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Velocity Aberration Correction for Parallel Observations

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ABSTRACT

The velocity aberration correction performed by the HST pointing control software is valid for the target direction only. For other positions in the field of view the correction differs and varies throughout the orbit. For directions within 500 arcsec of the target the variation of the correction difference does not exceed 24 milli-arcsec.

1. The question

A question was asked recently concerning variation of the aberration correction for parallel observations. As HST orbits about the earth, the barycentric velocity and hence the velocity aberration correction varies. The correction can be as large as 26 arcsec. Since the on-board software continuously adjusts for the velocity change, there is no impact on a primary observation. Within the limits of the Fine Guidance System, the target is held stationary on the detector. This can only work strictly for one point. There are instantaneous differential aberration effects which are negligible across a single aperture but possibly of concern when observing with two science instruments in parallel. The question is, does the apparent fluctuation in the uncorrected aperture become large enough to degrade the image?

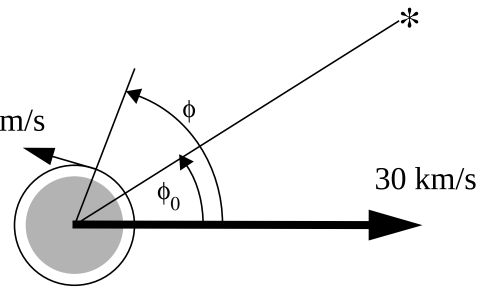
2. Discussion

The most extreme case for a single instrument would be for a target centered at the middle of the WFPC2 when the HST points in the direction of the earth's motion. Then the corners of the PC chips would have an aberration displacement of 0.1 pixels, or 0.01 arcsec. This may be more of a concern for the ACS where the displacement reaches 0.3 pixels in the corners, It is interesting to note that the differential effect is largest when the absolute effect is smallest.

If a primary target is tracked in a STIS aperture and a second target simultaneously placed in a NICMOS aperture, about 500 arcsec away, then the differential correction can be slightly over 0.06 arcsec. This is larger than a NICMOS camera 1 pixel or any of the STIS pixels. The remaining question is, does this relative shift change during an exposure and how does it depend on the pointing?

3. Analysis

A simple IDL program was written to investigate the effect of the HST orbital velocity on the aberration correction. The geometry was slightly idealized by considering the HST orbit to lie in a plane containing the earth's velocity vector. The geometry used is illustrated. The net velocity is composed of the earth's 30 km/s orbital velocity, considered constant, plus the approximately 7 km/s HST orbital velocity rotating continuously in the plane. If the unit vector in the barycentric direction of the star is $\hat{\mathbf{u}}$ and the instantaneous HST velocity is β in units of the velocity of light then the unit vector $\hat{\mathbf{v}}$, representing the star direction in the HST frame is given by



$$\hat{\boldsymbol{v}} = \frac{1}{1 + \hat{\boldsymbol{u}} \cdot \beta} \cdot \left[\frac{\hat{\boldsymbol{u}}}{\gamma} + \beta \cdot \left(1 + \left(1 - \frac{1}{\gamma}\right) \cdot \frac{\hat{\boldsymbol{u}} \cdot \beta}{\beta^2}\right)\right] \text{ in which } \gamma = \frac{1}{\sqrt{1 - \beta^2}}$$

The correction was calculated as a function of the orbital phase ϕ for an aperture pointing towards a star in the orbital plane at angle ϕ_0 to the earth's velocity. The correction was also found for the a direction $\phi_0+\delta$ where δ was chosen as 500 arcsec, or 0.14 degrees. This is approximately the separation between the STIS and NIC apertures. No analytic function was developed for the general case, rather the values were plotted and the form of the solution derived from the plots.

4. Conclusions

The correction for each aperture varies as sin $(\phi-\phi_0)$ with a peak-to-peak range of 9.6 arcsec the central value depending on ϕ_0. The important variable is the difference between the corrections for the two apertures and the variation in this difference. The somewhat surprising result is that even though each correction depends on ϕ_0, as does the average difference, the variation in the difference behaves like $\sin(\phi-\phi_0)$ with a peak-to-peak amplitude of about 23.3 milli-arcsec regardless of the star's direction, i.e., the amplitude depends very weakly on ϕ_0. The amplitude varies by less than 0.1milli-arcsec over the whole range. For targets out of the orbital plane, the behavior is similar except the amplitude is smaller, declining approximately as the cosine of the angle between the target direction and the orbital plane. For pointings near the poles, although the absolute corrections are at their largest, the relative displacement between apertures becomes less than 1 milli-arcsecond.

ϕ_o	**Minimum Correction**	**Maximum Correction**	**Range**	**Minimum Difference**	**Maximum Difference**	**Range**
		arcseconds			**milli-arcseconds**	
0	-4.81	4.81	9.63	-61.6	-38.3	23.3
30	-15.12	-5.50	9.63	-54.9	-31.6	23.3
60	-22.67	-13.05	9.63	-36.6	-13.3	23.3
90	-25.44	-15.81	9.63	-11.6	11.7	23.3