RESOLUTION B2
on recommended zero points for the absolute and apparent bolometric magnitude scales

Proposed by IAU Inter-Division A-G Working Group on Nominal Units for Stellar &

Planetary Astronomy

August 13, 2015

The XXIXth International Astronomical Union General Assembly,

Noting

1. the absence of an exact definition of the zero point for the *absolute and apparent bolometric magnitude* scales, which has resulted in the proliferation of different zero points for bolometric magnitudes and bolometric corrections in the literature (ranging at approximately the tenth of a magnitude level; see e.g., Bessell, Castelli, & Plez 1998; Torres 2010),

2. that IAU Commissions 25 and 36 approved identical draft resolutions for defining the zero point for the bolometric magnitude scale (Andersen 1999), but that the resolution never subsequently reached the stage of approval by the IAU General Assembly, and was only sporadically adopted within the astronomical community,

3. that recent total solar irradiance measurements have led to a revised solar luminosity that differs slightly from the value used to set the zero point of the absolute bolometric magnitude scale in the Commission 25 and 36 draft resolutions,

Considering

1. the need for a standardized absolute and apparent bolometric magnitude scale for accurately and repeatably transforming photometric measurements into radiative luminosities and irradiances, independently of the variable Sun,

2. that multiple zero points for bolometric corrections pervade the literature due to the lack of a commonly adopted standard zero point for the bolometric magnitude scale,

Recommends

1. to define the zero point of the *absolute bolometric magnitude* scale by specifying that a radiation source with absolute bolometric magnitude[1] $M_{\mathrm{Bol}} = 0$ mag has a radiative luminosity of exactly

$$L_\circ = 3.0128 \times 10^{28} \, \mathrm{W} \,. \qquad (1)$$

and the absolute bolometric magnitude M_{Bol} for a source of luminosity L (in W) is

$$M_{\mathrm{Bol}} = -2.5 \log (L/L_\circ) = -2.5 \log L + 71.197\,425 \ldots \qquad (2)$$

The zero point was selected so that the *nominal solar luminosity*[2] ($\mathcal{L}_\odot^{\mathrm{N}} = 3.828 \times 10^{26}$ W) corresponds closely to absolute bolometric magnitude $M_{\mathrm{Bol}\odot} = 4.74$ mag, the value most commonly adopted in the recent literature (e.g., Bessell, Castelli, & Plez 1998; Cox 2000; Torres 2010).

2. to define the zero point of the *apparent bolometric magnitude* scale by specifying that $m_{\mathrm{Bol}} = 0$ mag corresponds to an *irradiance* or *heat flux density*[3] of

$$f_\circ = 2.518\,021\,002 \ldots \times 10^{-8} \, \mathrm{W\,m^{-2}} \qquad (3)$$

and hence the apparent bolometric magnitude m_{Bol} for an irradiance f (in $\mathrm{W\,m^{-2}}$) is

$$m_{\mathrm{Bol}} = -2.5 \log\left(f/f_{\circ}\right) = -2.5 \log f - 18.997\,351\ldots \qquad (4)$$

The irradiance $f_{\circ}$ corresponds to that measured from an isotropically emitting radiation source with absolute bolometric magnitude $M_{\mathrm{Bol}} = 0\,\mathrm{mag}$ (luminosity $L_{\circ}$) at the standard distance[4] of 10 parsecs (based on the IAU 2012 definition of the astronomical unit).

The adopted value of $f_{\circ}$ agrees with some in common use (e.g., Lang 1974, Cox 2000) at the level of $< 0.1\%$. Using this zero point, the *nominal total solar irradiance* $S_{\odot}^{\mathrm{N}}$ ($1361\,\mathrm{W\,m^{-2}}$) corresponds to a solar apparent bolometric magnitude of $m_{\mathrm{Bol}\odot} \simeq -26.832\,\mathrm{mag}$.

References

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Notes

[1] The notation of M_{bol} referring to *absolute bolometric magnitude* and m_{bol} referring to *apparent bolometric magnitude* was adopted by Commission 3 (Notations) at the VIth IAU General Assembly in Stockholm in 1938: https://www.iau.org/static/resolutions/IAU1938_French.pdf. M_{Bol} and m_{Bol} refer specifically to bolometric magnitudes defined using the zero points of this resolution.

[2] Modern spaceborne total solar irradiance (TSI) instruments are absolutely calibrated at the 0.03% level (Kopp 2014). The TIM/SORCE experiment established a lower TSI value than previously reported based on the fully characterized TIM instrument (Kopp et al. 2005, Kopp & Lean 2011). This revised TSI scale was later confirmed by PREMOS/PICARD, the first spaceborne TSI radiometer that was irradiance-calibrated in vacuum at the TSI Radiometer Facility (TRF) with SI-traceability prior to launch (Schmutz et al. 2013). The DIARAD/PREMOS (Meftah et al. 2015), ACRIM3/ACRIMSat (Willson 2014), VIRGO/SoHO, and TCTE/STP-Sat3 (http://lasp.colorado.edu/home/tcte/) flight instruments are now consistent with this new TSI scale within instrument uncertainties, with the DIARAD, ACRIM3, and VIRGO having made post-launch corrections and the TCTE having been validated on the TRF prior to its 2013 launch. The cycle 23 observations with these experiments are consistent with a TSI value (rounded to an appropriate number of significant digits) and uncertainty of: $S_\odot = 1361\,(\pm 1)\,\mathrm{W\,m^{-2}}$ (2σ uncertainty). The uncertainty range includes contributions from the absolute accuracies of the latest TSI instruments as well as uncertainties in assessing a secular trend in TSI over solar cycle 23 using older measurements. Combining this total solar irradiance value with the IAU 2012 definition of the astronomical unit leads to a current best estimate of the mean solar luminosity of $L_\odot = 4\pi\,(1\,\mathrm{au})^2\,S_\odot = 3.8275\,(\pm 0.0014) \times 10^{26}\,\mathrm{W}$. Based on this, a *nominal solar luminosity* of $\mathcal{L}^{\mathrm{N}}_\odot = 3.828 \times 10^{26}\,\mathrm{W}$ is adopted. Using the proposed zero point $L_\circ$, the nominal solar luminosity $\mathcal{L}^{\mathrm{N}}_\odot$ corresponds to bolometric magnitude $M_{\mathrm{Bol}\odot} \simeq 4.739\,996\ldots$ mag — i.e., sufficiently close to 4.74 mag for any foreseeable practical purpose.

[3] The terms *irradiance* and *heat flux density* are used interchangeably, both with SI units of $\mathrm{W\,m^{-2}}$ (Wilkins 1989, Bureau International des Poids et Mesures 2006). See also https://www.iau.org/publications/proceedings_rules/units/.

[4] The parsec is defined as exactly $(648\,000/\pi)$ au (e.g. Cox 2000, Binney & Tremaine 2008). Using the IAU 2012 Resolution B2 definition of the astronomical unit, the parsec corresponds to $3.085\,677\,581\ldots \times 10^{16}\,\mathrm{m}$. As the absolute bolometric magnitude zero point and astronomical unit are defined exactly, further digits for the apparent bolometric magnitude zero point irradiance $f_\circ$ may be calculated if needed.