Instrumentation WG memo on instrument mounting options - 15 Dec 2022

Compiled from discussions within the Instrumentation WG by Eelco van Kampen, ESO

AtLAST currently foresees six instruments: 2 large ones (2 deg. field of view), and 4 smaller ones (1 deg. field of view). The latter are mounted at the rear of the M1 backup structure. For the 2 large ones there are two main options: have them co-rotating with the elevation axis, or have them set fixed on a Nasmyth platform on each side of the elevation axis, and one could de-rotate the incoming beam (not the entire instrument, which will be fixed on the platform), either in hardware or software.

This memo aims to summarize the advantages and disadvantages of these two options for the 2 large instruments, from the point of view of instrumentationalists, to help make an informed decision on which option to go for in the final AtLAST design. The content of this memo results from various discussions, meetings and videocons during 2022, and originates from the members of the AtLAST Instrumentation Working Group. It does not discuss the consequences of each option for the overall telescope design (which might or might not be significant), its operation (including accessibility), and science requirements.

Eight points are considered below (which are not quite independent).

1) de-rotation of the image plane (the beam)

The obvious difference between an instrument that wholly co-rotates with the telescope when moving in elevation, and one that is fixed on a Nasmyth platform, is that the image plane needs to be de-rotated in the latter case. If this is to be done in hardware, the instrument design will need to incorporate a de-rotator (for the beam, not the entire instrument), making it more complex and probably requiring a longer focal length. However, if the operating mode will mostly be scanning of some sort, de-rotation could also be done in software. This should be the preferred option, but might limit some observing modes or make these inpossible. It also depends a lot on the number of pixels used in a camera or IFU, which should be 'a lot' for AtLAST, or whether you under-sample or not (probably only an issue for heterodyne receivers).

One point to note is that for an instrument rotating on the elevation axis there still is the other direction (azimuth) that would need to be de-rotated, though less severly than in the elevation direction. This might not actually a problem, as one could design focal plane layouts that make it possible to scan in any direction and fully sample the sky in a single crossing. For AtLAST-sized focal planes this should be very easy.
A second point to note is that de-rotation can be done before the beam enters an instrument (a common 'facility' de-rotator), or in each instrument individually. A common de-rotator would be cheaper than individual ones in each instrument, but it would be prohibitively large and will most likely not fit in the AtLAST telescope design.

An interesting case to look at in more detail is Prime-Cam (a Nasmyth instrument for FYST), which has different modules looking at different parts of the sky: rotation is a significant issue for smaller maps as some of the modules will not just see a rotating patch of sky, but look at different parts of the sky rotating around the main pointing. But having the sky rotate through the detectors is a useful check / adds cross linking – see the CMB scanning patterns used by telescopes such as ACT. This will depend on the scanning pattern, though, so for a general-purpose telescope like AtLAST this remains a worry.

2) size of the instrument

The instrument might need to be larger when put on a Nasmyth platform instead of fixed to the elevation axis, as the focal length might need to be (somewhat) larger, although this appears not to be the case in the current designs from OHB. If the focal length would be longer, it would increase the size of a camera if we want to have the same field-of-view. The smaller we can make our instruments the better / cheaper / lower cooling costs. Mass is going to go as somewhere between the square and the cube of the size.

3) structural integrity

The two large instruments of the size foreseen for AtLAST (at least 4 meters on a side) will need to be able to rotate around if mounted on the elevation axis, and while doing so not vibrate, deform or shift too much (to be quantified) during rotation, and not suffer too much from gravitational flexure (yielding an elevation dependent elevation offset for the pointing). Such issues are not applicable if the two large instruments are mounted on a Nasmyth platform. For receivers that are mounted on the elevation axes some way of moving the instruments may be wanted for positioning and focus – this could be manual.

Flexure could be fixed with a good pointing model (works for APEX), but might be difficult for large and massive rotating instruments, as was seen for Concerto. A stable pointing model might be difficult to get for large, rotating instruments due to instabilities in pneumatics, amongst others. We should look at data from other telescopes to assess this, keeping in mind that such results might not scale up to AtLAST-sized instruments.

Instrument flexure is also detrimental to image stability as it deforms the image plane during integrations, leading to image smearing, cross-talk between pixels, and other undesirable effects. A rotating instrument would therefore need to be made stiffer than its Nasmyth equivalent, which requires more solid metal with a low thermal capacity (which is more expensive). As the time to cool down and warm up again scales directly with the instrument mass, making a rotating instrument stiffer will extend the time for cooldown and warm up. Note that this would be true also for laboratory thermal cycles, so this will complicate lab interventions (for testing, maintenance, etc.). There might also be a limit to what level instruments can be made stiff when increasing the size, so we need to find out whether this limit will be exceeded for AtLAST.

4) cryogenics

This should not a problem for the rotating case, if it is not rotating much more than the 70 degrees required for AtLAST. But for very large instruments there might be problems with alignments, differential shrinkage, stiffness, etc., which will need to be tested. Also, sky dips (fast moves in elevation) might be hard to do. Pulse tubes do work at different orientations, but they work differently with telescope elevation. This creates complications in temperature control, and requires stabilization procedures to be implemented, especially for single dish telescopes (this is less of a problem for interferometers).

5) throughput

With a hardware beam de-rotator (probably three extra mirrors) this might be reduced (might be up to 3% per extra optical element).

6) cabling

For a co-rotating instrument, the cables (power, interfacing cables, etc.) connecting it to the base structure will need to rotate along with the camera, which can cause issues (cable flexing, for example). Cables and especially their connectors are very sensitive. If they get loose, they create standing waves in the signals. This is already an issue for Nasmyth cabins, but for constantly rotating instruments this might be a significant problem.
The size of the instrument helps: most of the readout electronics can rotate with the cryostat, for example, requiring less cabling going out.

7) testing in instrumentation builders lab

A Nasmyth instrument can be tested in a lab by just putting it on a horizontal surface (a floor might be sufficient), whereas a for a co-rotating instrument the effecs of the rotation around the elevation axis needs to be tested by building at least a rotating, tilted axis that can be move like the telescope will move. This is likely to be a fairly large and expensive set-up that needs to fit in the laboratory as well.

8) cost

This will depend on all of the above, of course, but it an important factor in order to get instruments funded and built. There will also be implications for the cost of the telescope itself. A cost estimate for each option might be required, but not straightforward to do.

If a longer focal length is required (not likely), a bigger receiver would be need, increasing the cost. A (hardware) image rotator would add to that, so software de-rotation should be aimed for, and should indeed be possible in most cases. Simplified cooling and cabling would decrease the cost, as would simplified testing set-ups (for Nasmyth instruments) in the instrumentation labs.