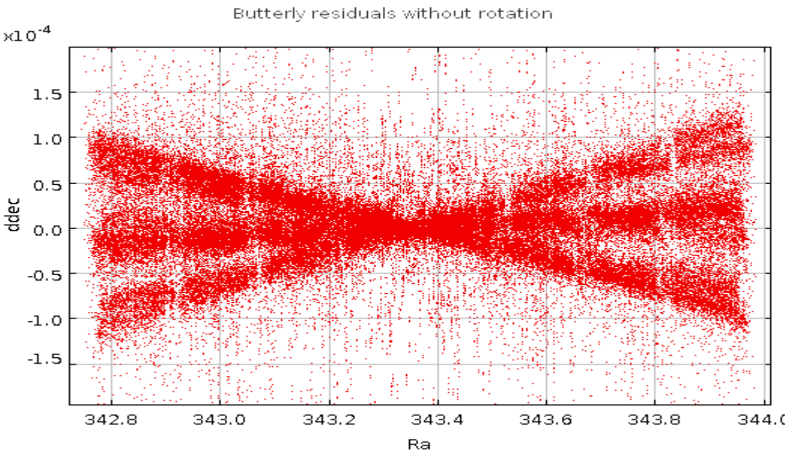
Global Astrometry and OmegaCAM/VST

Introduction

We have recently found a misconfiguration between the astrometric parametrization of the physical characteristics of the VST and OmegaCAM setup in terms of the algorithmic concepts used in the current astrometric solution code. This became clear after inspecting the residual positional errors after applying the standard astrometric pipeline. The residual plots showed systematic structure that could be related to the rotation of the full CCD array, the image rotator.

Analysis

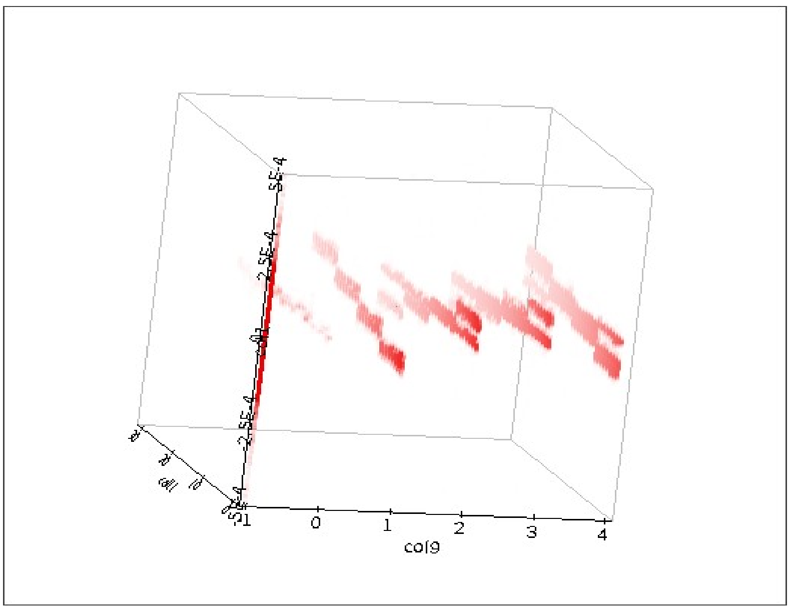
During normal operation we plotted the full residual catalog as a function of several distinctive parameters. One such plot is given below.



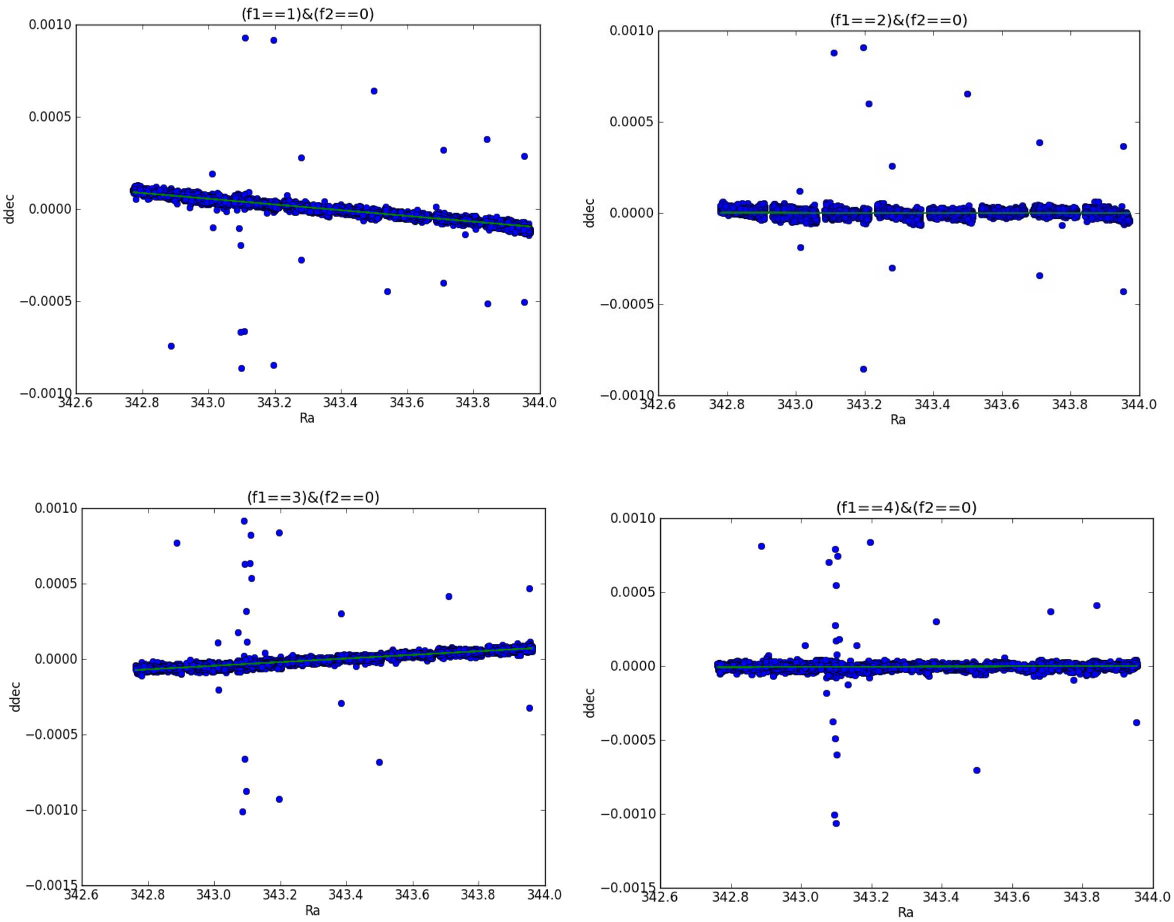
This plot shows all object residuals (difference between reference object position and calculated associated extracted object position and difference between overlap pairs calculated object positions). In particular the residuals between overlap pairs show a tight spiky distribution, which we can attribute to random rotation angles for individual pointings in a dither.

Inspecting the cause of the spiky structure we investigated the parameter space of the residual catalog. The following plot is a good representation of the separation of the individual spikes onto particular parameters, notably the chip sequence number (col11) and the pointing sequence number (col9) in the dither. For the second pointing (col9 = 1) we see steps in the position residuals that are clearly related to the layout of the chips on the focal plane, 8 chips in a row. This effect is also visible in the other pointings, but there the astrometric algorithm is clearly trying to enforce the residuals onto a straight line, sometimes splitting the residuals space into two distinct groups.

These two plots suggest that there is a rotation of the focal plane that is not well matched by the astrometric solution algorithm. In fact this is true if one looks at the intrinsic assumptions that are the input conditions for the algorithm. It was originally conceived for an equatorial telescope mount where the individual pointings were obtained by rotating the telescope about the equatorial axes. The camera/focal plane on such telescopes is fixed to the optical/telescope structure. In principle the only random errors created from pointing to pointing is the pointing in Ra and Dec itself.



Within a dither such an assembly will only allow the optical path to vary smoothly from pointing to pointing as the telescope/camera structure flexes and deforms while compensating for earth rotation. These particular facts are incorporated in the astrometric parametrization in the following way. Each individual CCD chip in the camera may have a polynomial deformation while mapping the extracted object pixel positions to sky coordinates. The parameters for this polynomial deformation of a single CCD chip are then allowed to vary between individual pointings in a polynomial fashion. On zero order they are kept constant between pointings, on first order they will vary linearly from the first to the last pointing, and so on. The main reasons for this are that when allowing full independent derivation of the polynomial deformation parameters for one and the same CCD chip between pointings one increases the total number of independent parameters in the model dramatically and does not take into account the constrained that the polynomial deformation of one CCD chip will not vary randomly between pointings in a dither. The more known constraints are allowed to enter the equation the better the solution mechanism is in handling extraneous data errors. The sky offset of the telescope is calculated independently for each individual pointing to allow fitting the random pointing errors. All other astrometric parameters are allowed only to vary smoothly with pointing.



The figures show the residuals of the overlap objects in calculated coordinates after the standard astrometric solution has been applied. The four plots show the residuals of the first pointing agains all other pointing in a dither. The slope in these plots represent the not well fitted random rotation differences of the focal plate between pointings. The small structure in the (f1==2)&(f2==0) plot correspond to the 8 CCD chip columns of the camera, where the per CCD column slope is an effect of the misfitting of the random focal plate rotation back into the single chip deformation parametrization.

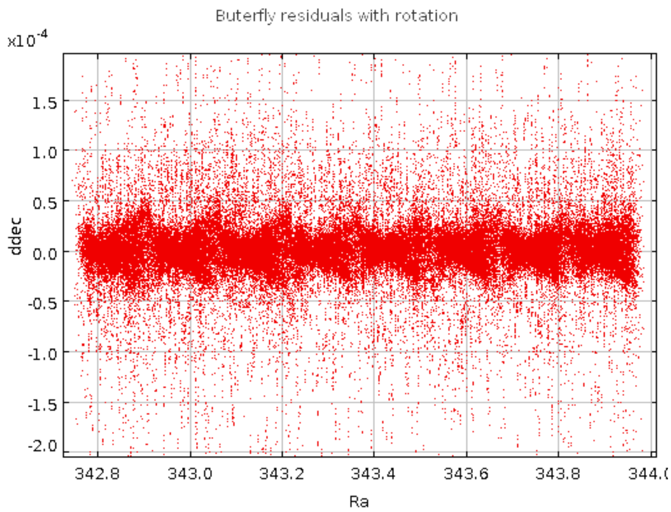
With the VST we have an ALT-AZ mounting. This introduces, next to the random (Ra,Dec)-pointing an additional random error: the rotation of the focal plane plate assembly. For each pointing the rotation of the plate is done by repositioning the plate assembly, while during exposure it is smoothly rotated to compensate for earth motion, just as the pointing is done by positioning the telescope in ALT-AZ and slewing taking place during exposure. Now, as explained above, the random pointing is represented in the astrometric algorithm, but random rotations of the full CCD plate assembly are not. So whenever the astrometric code is used on an ALT-AZ telescope it will try to smooth out the random plate rotations instead of solving them. This does have effect on the solution of all parameters in the model making the final global astrometric solution, depending on the scale of the random errors in the plate rotation, not much better than deriving single CCD astrometry.

Solution

Obviously one needs to incorporate the random rotation in the algorithm for the astrometric solution. This is what we have recently programmed: a simultaneous solution of the individual CCD parametrization, the random plate rotation and the random pointing. This is purely a programming effort and will involve a thorough testing sequence in order assure the correctness and robustness of the new algorithm and code.

As an intermediate test, one can apply previously derived focal plate rotations into the solution parameters of the astrometric code. This is an intermediate form of the astrometric solution code where the original code is extended by a parametrization of the focal plate rotation, but where the derivation of the CCD chip parameters is done with fixed values for the plate rotation. As a final test both the individual CCD chip parameters and the plate rotation parameters (rotation and origin of rotation) will be determined simultaneously in order to exchange residual information among all astrometric parameters to come to the final complete solution.

The results of the intermediate step where fixed, previously determined rotation parameters are implemented in the new astrometric code do show a significant increase in accuracy of the solution. The sawtooth like structure is due to the fact that plate rotation and CCD chip parametrization are not determined simultaneously.



Conclusion

We have shown that the current astrometric parametrization as used in the Astro-WISE pipeline is not a fully correct representation of the physical characteristics of the OmegaCAM/VST setup. We have identified the source of this misrepresentation and have developed a corrected code to handle this in an optimal way. It is in the final stages of debugging and should begin testing in the near term.