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Corrections and clarifications for FITS WCS papers I & II

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Abstract. One significant correction and several minor corrections and clarifications for the FITS World Coordinate System (WCS) papers have come to light since they were published in December 2002.

1. Corrections for Paper I

Corrections for Paper I (Greisen & Calabretta 2002):

1. The *s* subscript on the keywords in Fig. 1 should be *a*.
2. Table 2 gives the binary table form of the `PV`*i*`_`*ma* keywords as *i*`V`*n*`_`*ma*, and the pixel list form as `TV`*n*`_`*ma*.
   However, the forms *i*`PV`*n*`_`*ma* and `TPV`*n*`_`*ma* are also permitted if the number of characters occupied by *i*, *n*, *m*, and *a* do not cause the keyword name to exceed the eight character limit. This also applies for *i*`PS`*n*`_`*ma* and `TPS`*n*`_`*ma*.
   This is consistent with the usage in Tables 9 and 10 of Paper II which give `2PV5_1`, `2PV5_1A`, and `TPV3_1` as examples.

2. Corrections and clarifications for Paper II

Corrections and clarifications for Paper II (Calabretta & Greisen 2002):

1. In Sect. 2.2, the default value of `LONPOLE`*a* must be modified with the addition of ϕ_0:
   - For $\delta_0 \geq \theta_0$, the default for `LONPOLE`*a* is ϕ_0.
   - For $\delta_0 < \theta_0$, the default for `LONPOLE`*a* is $\phi_0 + 180°$.

   Normally ϕ_0 is zero unless a non-zero value has been set for it in the `PV`*i*`_1`*a* card associated with the *longitude* axis. This default applies for all values of θ_0, including $\theta_0 = 90°$, although use of non-zero values of ϕ_0 are discouraged in that case.
2. In Sect. 2.2, for $\delta_0 = \theta_0$ it would have been better if `LONPOLE`*a* had defaulted to $\phi_0 + 180°$ rather than ϕ_0.
   For $\delta_0 = \theta_0 \neq \pm 90°$ the two values for ϕ_p (i.e. $\phi_0 + 180°$ and ϕ_0) have identical effects; the spherical coordinate transformation becomes a simple change in origin of longitude such that the celestial meridian through α_0 coincides with the native meridian through ϕ_0.
   However, in the particular case where $\delta_0 = \theta_0 = \pm 90°$, this condition only applies when `LONPOLE`*a* is equal to $\phi_0 + 180°$. For the standard default, ϕ_0, the celestial meridian through α_0 coincides with the native meridian through $\phi_0 + 180°$. This is an undesirable exception to what would otherwise be a useful general rule.
   Thus, when $\delta_0 = \theta_0 = \pm 90°$, it may be desirable to set `LONPOLE`*a* explicitly to $\phi_0 + 180°$ rather than let it default to ϕ_0. Such a change in ϕ_p by 180° must be compensated by incrementing α_0 (= α_p) by 180°.
3. In Sect. 2.3, it should be clarified that (ϕ_p, θ_p) and (α_p, δ_p) refer to *different* points; the common "p" subscript simply indicates that they refer to the "pole", but not the same pole. (ϕ_p, θ_p) are the native coordinates of the *celestial pole*, and (α_p, δ_p) are the celestial coordinates of the *native pole*, and generally the native and celestial poles do not coincide.
   On the other hand, (ϕ_0, θ_0) and (α_0, δ_0) do refer to the same, *fiducial*, point, usually the reference point of the projection.
4. In Sect. 2.4, it is stated incorrectly that Eqs. (8), (9), and (10) are derived from Eqs. (6) and (7).
   - Eq. (8) is derived from the second of Eqs. (2).
   - Eq. (9) is derived from the second of Eqs. (6) (or the second of Eqs. (7) which is identical).
   - Eq. (10) is derived from the second of Eqs. (5).
5. In Sect. 2.4, in computing α_p for non-polar (ϕ_0, θ_0), it should be clarified that if $\delta_0 = \pm 90°$ then $\alpha_p = \alpha_0$ regardless of the value of δ_p.
   That is, if $\delta_0 = \pm 90°$ *and* $\delta_p = \pm 90°$, then condition (1) applies, not (2).
6. In Sect. 2.4, in condition (6), if $\delta_0 = \theta_0 = 0$ and $\phi_p - \phi_0 = \pm 90°$, then δ_p is not determined and `LATPOLE`*a* specifies it completely.
   It is stated that "`LATPOLE`*a* has no default value in this case." This should be interpreted to mean that `LATPOLE`*a* may legitimately take any value in the range $[-90°, +90°]$ and WCS header writers are obliged to specify it.
   However, values of `LATPOLE`*a* outside this range should be interpreted as usual, i.e. values of `LATPOLE`*a* greater than $+90°$ denote $\delta_p = +90°$, and values of `LATPOLE`*a* less than $-90°$ denote $\delta_p = -90°$.

7. In Sect. 3, the term "IAU 1984" used in Table 2, and also later in Sects. 7.3.1, and 7.3.2, and Tables 5, 7, 9, and 10, is not strictly correct as there was no corresponding resolution of the IAU General Assembly in that year. It refers to the IAU 1976 resolution, with the 1980 nutation theory, which came into force in 1984.0.
8. In Sect. 3.1, a variant of the `RADESYS`a keyword, `RADECSYS`, appeared in early drafts of Paper II and was used in some data. It should be recognized as being equivalent to `RADESYS` for the primary coordinate description.
9. In Sect. 5.6.3, for the QSC projection, the equation for S following Eq. (178) should have $S = +1$ for $\eta = |\xi|$, hence

   $$S = \begin{cases} +1 & \text{if } \xi > |\eta| \text{ or } \eta \geq |\xi| \\ -1 & \text{otherwise} \end{cases} .$$

   In computing the inverse, the equation for ξ should be

   $$\xi = \pm\sqrt{\frac{1-\zeta^2}{1+\omega^2}}, \tag{182}$$

   where the positive or negative solution is chosen so that ξ has the same sign as $x - \phi_c$. Likewise, the equation for η should be

   $$\eta = \pm\sqrt{\frac{1-\zeta^2}{1+\omega^2}}, \tag{184}$$

   where the positive or negative solution is chosen so that η has the same sign as $y - \theta_c$.

3. Timestamps

The original version of this document was dated 2004/01/23.
Erratum 1.2 was added on 2004/04/27.
Erratum 2.7 was added on 2004/08/12.
Erratum 2.8 was added on 2004/06/08.
Erratum 2.9 was added on 2004/06/01.

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References

Calabretta, M. R., & Greisen, E. W. 2002, A&A, 395, 1077 (Paper II)
Greisen, E. W., & Calabretta, M. R. 2002, A&A, 395, 1059 (Paper I)