Hi Chat-

On Mon, Mar 9, 2015 at 9:40 AM, Chat Hull <chat.hull@cfa.harvard.edu> wrote:

> Hi, George--
>
> This is excellent! Thanks so much. And I didn't mean to knock your
> slides -- I just needed words to go along with them.
>
>
Understood.

After reading through your explanation several times, I'm definitely closer
> to achieving conceptual understanding. It's still quite complicated -- and
> I think is even more complicated by the fact that I never had a 100% solid
> grasp on the crossed-circular case at CARMA.
>
>
("crossed-circular"?....)

I am working on some better pictures of what is going on in the XYf+QU step. Probably too detailed for the casaguide; more likely a comprehensive memo on all of this that has been on my todo list for awhile...

For the casual user, I think this step is just going to be a 'black box'. I exposed the insides of the box here because I am interested in this sort of discussion. For the case of a polarized calibrator, this really is the central step---it brings the cross-hands into a sensible phase frame (consistent with the p-hands) for the rest of the process, and establishes the source polarization model. Among the user-facing simplifications I will be adding in the coming months will be to absorb the ambiguity resolution operation so that the user doesn't have to maintain python variable for it and run a separate function.

To answer your question:
>
> When you talk of the XY phase refant in the context of CARMA, I think you
>> are referring to use of a calibraiton signal introduced on that antenna by
>> which an XY phase is calculated by looking at that antennas cross-hand
>> auto-correlation? Presumably, then the gain (or bandpass?) phase solution
>> is forced to exhibit that offset for that antenna, one way or another.
>
>
> That's exactly right: we inserted wire grids (PA known to within 1Â°) into
> the beams of the 10m antennas, and then calculated the XYphase passband on
> all 10m ants using the cross-hand autocorrelation spectra (a.k.a.
> cross-auto spectra XY, where X and Y are both from the same antenna). We
> were then *required* to use one of the 10m antennas as the passband refant,
> because that XYphase passband correction was only made to the 10m
> antennas.
>

An important point to make here is that, taken together, the ordinary bandpass phase spectra (solved from p-hands only) _and_ the per-antenna cross-hand phase spectra _over-determine_ the set of phase spectra needed to calibrate the data. The ordinary bandpass phase calibration implicitly accounts for all cross-hand phase relationships _except_one_, the refant's. And then you use the wire grid result to estimate that one correctly, and the correction requires rotating the phase of all antennas' Y w.r.t. X phase.

> And as I mentioned before, the absolute PA results could vary
> significantly when we used different refants because none of the errors
> intrinsic to that single telescope were averaged out the way they are with
> ALMA.
>
>
This has little, if anything, to do with the XY-phase calibration. It is because you use a refant in the D-term solve (unpolarized calibrator), which means all of the D's are referred to a single feed on the refant, which is assigned an impurity of zero. But that antenna actually has some impurity, including a non-zero real part which is its specific orientation. This will likely be different for different antennas, so your net PA calibration will depend on which antenna you use as refant in the D-term solve. Note that this need not be the same refant as the gain and bandpass calibration. A referenced D solution like this will satisfy the cross-hand terms linear in D and Stokes I, which is the dominant part of the effect.

When the D-term calibrator is sufficiently linearly polarized, and a reasonable estimate of its polarization available (e.g., via XYf+QU), the terms proportional to the Ds and Q and U in the cross-hands break the degeneracy implicit in the (D*I) terms, and no referencing to a single antenna
is necessary. I.e., we are getting "absolute" D-terms. "Absolute" here really just means "not referred to the (unknown) polarization of one hand on one antenna." In a broader sense, they are only "absolute" insofar as the Q,U,V assumed for the calibrator are correct. Since we have estimated these (Q,U) from the data itself, we remain subject to any systematic absolute offset in position angle and ellipticity. I think the smallish D-terms we tend to see (at most frequencies, at least) amounts to more of a statement about the ability of engineers to build _orthogonal_ feed systems. Absolute purity is harder, simply because an absolute reference is hard to establish.

Note that the polarization commissioning effort started in a regime where we had to assume the bright calibrators we were using were polarized, i.e. we were in the latter case describe above, by default. In fact, I grew to prefer this regime since it provides extra constraints.

No, I think this statement is conflating too many things. In fact, we
>> _do_ want a stable polarization calibrator (w/ non-zero polarization), and
>> we are _not_ fitting for absolute PA. Circularly polarized feeds also
>> respond "in an understandable way", actually, just differently.
>>
>
> I've erased most of that statement, and included a bolded "needs work!"
> comment in-line on the wiki.
>
> I suppose my only follow-up question at this point is this: in future
> cycles, how will we be able to do position-angle calibration in standard
> (snapshot) mode? Because the XYf solution requires significant parallactic
> angle coverage.
>
>
Creeping conflation again! For _position_angle_ calibration we need just two things:

1. An absolute position angle reference, e.g, a source like 3C286, or a rocky planet's limb, etc.
2. An update to CASA to support absolute position angle calibration for the linear feed basis. In polcal, the poltype='Xf' (where the X is a chi!) currently supports this for the _circular_ basis, where, in fact, it is doing the cross-hand phase calibration (because for circulars, PA and cross-hand phase are the same thing). Generalizing this for the linear basis case (for which cross-hand phase and PA are separate things!) is on my todo list. Syntactically, I have to make sure one can be specific enough about which is requested in the linear feed case.

For cross-hand phase, all we formally need is a single observation of a strongly-enough polarized source, observed at a parallactic angle for which its _cross-hand_ response dominates the instrumental polarization. If we are using an unpolarized D-term calibrator, then we can do the cross-hand phase _after_ we have the D-terms, by using poltype='Xf' (CAS-7318, which I will look at this week). This is almost exactly like the unpolarized D-term calibrator/polarized PA calibrator case for traditional VLA polarimetry, except (a) it doesn't calibrate the PA (because cross-hand phase and PA are separate for linears), and (b) there is no guarantee that the one scan on the polarized calibrator (if blindly scheduled) is one where the Q,U and parang are not conspiring to minimize the cross-hand response to the source (i.e,. -Qsin(2p)+Ucos(2p) ~ 0.0, by bad luck).

> I understand that we could do D-term calibration by observing an
> unpolarized calibrator. However, that doesn't help for finding the PA.
> Unless, perhaps, we observe another calibrator with significant
> polarization at a known PA during the observation (e.g., 3C286), the way
> VLA observations are. I suppose we could also use data from
> weekly/bi-weekly/monthly calibration observations, but then our calibration
> would only be as good as the most recent observation, which could be from a
> month prior. Not to mention that the data from the calibration run won't
> always be good. It seems risky to do PA calibration that way...but the
> only way to do it using data from within the SB is to have several hours'
> worth of observation! Are these doomsday thoughts accurate?
>
>
Not quite accurate, IMO. And conflation again! PA calibration doesn't demand a long observation. Fundamentally, the long observation is to permit extracting the calibrator's (otherwise unknown) polarization. Since that is done better if the cross-hand phase is accounted for, we extract that also, from the same data, in a manner that leverages the extended observation so as to make it relatively insensitive to the instrumental polarization. For PA calibration, if we are not satisfied with the mechanical registration (are we, or not?), then we do need to establish an absolute external reference somehow (and the preferred PA to observe it). 3C286 is decidedly inconvenient for ALMA (relatively weak at mm, way north), and the planet limb option is a bit tortured for routine use. I think I'd be pretty impressed by the science case that is sensitive to absolute PA calibration at the ~<1deg level......

And any efforts to establish the absolute external PA reference should also keep in mind the need for an external Stokes V reference....

Cheers,
George