321 $0.70 (+1.20)(-0.59)$ $1.000$ 333106054183616000HIP10321 $0.70 (+1.20)(-0.73)$ $1.000$ 333106054183616000HIP10321 $0.70 (+1.20)(-0.73)$ $1.000$ 333106054183616000HIP10321 $0.70 (+1.20)(-0.73)$ $1.000$ 333106054183616000HIP10321 $0.70 (+1.20)(-0.73)$ $1.000$ 3331060541836180671HIP2204864	$\begin{array}{c} 0.999 \ (+0.004)(-0.004)\\ 1.050 \ (+0.008)(-0.008)\\ 1.020 \ (+0.009)(-0.008)\\ 0.990 \ (+0.009)(-0.008)\\ 1.070 \ (+0.017)(-0.009)\\ 1.010 \ (+0.014)(-0.007)\\ 1.030 \ (+0.010)(-0.009)\\ 1.000 \ (+0.010)(-0.009)\\ 1.000 \ (+0.016)(-0.009)\\ 1.000 \ (+0.016)(-0.008)\\ 1.000 \ (+0.016)(-0.008)\\ 1.000 \ (+0.016)(-0.008)\\ 1.000 \ (+0.016)(-0.008)\\ 1.000 \ (+0.011)(-0.008)\\ 1.000 \ (+0.011)(-0.008)\\ 1.000 \ (+0.014)(-0.008)\\ 1.000 \ (+0.0014)(-0.008)\\ 1.000 \ (+0.0014)(-0.008)\\ 1.000 \ (+0.0014)(-0.008)\\ 1.000 \ (+0.0014)(-0.008)\\ 1.000 \ (+0.0014)(-0.008)\\ 1.000 \ (+0.0007)(-0.008)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.008)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.0015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.009)(-0.015)\\ 1.040 \ (+0.015)(-0.015)\\ 1.040 \ (+0.015)(-0.015)\\ 1.040 \ (+0.015)(-0.015)\\ 1.040 \ (+0.$	$\begin{array}{l} 0.902 \ (+0.004)(-0.004) \\ 1.000 \ (+0.010)(-0.009) \\ 1.130 \ (+0.007)(-0.009) \\ 1.010 \ (+0.007)(-0.008) \\ 0.970 \ (+0.016)(-0.015) \\ 1.180 \ (+0.016)(-0.013) \\ 1.120 \ (+0.008)(-0.008) \\ 0.900 \ (+0.008)(-0.007) \\ 0.970 \ (+0.009)(-0.008) \\ 0.970 \ (+0.009)(-0.008) \\ 0.930 \ (+0.009)(-0.008) \\ 0.930 \ (+0.009)(-0.007) \\ 0.920 \ (+0.009)(-0.007) \\ 0.920 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.920 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.920 \ (+0.0007)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.920 \ (+0.0007)(-0.007)(-0.007) \\ 0.920 \ (+0.0007)(-0.007)(-0.007) \\ 0.920 \ (+0.0007)(-0.007)(-0.007)(-0.007) \\ 0.920 \ (+0.0007)(-0.007)(-0.007)(-0.007)(-0.007) \\ 0.920 \ (+0.0007)(-0.007)(-0.007)(-0.007)(-0.007) \\ 0.920 \ (+0.0007)(-0.$	0.60 (+0.50)(-0.40) 2.20 (+0.50)(-0.60) 7.10 (+0.30)(-0.40) 5.60 (+0.40)(-0.60) 0.90 (+0.50)(-0.40) 2.80 (+0.70)(-0.50) 6.80 (+0.60)(-0.60) 7.80 (+0.40)(-0.30) 7.80 (+0.40)(-0.30) 0.70 (+0.40)(-0.60) 0.70 (+0.40)(-0.60) 0.70 (+0.40)(-0.60) 0.70 (+0.40)(-0.60) 0.70 (+0.40)(-0.50) 0.70 (+0.40)(-0.50) 0.20 (+0.70)(-0.50) 1.30 (+0.70)(-0.50) 1.20 (+0.70)(-0.50)	$\begin{array}{c} 0.998 \ (+0.008)(-0.008)\\ 1.050 \ (+0.010)(-0.010)\\ 1.000 \ (+0.008)(-0.008)\\ 0.973 \ (+0.018)(-0.010)\\ 1.065 \ (+0.010)(-0.013)\\ 1.008 \ (+0.008)(-0.010)\\ 1.018 \ (+0.008)(-0.010)\\ 0.978 \ (+0.008)(-0.010)\\ 0.978 \ (+0.008)(-0.010)\\ 0.940 \ (+0.008)(-0.010)\\ 1.060 \ (+0.010)(-0.010)\\ 1.055 \ (+0.010)(-0.010)\\ 0.958 \ (+0.010)(-0.010)\\ 1.078 \ (+0.008)(-0.010)\\ 0.988 \ (+0.010)(-0.010)\\ 0.988 \ (+0.010)(-0.010)\\ 0.940 \ (+0.010)(-0.010)\\ 0.940 \ (+0$	$\begin{array}{c} 0.893 \ (+0.008) (-0.010) \\ 0.993 \ (+0.010) (-0.010) \\ 0.993 \ (+0.010) (-0.010) \\ 0.998 \ (+0.008) (-0.008) \\ 0.973 \ (+0.008) (-0.008) \\ 0.973 \ (+0.008) (-0.010) \\ 0.955 \ (+0.010) (-0.010) \\ 0.115 \ (+0.010) (-0.010) \\ 0.940 \ (+0.008) (-0.010) \\ 0.940 \ (+0.008) (-0.010) \\ 0.922 \ (+0.010) (-0.010) \\ 0.923 \ (+0.008) (-0.008) \\ 0.922 \ (+0.010) (-0.010) \\ 0.920 \ (+0.008) (-0.008) \\ 0.922 \ (+0.008) (-0.008) \\ 0.922 \ (+0.008) (-0.008) \\ 0.921 \ (+0.008) (-0.008) \\ 0.921 \ (+0.008) (-0.008) \\ 0.921 \ (+0.008) (-0.010) \\ 0.908 \ (+0.008) (-0.01$	
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$ \begin{array}{llllllllllllllllllllllllllllllllllll$	$\begin{array}{c} 1.020 \ (+0.009) (-0.008) \\ 0.990 \ (+0.009) (-0.008) \\ 1.070 \ (+0.017) (-0.009) \\ 1.010 \ (+0.014) (-0.007) \\ 1.030 \ (+0.010) (-0.009) \\ 1.000 \ (+0.010) (-0.012) \\ 0.960 \ (+0.016) (-0.012) \\ 0.960 \ (+0.016) (-0.012) \\ 0.960 \ (+0.016) (-0.008) \\ 1.000 \ (+0.008) (-0.008) \\ 1.000 \ (+0.008) (-0.008) \\ 1.000 \ (+0.009) (-0.008) \\ 1.000 \ (+0.011) (-0.008) \\ 1.000 \ (+0.007) (-0.008) \\ 1.020 \ (+0.009) (-0.008) \\ 1.070 \ (+0.009) (-0.015) \\ 1.040 \ (+0.0015) \\ 1.040 \ (+0.009) (-0.015) \\ 1.040 \ (+0.0015) \\ 1.040 \$	$\begin{array}{l} 1.130 \ (+0.009)(-0.009) \\ 1.010 \ (+0.007)(-0.008) \\ 0.980 \ (+0.016)(-0.015) \\ 1.180 \ (+0.016)(-0.015) \\ 1.180 \ (+0.016)(-0.023) \\ 1.120 \ (+0.008)(-0.008) \\ 0.990 \ (+0.008)(-0.008) \\ 0.970 \ (+0.009)(-0.008) \\ 0.930 \ (+0.008)(-0.007) \\ 0.920 \ (+0.008)(-0.007) \\ 0.930 \ (+0.008)(-0.007) \\ 0.930 \ (+0.009)(-0.007) \\ 0.930 \ (+0.009)(-0.007) \\ 0.920 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.920 \ (+0.0007)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.920 \ (+0.0007)(-0.007)(-0.007) \\ 0.920 \ (+0.0007)(-0.007)(-0.007) \\ 0.920 \ (+0.0007)(-0.007)(-0.007)(-0.007) \\ 0.920 \ (+0.0007)(-0.007)(-0$	7.10 (+0.30)(-0.40) 5.60 (+0.40)(-0.60) 0.90 (+0.50)(-0.40) 2.60 (+0.70)(-0.50) 6.80 (+0.60)(-0.40) 7.80 (+0.40)(-0.30) 5.70 (+0.40)(-0.30) 0.80 (+0.60)(-0.60) 0.80 (+0.70)(-0.90) 0.70 (+0.70)(-0.90) 0.70 (+0.70)(-0.90) 1.30 (+0.70)(-0.50) 1.30 (+0.70)(-0.50) 1.20 (+0.70)(-0.50)	$\begin{array}{c} 1.000 \ (+0.008)(-0.008)\\ 0.973 \ (+0.015)(-0.010)\\ 1.065 \ (+0.010)(-0.010)\\ 1.008 \ (+0.010)(-0.013)\\ 1.018 \ (+0.008)(-0.010)\\ 0.978 \ (+0.008)(-0.010)\\ 0.940 \ (+0.008)(-0.010)\\ 0.940 \ (+0.008)(-0.010)\\ 1.060 \ (+0.010)(-0.010)\\ 1.055 \ (+0.010)(-0.010)\\ 1.068 \ (+0.010)(-0.010)\\ 0.955 \ (+0.010)(-0.010)\\ 0.968 \ (+0.010)(-0.010)\\ 1.008 \ (+0.010)(-0.010)\\ 0.988 \ (+0.010)(-0.010)\\ 0.988 \ (+0.010)(-0.010)\\ 0.940 \ (+0.010)(-0.010)\\ 0.940 \ (+0.010)(-0.010)(-0.010)\\ 0.940 \ (+0.010)(-0.010)(-0.0$	$\begin{array}{c} 1.123 \ (+0.010)(-0.010)\\ 0.998 \ (+0.008)(-0.008)\\ 0.973 \ (+0.008)(-0.008)\\ 0.955 \ (+0.010)(-0.010)\\ 1.160 \ (+0.010)(-0.010)\\ 1.115 \ (+0.010)(-0.010)\\ 0.940 \ (+0.008)(-0.008)\\ 0.920 \ (+0.008)(-0.008)\\ 0.922 \ (+0.010)(-0.010)\\ 0.980 \ (+0.008)(-0.008)\\ 0.922 \ (+0.010)(-0.010)\\ 0.980 \ (+0.008)(-0.008)\\ 0.925 \ (+0.010)(-0.010)\\ 0.908 \ (+0.008)(-0.010)\\ 0.920 \ (+0.008)(-0.010)\\ 0.921 \ (+0.008)(-0.010)\\ 0.920 \ (+0.008)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)(-0.010)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)(-0.010)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)(-0.010)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)(-0.010)(-0.010)\\ 0.921 \ (+0.008)(-0.010)(-0.010)(-0$	
990844114760515840         HD49425         5.40 (+1.07)(-0.67)         0.990           272026980672350336         HIP20722         1.00 (+0.62)(-0.27)         1.070           272026980672350336         HIP49580         2.80 (+1.14)(-0.79)         1.010           158557582834745088         HIP69709         6.90 (+0.02)1(-0.67)         1.030           3557158782834062080         HIP69709         6.90 (+1.03)(-0.57)         1.000           3557158782834062080         HIP69230         1.19 (+1.29)(-0.57)         1.000           3157158782894062080         HIP697230         1.10 (+1.29)(-0.43)         1.000           315715878294062403         HIP9172         1.00 (+1.08)(-0.63)         1.000           31571587829405403583         HIP9172         1.00 (+1.07)(-0.47)         1.000           3203761005400205824         HIP79068         1.00 (+1.07)(-0.47)         1.000           3210654102582440         HIP79068         1.00 (+1.07)(-0.47)         1.000           32331065413861         HIP7244         1.64 (+1.07)(-0.47)         1.000           3331065413861         HIP7244         1.64 (+1.07)(-0.47)         1.000           3331065413861         HIP7244         1.64 (+1.07)(-0.47)         1.000           333106541383355555440         HIP7244 <td< td=""><td><math display="block">\begin{array}{c} 0.990 \ (+0.009) (-0.008) \\ 1.070 \ (+0.017) (-0.007) \\ 1.010 \ (+0.014) (-0.007) \\ 1.010 \ (+0.014) (-0.007) \\ 1.000 \ (+0.018) (-0.009) \\ 1.000 \ (+0.016) (-0.0012) \\ 0.960 \ (+0.016) (-0.012) \\ 0.960 \ (+0.016) (-0.012) \\ 0.960 \ (+0.016) (-0.008) \\ 1.000 \ (+0.008) (-0.008) \\ 1.000 \ (+0.0013) (-0.008) \\ 1.000 \ (+0.014) (-0.008) \\ 1.000 \ (+0.014) (-0.008) \\ 1.000 \ (+0.014) (-0.008) \\ 1.000 \ (+0.0014) (-0.008) \\ 1.000 \ (+0.0014) (-0.008) \\ 1.000 \ (+0.0014) (-0.008) \\ 1.000 \ (+0.0014) (-0.008) \\ 1.000 \ (+0.0014) (-0.008) \\ 1.000 \ (+0.009) (-0.016) \\ 1.000 \ (+0.009) (-0.015) \\ 1.040 \ (+0.015) \\ 1.040 \</math></td><td><math display="block">\begin{array}{l} 1.010 (+0.007)(-0.009) \\ 0.980 (+0.016)(-0.008) \\ 0.970 (+0.016)(-0.015) \\ 1.180 (+0.016)(-0.023) \\ 1.120 (+0.029)(-0.008) \\ 0.900 (+0.008)(-0.007) \\ 0.970 (+0.009)(-0.008) \\ 0.930 (+0.011)(-0.007) \\ 0.920 (+0.008)(-0.008) \\ 0.930 (+0.008)(-0.007) \\ 0.920 (+0.008)(-0.007) \\ 0.920 (+0.002)(-0.007) \\ 0.921 (+0.009)(-0.007) \\ 0.921 (+0.009)(-0.007) \\ 0.921 (+0.009)(-0.007) \\ 0.921 (+0.009)(-0.007) \\ 0.921 (+0.009)(-0.007) \\ 0.921 (+0.009)(-0.007) \\ 0.920 (+0.002)(-0.007) \\ 0.920 (+0.002)(-0.007) \\ 0.921 (+0.009)(-0.007) \\ 0.921 (+0.009)(-0.007) \\ 0.920 (+0.002)</math></td><td>5.60 (+0.40)(-0.60) 0.90 (+0.50)(-0.40) 2.60 (+0.70)(-0.50) 6.80 (+0.50)(-0.40) 7.80 (+0.40)(-0.30) 7.80 (+0.40)(-0.30) 5.70 (+0.40)(-0.60) 0.80 (+0.60)(-0.60) 0.20 (+0.70)(-0.90) 0.70 (+0.40)(-0.40) 0.210 (+0.70)(-0.50) 0.20 (+0.70)(-0.50) 1.30 (+0.70)(-0.50) 1.20 (+0.70)(-0.60)</td><td>0.973 (+0.015)(-0.010) 1.065 (+0.010)(-0.010) 1.008 (+0.010)(-0.013) 1.018 (+0.008)(-0.010) 0.978 (+0.008)(-0.010) 0.940 (+0.008)(-0.010) 1.060 (+0.010)(-0.010) 1.025 (+0.010)(-0.010) 0.968 (+0.018)(-0.010) 0.958 (+0.010)(-0.010) 0.988 (+0.010)(-0.010)</td><td><math display="block">\begin{array}{c} 0.998 \ (+0.008) (-0.008) \\ 0.973 \ (+0.010) (-0.008) \\ 0.955 \ (+0.010) (-0.008) \\ 0.955 \ (+0.010) (-0.010) \\ 1.115 \ (+0.010) (-0.010) \\ 0.940 \ (+0.008) (-0.010) \\ 0.940 \ (+0.008) (-0.008) \\ 0.920 \ (+0.008) (-0.008) \\ 0.925 \ (+0.010) (-0.010) \\ 0.920 \ (+0.008) (-0.008) \\ 0.925 \ (+0.008) (-0.010) \\ 0.908 \ (-0.008) (-0.010) \\ 0.921 \ (+0.008) (-0.010) \\ 0.920 \ (+0.008) (-0.010) \\ 0.921 \ (+0.008) (-0.010) \\ 0.921 \ (+0.008) (-0.010) \\ 0.921 \ (+0.008) (-0.008) \\ 0.921 \ (+0.008) (-0.010) (-0.010) \\ 0.921 \ (+0.008) (-0.010) (-0.010) \\ 0.921 \ (+0.008) (-0.010) (-0.010) \\ 0.921 \ (+0.008) (-0.010) (-0.010) \\ 0.921 \ (+0.008) (-0.010) (-0.010) \\ 0.921 \ (+0.008) (-0.010) (-0.010) \\ 0.921 \ (+0.008) (-0.010) (-0.010) \\ 0.921 \ (+0.008) 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272026980672350336HIP20722 $1.00 (+0.62)(-0.27)$ $1.070$ 740735868326875828HIP49580 $2.80 (+1.14)(-0.79)$ $1.010$ $1508557582834745088$ HIP69709 $6.90 (+0.051)(-0.67)$ $1.00$ $3557158782894062080$ HIP52649 $6.90 (+1.08)(-0.25)$ $1.00$ $355715878289406208752$ HIP69730 $6.90 (+1.08)(-0.25)$ $1.00$ $355715878289406208752$ HIP52649 $6.90 (+1.08)(-0.25)$ $1.00$ $355715878289406208752$ HIP52649 $6.90 (+1.08)(-0.48)$ $1.00$ $35730567158782891443968$ HIP9172 $1.00 (+0.75)(-0.19)$ $1.00$ $345765551891443968$ HIP9172 $1.00 (+0.75)(-0.19)$ $1.00$ $3373206740754020583584$ HIP20218 $2.50 (+0.91)(-0.44)$ $1.00$ $33731065418361600$ HIP72048 $1.00 (+1.00)(-0.59)$ $1.00$ $33310655418361600$ HIP7244 $1.64 (+1.07)(-0.47)$ $1.00$ $4511284924268544$ HIP221103 $2.80 (+0.70)(-0.27)$ $1.00$ $33310655418361600$ HIP229450A $6.30 (+1.25)(-0.29)$ $1.00$ $4511284923120$ HIP221103 $2.80 (+1.20)(-0.27)$ $1.00$ $4511284933120$ HIP221103 $2.80 (+1.20)(-0.24)$ $1.00$ $453430777345114038633250176$ HID229450A $6.00 (+1.21)(-0.29)$ $1.00$ $453430777345114038633250176$ HID2213244 $1.20 (+1.20)(-0.27)$ $1.00$ $453430777345117403813806843320HID22132441.20 (+1.20)(-0.27)1.0045343077734518633723476HID223248-17641.20 (+1.20)(-0.29)$	1.070 (+0.017)(-0.009) 1.010 (+0.014)(-0.007) 1.030 (+0.010)(-0.009) 1.000 (+0.010)(-0.009) 1.000 (+0.008)(-0.012) 0.960 (+0.016)(-0.012) 0.960 (+0.008)(-0.008) 1.060 (+0.008)(-0.008) 1.000 (+0.008)(-0.008) 1.000 (+0.017)(-0.008) 1.000 (+0.013)(-0.008) 1.010 (+0.014)(-0.008) 1.020 (+0.007)(-0.008) 1.020 (+0.007)(-0.008) 1.040 (+0.009)(-0.015)	0.980 (+0.016)(-0.008) 0.970 (+0.016)(-0.015) 1.180 (+0.016)(-0.023) 1.120 (+0.029)(-0.008) 0.900 (+0.008)(-0.007) 0.970 (+0.009)(-0.008) 0.930 (+0.011)(-0.007) 0.920 (+0.008)(-0.008) 0.930 (+0.008)(-0.007) 0.920 (+0.016)(-0.007) 0.921 (+0.009)(-0.007) 0.921 (+0.009)(-0.007)	0.90 (+0.50)(-0.40) 2.60 (+0.70)(-0.50) 6.80 (+0.50)(-0.40) 7.80 (+0.40)(-0.30) 2.40 (+0.80)(-0.60) 5.70 (+0.40)(-0.30) 0.80 (+0.60)(-0.60) 0.70 (+0.40)(-0.40) 0.70 (+0.40)(-0.40) 2.240 (+0.70)(-0.50) 0.60 (+0.40)(-0.50) 1.30 (+0.70)(-0.50) 1.20 (+0.60)(-0.60)	$\begin{array}{c} 1.065 \ (+0.010)(-0.010) \\ 1.008 \ (+0.010)(-0.013) \\ 1.018 \ (+0.008)(-0.010) \\ 0.978 \ (+0.008)(-0.010) \\ 0.958 \ (+0.013)(-0.010) \\ 1.060 \ (+0.010)(-0.010) \\ 1.060 \ (+0.010)(-0.010) \\ 1.025 \ (+0.010)(-0.010) \\ 0.968 \ (+0.018)(-0.010) \\ 1.078 \ (+0.008)(-0.010) \\ 1.078 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010)(-0.010)(-0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.0$	$\begin{array}{c} 0.973 \ (+0.010)(-0.008) \\ 0.955 \ (+0.008)(-0.010) \\ 1.160 \ (+0.010)(-0.010) \\ 1.115 \ (+0.010)(-0.010) \\ 0.940 \ (+0.008)(-0.008) \\ 0.940 \ (+0.008)(-0.008) \\ 0.921 \ (+0.010)(-0.010) \\ 0.922 \ (+0.010)(-0.010) \\ 0.922 \ (+0.010)(-0.008) \\ 0.922 \ (+0.010)(-0.008) \\ 0.925 \ (+0.008)(-0.008) \\ 0.925 \ (+0.008)(-0.010) \\ 0.008 \ (-0.008)(-0.010)(-0.010) \\ 0.008 \ (-0.008)(-0.010)(-0.010)(-0.010) \\ 0.008 \ (-0.008)(-0.010)(-0.01$	
7407358632685368HIP49580 $2.80 (+1.14)(-0.79)$ $1.010$ $7407358632685358$ HIP69709 $6.90 (+0.91)(-0.67)$ $1.030$ $3557158782894062080$ HIP52649 $6.90 (+1.08)(-0.25)$ $1.000$ $355715878289406208752$ HIP52649 $6.90 (+1.08)(-0.25)$ $1.000$ $355715878289406208752$ HIP52649 $6.90 (+1.08)(-0.25)$ $1.000$ $39154297333618539522$ HIP55820 $5.50 (+0.98)(-0.44)$ $0.960$ $31571551891443968$ HIP9172 $1.00 (+0.75)(-0.19)$ $1.000$ $315765551891443968$ HIP9172 $1.00 (+0.108)(-0.63)$ $1.000$ $32376530383555440$ HIP92018 $2.50 (+0.91)(-0.47)$ $1.000$ $32376100540020582440$ HIP72048 $1.00 (+1.00)(-0.59)$ $1.000$ $3233106054183016000$ HIP7244 $1.64 (+1.07)(-0.47)$ $1.000$ $333106054183058600$ HIP221103 $2.80 (+0.120)(-0.27)$ $1.000$ $3331060541830516000$ HID221103 $2.80 (+1.21)(-0.29)$ $1.000$ $451128459948426854$ HID221103 $2.80 (+1.21)(-0.29)$ $1.000$ $3331060541830516000$ HID2213244 $1.20 (+1.20)(-0.27)$ $1.000$ $21634331774608863250176$ HID221303 $2.30 (+1.23)(-0.24)$ $1.000$ $355968486853250176$ HID213244 $1.20 (+1.20)(-0.26)$ $1.000$ $15534331774608863250176$ HID213244 $1.20 (+1.20)(-0.27)$ $1.000$ $1609471786118933120$ HID213244 $1.20 (+1.20)(-0.26)$ $1.000$ $1909471786118933120$ HID213244 $1.20 (+1.20)(-0.26)$ $1.00$	$\begin{array}{c} 1.010 \ (+0.014)(-0.007) \\ 1.030 \ (+0.008)(-0.009) \\ 1.000 \ (+0.008)(-0.009) \\ 1.000 \ (+0.017)(-0.012) \\ 0.960 \ (+0.016)(-0.009) \\ 1.060 \ (+0.008)(-0.008) \\ 1.030 \ (+0.008)(-0.008) \\ 1.000 \ (+0.008)(-0.008) \\ 1.000 \ (+0.008)(-0.008) \\ 1.000 \ (+0.011)(-0.008) \\ 1.000 \ (+0.013)(-0.009) \\ 1.000 \ (+0.013)(-0.008) \\ 1.000 \ (+0.009)(-0.008) \\ 1.000 \ (+0.009)(-0.015) \\ 1.040 \ (+0.0015) \\ 1.040 \ (+0.0015$	0.970 (+0.016)(-0.015) 1.180 (+0.016)(-0.023) 1.120 (+0.029)(-0.008) 0.900 (+0.008)(-0.007) 0.950 (+0.001)(-0.007) 0.930 (+0.001)(-0.007) 0.920 (+0.008)(-0.008) 0.940 (+0.008)(-0.007) 0.920 (+0.016)(-0.007) 0.921 (+0.009)(-0.007) 0.921 (+0.009)(-0.007) 0.921 (+0.009)(-0.007)	2.60 (+0.70)(-0.50) 6.80 (+0.50)(-0.40) 7.80 (+0.40)(-0.30) 2.40 (+0.80)(-0.60) 5.70 (+0.40)(-0.30) 0.80 (+0.60)(-0.60) 0.70 (+0.40)(-0.40) 2.20 (+0.70)(-0.50) 0.20 (+0.70)(-0.50) 1.30 (+0.70)(-0.50) 1.20 (+0.70)(-0.50)	$\begin{array}{c} 1.008 \ (+0.010)(-0.013) \\ 1.018 \ (+0.008)(-0.010) \\ 0.978 \ (+0.008)(-0.008) \\ 0.958 \ (+0.013)(-0.010) \\ 0.940 \ (+0.008)(-0.010) \\ 1.060 \ (+0.010)(-0.010) \\ 1.055 \ (+0.010)(-0.010) \\ 0.968 \ (+0.018)(-0.013) \\ 0.955 \ (+0.010)(-0.008) \\ 1.078 \ (+0.008)(-0.010) \\ 1.008 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \\ 0.9100 \ 0.010) \\ 0.988 \ (+0.010)(-0.010) \\ 0.9100 \ 0.010) \\ 0.988 \ (+0.010)(-0.010) \\ 0.0100 \ 0.010) \\ 0.988 \ (+0.010)(-0.010) \\ 0.9100 \ 0.010) \\ 0.9100 \ 0.010 \ 0.010) \\ 0.9100 \ 0.010 \ 0.010) \\ 0.9100 \ 0.010 \ 0.010) \\ 0.9100 \ 0.010 \ 0.010 \ 0.010) \\ 0.9100 \ 0.010 \ 0.010 \ 0.010) \\ 0.9100 \ 0.010 \ 0.010 \ 0.010 \ 0.010) \\ 0.9100 \ 0.010 \$	$\begin{array}{c} 0.955 \ (+0.008) (-0.010) \\ 1.160 \ (+0.010) (-0.010) \\ 1.115 \ (+0.010) (-0.010) \\ 0.893 \ (+0.010) (-0.010) \\ 0.940 \ (+0.008) (-0.008) \\ 0.925 \ (+0.010) (-0.010) \\ 0.922 \ (+0.010) (-0.008) \\ 0.913 \ (+0.008) (-0.008) \\ 0.925 \ (+0.010) (-0.010) \\ 0.925 \ (+0.008) (-0.010) \\ 0.925 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.010) \\ 0.925 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.010) \\ 0.925 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.010) \\ 0.925 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) \\ 0.926 \ (+0.008) (-0.010) (-0.010) (-0.010) \\ 0.926 \ (+0.010) (-0.010) (-0.010) \\ 0.926 \ ($	
	$\begin{array}{c} 1.030 \ (+0.010)(-0.009) \\ 1.000 \ (+0.008)(-0.009) \\ 1.000 \ (+0.017)(-0.012) \\ 0.960 \ (+0.016)(-0.009) \\ 1.060 \ (+0.008)(-0.008) \\ 1.030 \ (+0.008)(-0.008) \\ 1.000 \ (+0.008)(-0.008) \\ 1.000 \ (+0.008)(-0.008) \\ 1.000 \ (+0.013)(-0.008) \\ 1.010 \ (+0.011)(-0.008) \\ 1.000 \ (+0.013)(-0.008) \\ 1.010 \ (+0.014)(-0.008) \\ 1.020 \ (+0.009)(-0.105) \\ 1.040 \ (+0.009)(-0.115) \\ 1.040 \ (+0.009)(-0.115) \\ 1.040 \ (+0.009)(-0.105) \\ 1.040 \ (+0.009)(-0.105) \\ 1.040 \ (+0.009)(-0.105) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.0015) \\ 1.040 \ ($	$\begin{array}{l} 1.180\ (+0.016)(-0.023)\\ 1.120\ (+0.029)(-0.008)\\ 0.900\ (+0.008)(-0.007)\\ 0.950\ (+0.001)(-0.007)\\ 0.970\ (+0.009)(-0.008)\\ 0.930\ (+0.011)(-0.007)\\ 0.940\ (+0.008)(-0.008)\\ 0.990\ (+0.016)(-0.007)\\ 0.920\ (+0.002)(-0.007)\\ 0.920\ (+0.002)(-0.007)\\ 0.920\ (+0.002)(-0.007)\\ 0.910\ (+0.009)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)(-0.007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)(-0.007)(-0.007)(-0.007)(-0.007)\\ 0.910\ (+0.0007)(-0.007)(-$	6.80 (+0.50)(-0.40) 7.80 (+0.40)(-0.30) 2.40 (+0.80)(-0.60) 5.70 (+0.40)(-0.30) 0.80 (+0.60)(-0.60) 0.70 (+0.40)(-0.40) 0.70 (+0.70)(-0.50) 0.60 (+0.70)(-0.50) 1.30 (+0.70)(-0.50) 1.30 (+0.70)(-0.60)	$\begin{array}{c} 1.018 \ (+0.008)(-0.010) \\ 0.978 \ (+0.008)(-0.008) \\ 0.958 \ (+0.013)(-0.010) \\ 0.940 \ (+0.008)(-0.010) \\ 1.060 \ (+0.010)(-0.010) \\ 1.025 \ (+0.010)(-0.010) \\ 0.968 \ (+0.018)(-0.013) \\ 0.995 \ (+0.010)(-0.008) \\ 1.078 \ (+0.008)(-0.010) \\ 1.008 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \\ 0.910 \ 0.010) \\ 0.910 \ 0.010 \ 0.010) \\ 0.910 \ 0.010 \ 0.010 \ 0.010) \\ 0.910 \ 0.010$	$\begin{array}{c} 1.160 \ (+0.010) (-0.010) \\ 1.115 \ (+0.010) (-0.010) \\ 0.893 \ (+0.010) (-0.010) \\ 0.940 \ (+0.008) (-0.008) \\ 0.965 \ (+0.010) (-0.010) \\ 0.920 \ (+0.010) (-0.008) \\ 0.913 \ (+0.010) (-0.008) \\ 0.935 \ (+0.010) (-0.008) \\ 0.925 \ (+0.008) (-0.010) \\ 0.925 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.010) \\ 0.925 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.010) \\ 0.925 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) \\$	
3557158782894062080HIP52649 $6.90 (+1.08) (-0.25)$ $1.000$ $1260316891261098752$ HIP $952820$ $5.50 (+0.86) (-0.44)$ $0.960$ $2136741591197747712$ HIP $9172$ $0.00 (+0.75) (-0.19)$ $1.000$ $345765551891443968$ HIP $9172$ $1.00 (+1.08) (-0.63)$ $1.000$ $337320067477530568$ HIP $202188$ $2.50 (+0.91) (-0.44)$ $1.000$ $33236330835255440$ HIP $72048$ $1.00 (+1.00) (-0.75) (-0.19)$ $1.000$ $3323106054183616000$ HIP $7244$ $1.60 (+1.20) (-0.73)$ $1.000$ $333106054183616000$ HIP $102321$ $0.70 (+1.35) (-0.24)$ $1.000$ $333106054183616000$ HIP $102321$ $0.70 (+1.23) (-0.27)$ $1.000$ $4511284594842588-6756-1$ $0.60 (+1.21) (-0.27)$ $1.000$ $216343371746084352$ HD $22329450A$ $6.30 (+0.82) (-0.24)$ $1.000$ $216343371746084352$ HD $2232769$ $0.300 (+1.26) (-0.26)$ $1.000$ $216343371746084352$ HD $213244$ $1.20 (+1.20) (-0.27)$ $1.000$ $216343371746084352$ HD $213244$ $1.20 (+1.26) (-0.26)$ $1.000$ $216343371746084352$ HD $213244$ $1.20 (+1.26) (-0.26)$ $1.000$ $216343371746084352$ HD $213244$ $1.20 (+1.26) (-0.26)$ $1.000$ $216343371746084352$ HD $213244$ $1.20 ($	1.000 (+0.008)(-0.009) 1.000 (+0.017)(-0.012) 0.960 (+0.016)(-0.009) 1.060 (+0.008)(-0.008) 1.030 (+0.017)(-0.010) 1.000 (+0.008)(-0.007) 1.000 (+0.014)(-0.008) 1.010 (+0.011)(-0.008) 1.010 (+0.013)(-0.007) 1.010 (+0.014)(-0.008) 1.020 (+0.014)(-0.008) 1.020 (+0.0014)(-0.008) 1.040 (+0.009)(-0.015)	$\begin{array}{c} 1.120 \ (+0.029)(-0.008) \\ 0.900 \ (+0.008)(-0.007) \\ 0.950 \ (+0.001)(-0.007) \\ 0.970 \ (+0.009)(-0.008) \\ 0.930 \ (+0.011)(-0.007) \\ 0.940 \ (+0.008)(-0.008) \\ 0.990 \ (+0.016)(-0.007) \\ 0.930 \ (+0.009)(-0.007) \\ 0.921 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.009)(-0.007) \\ 0.910 \ (+0.0007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007)(-0.007)(-0.007)(-0.007) \\ 0.910 \ (+0.0007)(-0.007)(-0$	7.80 (+0.40)(-0.30) 2.40 (+0.80)(-0.60) 5.70 (+0.40)(-0.30) 0.80 (+0.60)(-0.60) 0.70 (+0.40)(-0.40) 0.70 (+0.40)(-0.40) 2.20 (+0.70)(-0.50) 0.60 (+0.40)(-0.30) 1.30 (+0.60)(-0.60)	0.978 (+0.008)(-0.008) 0.958 (+0.013)(-0.010) 0.940 (+0.008)(-0.010) 1.060 (+0.010)(-0.010) 1.025 (+0.010)(-0.010) 0.968 (+0.018)(-0.013) 0.955 (+0.010)(-0.008) 1.078 (+0.008)(-0.010) 1.008 (+0.010)(-0.010) 0.988 (+0.010)(-0.010)	$\begin{array}{c} 1.115 \ (+0.010) (-0.010) \\ 0.893 \ (+0.010) (-0.010) \\ 0.940 \ (+0.008) (-0.008) \\ 0.965 \ (+0.010) (-0.010) \\ 0.920 \ (+0.010) (-0.008) \\ 0.913 \ (+0.010) (-0.008) \\ 0.935 \ (+0.010) (-0.008) \\ 0.920 \ (+0.008) (-0.008) \\ 0.925 \ (+0.008) (-0.010) \\ 0.908 \ (-0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ ($	
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	$\begin{array}{c} 1.000 \ (+0.017)(-0.012) \\ 0.960 \ (+0.016)(-0.009) \\ 1.060 \ (+0.008)(-0.008) \\ 1.030 \ (+0.008)(-0.008) \\ 1.000 \ (+0.008)(-0.007) \\ 1.000 \ (+0.009)(-0.007) \\ 1.000 \ (+0.011)(-0.008) \\ 1.010 \ (+0.011)(-0.008) \\ 1.010 \ (+0.011)(-0.008) \\ 1.010 \ (+0.012)(-0.008) \\ 1.010 \ (+0.012)(-0.008) \\ 1.010 \ (+0.012)(-0.008) \\ 1.010 \ (+0.012)(-0.008) \\ 1.010 \ (+0.012)(-0.008) \\ 1.020 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.009)(-0.015) \\ 1.040 \ (+0.0015)(-0.008) \\ 1.040 \ (+0.0015)(-0.008) \\ 1.040 \ (+0.0015)(-0.0015) \\ 1.040 \ (+0.0015)(-0.008)(-0.015) \\ 1.040 \ (+0.0015)(-0.0015) \\ 1.040 \ (+0.0015)(-0.0015)(-0.015) \\ 1.040 \ (+0.0015)(-0.0015)(-0.015) \\ 1.040 \ (+0.0015)(-0.0015)(-0.015)(-0.015) \\ 1.040 \ (+0.0015)(-0.0015)(-0.01$	0.900 (+0.008)(-0.007) 0.950 (+0.011)(-0.007) 0.970 (+0.009)(-0.008) 0.930 (+0.011)(-0.007) 0.940 (+0.008)(-0.008) 0.990 (+0.016)(-0.007) 0.930 (+0.009)(-0.007) 0.921 (+0.009)(-0.007) 0.910 (+0.009)(-0.007)	2.40 (+0.80)(-0.60) 5.70 (+0.40)(-0.30) 0.80 (+0.60)(-0.60) 0.70 (+0.40)(-0.40) 2.20 (+0.70)(-0.90) 2.40 (+0.70)(-0.50) 0.60 (+0.40)(-0.50) 1.30 (+0.70)(-0.60)	$\begin{array}{c} 0.958 \ (+0.013)(-0.010) \\ 0.940 \ (+0.008)(-0.010) \\ 1.060 \ (+0.010)(-0.010) \\ 1.025 \ (+0.010)(-0.010) \\ 0.968 \ (+0.018)(-0.013) \\ 0.995 \ (+0.010)(-0.008) \\ 1.078 \ (+0.008)(-0.010) \\ 1.008 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \end{array}$	$\begin{array}{c} 0.893 \ (+0.010) (-0.010) \\ 0.940 \ (+0.008) (-0.008) \\ 0.965 \ (+0.010) (-0.010) \\ 0.920 \ (+0.010) (-0.008) \\ 0.913 \ (+0.010) (-0.008) \\ 0.935 \ (+0.010) (-0.008) \\ 0.920 \ (+0.008) (-0.008) \\ 0.925 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) (-0.008) \\ $	
3915429733361853952HIP558205.50 ( $+0.86$ )( $-0.44$ )0.9602136741591197747712HIP9172 $0.80 (+1.18)(-0.48)$ $1.060$ 345765551891443968HIP9172 $1.00 (+0.75)(-0.19)$ $1.030$ 537329067477530368HIP9172 $1.00 (+0.75)(-0.19)$ $1.000$ 537329067477530368HIP9172 $1.00 (+0.75)(-0.19)$ $1.000$ 537329067477530368HIP20218 $2.50 (+0.91)(-0.44)$ $1.000$ $13235633035555440$ HIP79068 $1.00 (+1.00)(-0.59)$ $1.000$ $132356330355555440$ HIP72048 $1.00 (+1.07)(-0.77)$ $1.010$ $282410278028835584$ HIP7244 $1.64 (+1.07)(-0.77)$ $1.010$ $333106054183616000$ HIP10321 $0.70 (+1.35)(-0.24)$ $1.000$ $2869747927146084352$ HD2219450A $6.30 (+0.82)(-0.36)$ $1.000$ $2163433717746084352$ TYC2358-6756-1 $0.60 (+1.21)(-0.29)$ $1.000$ $216343317746084352$ HD213244 $1.20 (+1.44)(-0.64)$ $1.000$ $165343317746084352$ HIP01893 $0.80 (+1.36)(-0.24)$ $1.000$ $16534331207345174374$ $1.20 (+1.24)(-0.64)$ $1.000$ $1653433117746084352$ HIP01893 $0.90 (+1.26)(-0.26)$ $1.000$ $1653433117746084352$ TYC1678-109-1 $2.30 (+1.26)(-0.26)$ $1.000$ $165395848086325016$ HIP01893 $0.90 (+1.26)(-0.26)$ $1.000$ $16539573863523120$ HIP213244 $1.20 (+1.26)(-0.26)$ $1.000$ $1792706331305733808TYC1678-109-12.30 (+1.26)(-0.24)1.00017968255829009250$	0.960 (+0.016)(-0.009) 1.060 (+0.008)(-0.008) 1.030 (+0.017)(-0.010) 1.000 (+0.008)(-0.007) 1.000 (+0.009)(-0.007) 1.010 (+0.011)(-0.008) 1.010 (+0.013)(-0.007) 1.010 (+0.014)(-0.008) 1.020 (+0.014)(-0.008) 1.020 (+0.007)(-0.008) 1.040 (+0.009)(-0.015)	0.950 (+0.011)(-0.007) 0.970 (+0.009)(-0.008) 0.930 (+0.011)(-0.007) 0.920 (+0.020)(-0.007) 0.940 (+0.008)(-0.008) 0.990 (+0.016)(-0.007) 0.930 (+0.002)(-0.007) 0.921 (+0.002)(-0.007)	5.70 (+0.40)(-0.30) 0.80 (+0.60)(-0.60) 0.70 (+0.40)(-0.40) 2.90 (+0.70)(-0.90) 2.40 (+0.70)(-0.90) 0.60 (+0.40)(-0.30) 1.30 (+0.70)(-0.60) 1.30 (+0.60)(-0.60)	$\begin{array}{c} 0.940 \ (+0.008)(-0.010) \\ 1.060 \ (+0.010)(-0.010) \\ 1.025 \ (+0.010)(-0.010) \\ 0.968 \ (+0.018)(-0.013) \\ 0.995 \ (+0.010)(-0.008) \\ 1.078 \ (+0.008)(-0.010) \\ 1.008 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \end{array}$	$\begin{array}{c} 0.940 \ (+0.008) (-0.008) \\ 0.965 \ (+0.010) (-0.010) \\ 0.920 \ (+0.010) (-0.008) \\ 0.913 \ (+0.010) (-0.008) \\ 0.935 \ (+0.010) (-0.010) \\ 0.980 \ (+0.008) (-0.008) \\ 0.920 \ (+0.008) (-0.008) \\ 0.925 \ (+0.008) (-0.010) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) (-0.008) \\ 0.910 \ (+0.008) (-0.008) (-0.008) (-0.008) \\ $	
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	1.060 (+0.008)(-0.008) 1.030 (+0.017)(-0.010) 1.000 (+0.008)(-0.008) 1.000 (+0.009)(-0.007) 1.000 (+0.014)(-0.008) 1.010 (+0.011)(-0.008) 1.010 (+0.013)(-0.007) 1.010 (+0.014)(-0.008) 1.020 (+0.014)(-0.008) 1.040 (+0.009)(-0.015)	0.970 (+0.009)(-0.008) 0.930 (+0.011)(-0.007) 0.920 (+0.020)(-0.007) 0.940 (+0.008)(-0.008) 0.990 (+0.016)(-0.007) 0.930 (+0.012)(-0.007) 0.921 (+0.002)(-0.007)	0.80 (+0.60)(-0.60) 0.70 (+0.40)(-0.40) 2.90 (+0.70)(-0.90) 2.40 (+0.70)(-0.90) 0.60 (+0.40)(-0.30) 1.30 (+0.70)(-0.60) 1.280 (+0.60)(-0.60)	$\begin{array}{c} 1.060 \ (+0.010)(-0.010) \\ 1.025 \ (+0.010)(-0.010) \\ 0.968 \ (+0.018)(-0.013) \\ 0.995 \ (+0.010)(-0.008) \\ 1.078 \ (+0.008)(-0.010) \\ 1.008 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \end{array}$	$\begin{array}{c} 0.965 \ (+0.010) (-0.010) \\ 0.920 \ (+0.010) (-0.008) \\ 0.913 \ (+0.010) (-0.008) \\ 0.935 \ (+0.010) (-0.010) \\ 0.980 \ (+0.008) (-0.008) \\ 0.920 \ (+0.008) (-0.008) \\ 0.925 \ (+0.008) (-0.010) \\ 0.010 \ (-0.008) \\ 0.010 \ (-0.008) \\ 0.010 \ (-0.008) \\ 0.010 \ (-0.010) \ (-0.010) \ (-0.010) \\ 0.010 \ (-0.010) \ (-0.010) \\ 0.010$	
34576551891443968HIP9172 $1.00 (+0.75)(-0.19)$ $1.030$ $537329067477530368$ HIP9172 $1.00 (+1.08)(-0.63)$ $1.000$ $537329067477530368$ HIP20218 $2.50 (+0.91)(-0.44)$ $1.000$ $132356330835525440$ HIP79068 $1.00 (+1.00)(-0.59)$ $1.000$ $132356330835584$ HIP720218 $2.50 (+0.07)(-0.47)$ $1.000$ $132356330835584$ HIP72048 $1.00 (+1.07)(-0.47)$ $1.000$ $882410278028835584$ HIP7244 $1.64 (+1.07)(-0.47)$ $1.000$ $333106054183616000$ HIP7244 $1.64 (+1.07)(-0.47)$ $1.000$ $291701396922348672$ HIP7244 $1.64 (+1.07)(-0.27)$ $1.000$ $451128459484268544$ HID229450A $6.30 (+0.82)(-0.26)$ $1.000$ $451128459484268574$ HID221103 $2.80 (+0.70)(-0.27)$ $1.000$ $451128459484268574$ HID221103 $2.80 (+1.21)(-0.29)$ $1.000$ $451128459480863250176$ HID213244 $1.20 (+1.44)(-0.64)$ $1.000$ $1855968480863250176$ HID213244 $1.20 (+1.44)(-0.64)$ $1.000$ $1909471786118933120$ HD213244 $1.20 (+1.44)(-0.64)$ $1.000$ $1909471786118933120$ HD213244 $1.20 (+1.45)(-0.26)$ $1.000$ $1909471786118933120$ HD213244 $1.20 (+1.44)(-0.64)$ $1.000$ $1909471786118933120$ HD213244 $1.20 (+1.44)(-0.64)$ $1.000$ $1909471786118933120$ HD213244 $1.20 (+1.45)(-0.28)$ $1.000$ $1909471786118933120$ HD213244 $1.20 (+1.45)(-0.28)$ $1.000$ $192$	1.030 (+0.017)(-0.010) 1.000 (+0.008)(-0.008) 1.000 (+0.009)(-0.007) 1.080 (+0.014)(-0.008) 1.010 (+0.011)(-0.008) 1.010 (+0.013)(-0.007) 1.010 (+0.014)(-0.008) 1.020 (+0.014)(-0.008) 1.040 (+0.009)(-0.015)	0.930 (+0.011)(-0.007) 0.920 (+0.020)(-0.007) 0.940 (+0.008)(-0.008) 0.990 (+0.016)(-0.007) 0.930 (+0.012)(-0.007) 0.920 (+0.012)(-0.007) 0.910 (+0.009)(-0.007)	0.70 (+0.40)(-0.40) 2.90 (+0.70)(-0.90) 2.40 (+0.70)(-0.50) 0.60 (+0.40)(-0.50) 1.30 (+0.70)(-0.60) 1.80 (+0.60)(-0.60)	$\begin{array}{c} 1.025 \ (+0.010)(-0.010) \\ 0.968 \ (+0.018)(-0.013) \\ 0.995 \ (+0.010)(-0.008) \\ 1.078 \ (+0.008)(-0.010) \\ 1.008 \ (+0.010)(-0.010) \\ 0.988 \ (+0.010)(-0.010) \end{array}$	0.920 (+0.010)(-0.008) 0.913 (+0.010)(-0.008) 0.935 (+0.010)(-0.010) 0.980 (+0.008)(-0.008) 0.920 (+0.010)(-0.008) 0.925 (+0.008)(-0.010) 0.910 (+0.008)(-0.010)	,
637329067477530368HIP460762.10 (+1.08)(-0.63)1.0003203761005400205824HIP202182.56 (+0.91)(-0.44)1.00013235633083555440HIP790681.00 (+1.00)(-0.59)1.080882410278028835544HIP790681.00 (+1.07)(-0.47)1.010333106054183616000HIP72441.64 (+1.07)(-0.47)1.000291701396922348672HIP72441.64 (+1.07)(-0.47)1.000333106054183616000HIP72441.64 (+1.07)(-0.27)1.0104511284599484268544HID229450A6.30 (+0.82)(-0.36)1.020451128459484268544HID2211032.80 (+0.70)(-0.27)1.070269747927140286208HID2211032.80 (+1.21)(-0.29)1.00016534307273451743744HID2132441.20 (+1.44)(-0.64)1.0001855968480863250176HID2132441.20 (+1.44)(-0.64)1.0001909471786118933120HD2132441.20 (+1.44)(-0.64)1.0001909471786118933120HD2132441.20 (+1.44)(-0.64)1.0001792506331305783808TYC1678-109-12.30 (+1.25)(-0.37)1.0301909471786118933120HD2132441.20 (+1.44)(-0.64)1.000179270633130578385872344704HD2132441.20 (+1.44)(-0.64)1.000179285582900925056TYC1678-109-12.30 (+1.26)(-0.26)0.9901796825582900925056TYC2211-2123-13.90 (+0.27)(-0.33)1.0101957736635726467840TYC23208-1984-12.30 (+0.25)(-0.25)0.9070198993009567735616HD23559578.10 (+0.53)(-0.25)0.9070	1.000 (+0.008)(-0.008) 1.000 (+0.009)(-0.007) 1.080 (+0.014)(-0.008) 1.010 (+0.011)(-0.008) 1.010 (+0.013)(-0.007) 1.010 (+0.014)(-0.008) 1.020 (+0.014)(-0.008) 1.070 (+0.014)(-0.008) 1.040 (+0.009)(-0.015)	0.920 (+0.020)(-0.007) 0.940 (+0.008)(-0.008) 0.990 (+0.016)(-0.007) 0.930 (+0.009)(-0.007) 0.920 (+0.012)(-0.007) 0.910 (+0.009)(-0.007)	$\begin{array}{c} 2.90 \ (+0.70)(-0.90) \\ 2.40 \ (+0.70)(-0.50) \\ 0.60 \ (+0.40)(-0.30) \\ 1.30 \ (+0.70)(-0.60) \\ 1.80 \ (+0.60)(-0.60) \\ \end{array}$	0.968 (+0.018)(-0.013) 0.995 (+0.010)(-0.008) 1.078 (+0.008)(-0.010) 1.008 (+0.010)(-0.010) 0.988 (+0.010)(-0.010)	0.913 (+0.010)(-0.008) 0.935 (+0.010)(-0.010) 0.980 (+0.008)(-0.008) 0.920 (+0.010)(-0.008) 0.925 (+0.008)(-0.010) 0.910 (+0.008)(-0.010)	,
3203761005400205824HIP20218 $2.50 (+0.91)(-0.44)$ $1.000$ 1323563308352525440HIP79068 $1.00 (+1.00)(-0.59)$ $1.080$ 882410278028835584HIP79068 $1.00 (+1.07)(-0.47)$ $1.010$ 333106054183616000HIP7244 $1.64 (+1.07)(-0.47)$ $1.000$ 333106054183616000HIP7244 $1.64 (+1.07)(-0.47)$ $1.000$ 451128459484268544HID229450A $6.30 (+1.25)(-0.24)$ $1.010$ 451128459484268544HID221103 $2.80 (+0.70)(-0.27)$ $1.070$ 2669747927140286208HID221103 $2.80 (+1.21)(-0.29)$ $1.000$ 4533717746084352HID221103 $2.80 (+1.21)(-0.29)$ $1.000$ 4534307273451743744HID213244 $1.20 (+1.44)(-0.64)$ $1.000$ 1855968480863250176HID213244 $1.20 (+1.44)(-0.64)$ $1.000$ 1909471786118933120HD213244 $1.20 (+1.45)(-0.26)$ $1.000$ 1909471786118933120HD213244 $1.20 (+1.45)(-0.26)$ $1.000$ 1909471786118933120HD213244 $1.20 (+1.45)(-0.26)$ $1.000$ 1909471786118933120HD213244 $1.20 (+1.25)(-0.26)$ $1.000$ 1909471786118933120HD213244 $1.20 (+1.26)(-0.26)$ $1.000$ 1909471786118933120HD21	1.000 (+0.009)(-0.007) 1.080 (+0.014)(-0.008) 1.010 (+0.011)(-0.008) 1.010 (+0.013)(-0.007) 1.010 (+0.014)(-0.009) 1.020 (+0.014)(-0.008) 1.070 (+0.014)(-0.008) 1.040 (+0.009)(-0.015)	0.940 (+0.008)(-0.008) 0.990 (+0.016)(-0.007) 0.930 (+0.009)(-0.007) 0.920 (+0.012)(-0.007) 0.910 (+0.009)(-0.007)	2.40 (+0.70)(-0.50) 0.60 (+0.40)(-0.30) 1.30 (+0.70)(-0.60) 1.80 (+0.60)(-0.60)	0.995 (+0.010)(-0.008) 1.078 (+0.008)(-0.010) 1.008 (+0.010)(-0.010) 0.988 (+0.010)(-0.010)	0.935 (+0.010)(-0.010) 0.980 (+0.008)(-0.008) 0.920 (+0.010)(-0.008) 0.925 (+0.008)(-0.010) 0.925 (+0.008)(-0.010)	,
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291701396922348672HIP7244 $1.64 (+1.07) (-0.47)$ $1.000$ 333106054183616000HIP10321 $0.70 (+1.35) (-0.24)$ $1.010$ 451128459484268544HID229450A $6.30 (+0.82) (-0.36)$ $1.020$ 2869747927140286208HID221103 $2.80 (+0.70) (-0.27)$ $1.070$ 2163433717746084352TYC3588-6756-1 $0.60 (+1.21) (-0.29)$ $1.000$ 4534307273451743744HID101893 $0.80 (+1.21) (-0.29)$ $1.000$ 1855968480863250176HID101893 $0.80 (+1.36) (-0.70)$ $1.000$ 1909471786118933120HID213244 $1.20 (+1.44) (-0.64)$ $1.000$ 1909471786118933120HD213244 $1.20 (+1.44) (-0.64)$ $1.000$ 1909471786118933120HD213244 $1.20 (+1.44) (-0.64)$ $1.000$ 1909471786118933120HD213244 $1.20 (+1.44) (-0.64)$ $1.000$ 1792706331305783808TYC1678-109-1 $2.30 (+1.50) (-0.37)$ $1.030$ 1792706331305783808TYC1678-109-1 $2.30 (+1.26) (-0.26)$ $0.990$ 1792855736467840TYC2211-2123-1 $3.90 (+0.87) (-0.39)$ $1.010$ 1957736635726467840TYC2308-1984+1 $2.30 (+0.92) (-0.53)$ $1.010$ 1989930095677359616HD2355957 $8.10 (+0.53) (-0.25)$ $0.970$	1.000 (+0.013)(-0.007) 1.010 (+0.014)(-0.009) 1.020 (+0.007)(-0.008) 1.070 (+0.014)(-0.008) 1.040 (+0.009)(-0.015)	0.920 (+0.012)(-0.007) 0.910 (+0.009)(-0.007)	1.80 (+0.60)(-0.60)	0.988 (+0.010)(-0.010)	0.925 (+0.008)(-0.010) 0 910 (+0 008)(-0 010)	<del></del> .
333106054183616000         HIP10321         0.70 (+1.35)(-0.24)         1.010           451128459484268544         HD229450A         6.30 (+0.82)(-0.36)         1.020           2869747927140286208         HD2221103         2.80 (+0.70)(-0.27)         1.070           2163433717746084352         TYC3588-6756-1         0.60 (+1.21)(-0.29)         1.040           4534307273451743744         HD221103         2.80 (+1.21)(-0.29)         1.000           4534307273451743744         HD342979         1.30 (+1.49)(-0.70)         1.000           1855968480863250176         HIP101893         0.80 (+1.36)(-0.24)         1.000           1909471786118933120         HD213244         1.20 (+1.44)(-0.64)         1.000           1792706331305783808         TYC1678-109-1         2.20 (+0.67)(-0.37)         1.030           1792706331305783808         TYC1678-109-1         2.30 (+1.50)(-0.86)         1.010           179270633130042007448704         HD2355929         0.90 (+1.13)(-0.31)         1.030           19625578858203250566         TYC23210-873-1         1.30 (+1.13)(-0.25)         0.300           1957736635726467840         TYC23208-1984-1         2.30 (+0.25)(-0.25)         1.010           19557736616         HD235557         8.10 (+0.53)(-0.25)         0.010	1.010 (+0.014)(-0.009) 1.020 (+0.007)(-0.008) 1.070 (+0.014)(-0.008) 1.040 (+0.009)(-0.015)	0.910 (+0.009)(-0.007)			0 010 (+0 008)(-0 010)	,
$\begin{array}{llllllllllllllllllllllllllllllllllll$	1.020 (+0.007)(-0.008) 1.070 (+0.014)(-0.008) 1.040 (+0.009)(-0.015)		1.60 (+0.60)(-0.60)	0.995 (+0.010)(-0.010)	UNTRY VARIATION (VALUE)	1
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1.070 (+0.014)(-0.008) 1.040 (+0.009)(-0.015)	1.100 (+0.008)(-0.008)	6.70 (+0.50)(-0.50)	1.005 (+0.008)(-0.010)	1.085 (+0.013)(-0.010)	1
2163433717746084352       TYC3588-6756-1       0.60 (+1.21)(-0.29)       1.040         4534307273451743744       HID342979       1.30 (+1.49)(-0.70)       1.000         1855968480863250176       HID101893       0.80 (+1.36)(-0.24)       1.030         1909471786118933120       HD213244       1.20 (+1.44)(-0.64)       1.000         2196984318618671360       TYC4250-13644       1.20 (+1.44)(-0.64)       1.000         1792706331305783808       TYC1678-109-1       2.20 (+0.67)(-0.37)       1.030         1792706331305783808       TYC1678-109-1       2.30 (+1.50)(-0.86)       1.010         1962597885872344704       HD2355929       0.90 (+1.13)(-0.31)       1.030         19625597885872344704       HD2355929       0.90 (+1.26)(-0.26)       0.990         1796825582900925056       TYC2211-2123-1       3.90 (+0.877)(-0.39)       1.030         1957736635726467840       TYC3210-874-1       2.30 (+0.25)(-0.25)       0.990         1957736615       HD235557       8.10 (+0.53)(-0.25)       0.970	1.040 (+0.009)(-0.015)	1.050 (+0.008)(-0.008)	3.20 (+0.40)(-0.30)	1.060 (+0.008)(-0.010)	1.045 (+0.008)(-0.010)	1
$\begin{array}{llllllllllllllllllllllllllllllllllll$		0.940 (+0.010)(-0.007)	1.00 (+0.80)(-0.60)	1.023 (+0.010)(-0.013)	0.930 (+0.010)(-0.010)	1
I855968480863250176         HIP101893         0.80 (+1.36)(-0.24)         1.030           1909471786118933120         HD213244         1.20 (+1.44)(-0.64)         1.000           2196984318618671360         TYC4250-1364-1         2.20 (+0.67)(-0.37)         1.030           1792706331305783808         TYC1678-109-1         2.30 (+1.50)(-0.86)         1.010           1962597885872344704         TYC3210-873-1         1.30 (+1.3)(-0.31)         1.030           1962597885872344704         HD2355929         0.90 (+1.26)(-0.26)         0.990           1796825582900925056         TYC2211-2123-1         3.90 (+0.87)(-0.39)         1.030           1957736633726467840         TYC2310-12123-1         3.90 (+0.27)(-0.39)         1.030           1957736633726467840         TYC3210-2123-1         3.90 (+0.27)(-0.39)         1.010           1957736633726467840         TYC3210-310-2359         1.010         1930	1.000 (+0.011)(-0.008)	0.910 (+0.009)(-0.007)	1.30 (+0.50)(-0.60)	0.995 (+0.010)(-0.010)	0.903 (+0.008)(-0.008)	1
1909471786118933120         HD213244         1.20 (+1.44)(-0.64)         1.000           2196984318618671360         TYC4250-1364-1         2.20 (+0.67)(-0.37)         1.030           1792706331305783808         TYC1678-109-1         2.30 (+1.50)(-0.86)         1.010           1962597885872344704         TYC3210-873-1         1.30 (+1.13)(-0.31)         1.030           1962597885872344704         HD2355929         0.90 (+1.26)(-0.26)         0.990           1796825582900925056         TYC2211-2123-1         3.90 (+0.87)(-0.39)         1.030           1957736635726467840         TYC3210-814-1         2.30 (+0.92)(-0.53)         1.010           1957736635726467840         TYC3210-8257         8.10 (+0.53)(-0.53)         1.010	1.030 (+0.014)(-0.019)	0.930 (+0.009)(-0.007)	1.20 (+0.60)(-0.60)	1.013 (+0.010)(-0.010)	0.920 (+0.010)(-0.008)	1
2196984318618671360       TYC4250-1364-1       2.20 (+0.67)(-0.37)       1.030         1792706331305783808       TYC1678-109-1       2.30 (+1.50)(-0.86)       1.010         1962597885872344704       TYC3210-873-1       1.30 (+1.13)(-0.31)       1.030         1962597885872344704       TYC3210-873-1       1.30 (+1.13)(-0.31)       1.030         1795825582900925056       TYC2211-2123-1       3.90 (+1.26)(-0.26)       0.990         1796825582900925056       TYC2211-2123-1       3.90 (+0.87)(-0.39)       1.030         1957736635726467840       TYC3208-1984-1       2.30 (+0.92)(-0.53)       1.010         1989930095677359616       HD2355957       8.10 (+0.53)(-0.25)       0.970	1.000(+0.008)(-0.009)	0.900 (+0.010)(-0.007)	1.00 (+0.60)(-0.40)	0.988 (+0.008)(-0.010)	0.890 (+0.008)(-0.010)	1
1792706331305783808         TYC1678-109-1         2.30 (+1.50)(-0.86)         1.010           1962597885872344704         TYC3210-873-1         1.30 (+1.13)(-0.31)         1.030           2003130042007448704         HD235929         0.90 (+1.26)(-0.26)         0.990           1796825582900925056         TYC2211-2123-1         3.90 (+0.87)(-0.39)         1.030           1957736635726467840         TYC23108-1984-1         2.30 (+0.92)(-0.53)         1.010           1989930095677359616         HD2355957         8.10 (+0.53)(-0.25)         0.970	1.030 (+0.016)(-0.007)	0.970 (+0.014)(-0.010)	1.50 (+0.50)(-0.60)	1.030 (+0.010)(-0.008)	0.948 (+0.010)(-0.010)	1
1962597885872344704         TYC3210-873-1         1.30 (+1.13)(-0.31)         1.030           2003130042007448704         HD235929         0.90 (+1.26)(-0.26)         0.990           1796825582900925056         TYC2211-2123-1         3.90 (+0.87)(-0.39)         1.030           1957736635726467840         TYC3208-1984-1         2.30 (+0.92)(-0.53)         1.010           1989930095677356616         HD235597         8.10 (+0.53)(-0.25)         0.970	1.010 (+0.009)(-0.009)	0.950 (+0.016)(-0.009)	2.20 (+0.50)(-0.60)	1.003 (+0.010)(-0.010)	0.935 (+0.010)(-0.010)	-
2003130042007448704 HD235929 0.90 (+1.26)(-0.26) 0.990 (1796825582900925056 TYC2211-2123-1 3.90 (+0.87)(-0.39) 1.030 1957736635726467840 TYC3208-1984-1 2.30 (+0.92)(-0.53) 1.010 1989930095677359616 HD235957 8.10 (+0.53)(-0.25) 0.970	1.030 (+0.017)(-0.010)	0.940 (+0.009)(-0.007)	1.00 (+0.50)(-0.50)	1.033 (+0.010)(-0.010)	0.935 (+0.010)(-0.008)	1
1796825582900925056 TYC2211-2123-1 3.90 (+0.87)(-0.39) 1.030 1957736635726467840 TYC3208-1984-1 2.30 (+0.92)(-0.53) 1.010 1989930095677359616 HD235957 8.10 (+0.53)(-0.25) 0.970	0.990 (+0.016)(-0.012)	0.890 (+0.008)(-0.008)	0.70 (+0.80)(-0.50)	0.975 (+0.010)(-0.010)	0.873 (+0.010)(-0.008)	-
1957736635726467840 TYC3208-1984-1 2.30 (+0.53) 1.010 1989930095677359616 HD235957 8.10 (+0.53)(-0.25) 0.970	1.030 (+0.014)(-0.009)	1.010 (+0.009)(-0.007)	3.70 (+0.50)(-0.60)	1.025 (+0.008)(-0.010)	1.003 (+0.010)(-0.010)	1
1989930095677359616 HD235957 8.10 (+0.53)(-0.25) 0.970	1.010 (+0.009)(-0.009)	0.940 (+0.014)(-0.008)	1.60 (+0.40)(-0.60)	1.010 (+0.010)(-0.010)	0.923 (+0.008)(-0.010)	1
	0.970 (+0.014)(-0.009)	1.070 (+0.014)(-0.007)	8.00 (+0.50)(-0.40)	0.958 (+0.008)(-0.010)	1.053 (+0.010)(-0.008)	1
225038148667264384 HD22875 1.70 (+1.04)(-0.67) 1.010	1.010 (+0.008)(-0.008)	0.920 (+0.009)(-0.007)	1.60 (+0.70)(-0.60)	0.995 (+0.010)(-0.010)	0.913 (+0.010)(-0.008)	1
1807690750662760576 HD190340 3.70 (+0.75)(-0.36) 1.070	1.070 (+0.009)(-0.009)	1.080 (+0.014)(-0.008)	4.10 (+0.40)(-0.50)	1.053 (+0.010)(-0.010)	1.070 (+0.010)(-0.010)	$1\div$
2592050460064616832 HD9201 3.60 (+1.06)(-0.65) 1.020	1.020 (+0.014)(-0.009)	(000.0-)(800.0+) 066.0	3.10 (+0.60)(-0.40)	1.015 (+0.010)(-0.010)	0.978 (+0.008)(-0.010)	-
132371961511017856 HIP11253 6.90 (+0.81)(-0.40) 1.010	1.010 (+0.015)(-0.008)	1.130 (+0.018)(-0.014)	7.50 (+0.50)(-0.40)	1.000 (+0.010)(-0.008)	1.153 (+0.020)(-0.018)	1†
1605622057017876992 HIP71989 0.37 (+0.47)(-0.23) 1.050	1.050 (+0.014)(-0.007)	0.940 (+0.015)(-0.007)	0.30 (+0.40)(-0.30)	1.048 (+0.008)(-0.010)	0.943 (+0.008)(-0.008)	1†
2257140386478701568 HIP91210 1.30 (+0.96)(-0.42) 1.060	1.060 (+0.015)(-0.009)	0.980 (+0.008)(-0.007)	1.40 (+0.50)(-0.50)	1.053 (+0.010)(-0.008)	0.975 (+0.010)(-0.008)	1÷
3827020717791837056 HIP47312 3.90 (+1.01)(-0.34) 1.040	1.040 (+0.009)(-0.010)	1.050 (+0.014)(-0.007)	4.70 (+0.40)(-0.50)	1.023 (+0.008)(-0.010)	1.053 (+0.010)(-0.010)	1÷
855523714036230016 HIP52278 2.10 (+0.99)(-0.40) 0.990	0.990 (+0.007)(-0.008)	0.910 (+0.010)(-0.007)	3.40 (+0.50)(-0.50)	0.950 (+0.010)(-0.008)	0.903 (+0.010)(-0.010)	1÷
3574377616021489024 HD105590A 4.50 (+1.07)(-0.45) 1.000	1.000 (+0.009)(-0.009)	1.000 (+0.015)(-0.009)	5.40 (+0.30)(-0.60)	0.980 (+0.010)(-0.008)	0.995 (+0.010)(-0.008)	1†
1610658885425227264 HIP71440 7.40 (+1.09)(-0.53) 1.000	1.000 (+0.010)(-0.009)	1.150 (+0.020)(-0.031)	8.20 (+0.70)(-0.60)	0.978 (+0.010)(-0.013)	1.138 (+0.033)(-0.028)	1†

ID	S <sub>HK,TS23</sub>	$\sigma(S_{\rm HK,TS23})$	S <sub>MW</sub>	$\sigma(S_{\rm MW})$	Reference
HIP7585	0.128	0.003	0.177	0.004	(★)
HIP49756	0.118	0.002	0.163	0.002	(★)
HIP79672	0.125	0.001	0.167	0.004	(★)
HIP95962	0.113	0.001	0.163	0.002	(★)
HIP8507	0.129	0.005	0.174	0.005	(★)
HIP77052	0.143	0.000	0.214	0.015	(★)
HIP28066	0.117	0.001	0.158	0.001	(★)
HIP85042	0.112	0.001	0.158	0.004	(★)
HIP118115	0.111	0.001	0.157	0.001	(★)
HIP102040	0.129	0.000	0.176	0.005	(★)
HIP113357	0.109	0.004	0.154	0.001	(†)
HIP8102	0.127	0.001	0.171	0.001	(†)
HIP1499	0.113	0.002	0.157	0.002	(†)
HIP59532	0.109	0.005	0.158	0.002	(†)
HIP106006	0.114	0.001	0.158	0.003	(†)

**Table A3.** Solar twin stars used to calibrated our  $S_{\text{HK,TS23}}$  indices into the Mount Wilson system (MW).

Notes. (\*) Lorenzo-Oliveira et al. (2018); (†) this work.

 Table A4. Spectroscopic binary stars.

Identifier
HIP 54191
TYC 4202-561-1
HD 224033
TYC 1762-1034-1

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