**Summary:**
The cause of the 1 arcsecond per hour drift seen on NIRSPEC is unknown. Investigations are on-going. We intend to ask observers in the problem mode to take deep SCAM images while taking spectra so that we may track the drift. We will measure and, if necessary, correct the NIRSPEC pointing origins. We suggest users of the problem mode return to their offset star between nods to verify centering.

**Background:**
Observers have seen drift on NIRSPEC when guiding on the annular guider in position angle (PA) mode on the rotator. The drift is on the order of 1 arcsecond per hour and has been confirmed via saved SCAM images from 2010 Nov 17 and 2010 Nov 21 UT. Initially, the observer on 2010 Nov 21 did not detect any drift, but drift was confirmed in later analysis of the SCAM images. A plot of the observed drift is included below.

The fact that one observer did not see drift even after warnings from Keck staff and the previous observers indicates that the effect is subtle and hard to detect. The important pointing origins (POs) at work here are REFA (annular guider) and SLIT (SCAM).
These pointing origins have not been reported to be grossly off because the OA can adjust pointing on REFA, then send the object to SLIT and it is very close to the defined position. Because we think the POs are roughly correct, if the issue is incorrectly defined pointing origins, it will require excellent seeing to measure and correct the error.

We defined several on-sky tests, but one has the highest priority: verifying the SLIT pointing origin.

The observers who initially detected the drift elected not to have us take observing time to run our tests. They felt that they understood and could compensate for the problem. They have since stated that they were unable to compensate properly and that only 40-50% of their spectra has the object fully on-slit.

The drift was not reported by observers using slit guiding or observing with the rotator in stationary mode. These guiding modes are fundamentally different than the problem mode. When using PA mode and guiding on the annular guider, DCS does the “heavy lifting”: DCS calculates the guide box position and sends that information to MAGIQ. MAGIQ exposes the guider, finds the centroid of the guide star, then transforms that centroid into XIM, YIM coordinates and returns that value to DCS. This is why our initial focus was on pointing origins.

Once NIRSPEC went into AO, we received some anecdotal information that led us to question our focus on pointing origins. The NIRSPAO observers stated that they saw drift of exactly 1 pixel on SCAM per minute. It appeared on some targets, but not all. When present, it was so regular that they scripted a telescope nudge correction. Behind AO, 1 pixel on SCAM is 16.8 mas. This yields a drift of 1 arcsecond per hour—of same order as the observed drift not behind AO. Additionally, the drift was noted to be constant in instrument coordinates— independent of the slit PA. Anecdotal information must be treated with caution, but in this case, the observers had scripted a correction to the drift. We judged this evidence of a real effect.

In light of this evidence, we had to re-think our approach to the drift problem. The magnitude of the drift appeared to be the same (or of the same order) both in NIRSPEC and NIRSPAO. We understood that this could be a coincidence, but the evidence seemed valid. If all observations of drift were correct, we could state the following: 1) The drift was not due to the NIRSPEC rotator because the rotator was not used behind AO; 2) The drift was not due to the NIRSPEC pointing origins because these were not used behind AO; 3) The drift was not due to differential atmospheric refraction (DAR) because the drift was independent of slit PA; and 4) The drift was not due to MAGIQ because a) MAGIQ does not handle the guide box positioning and b) it is not used with AO.

The only common elements remaining are the NIRSPEC dewar and the telescope.
We concluded that a loose optic within the dewar would lead to an image shift instead of a drift. We investigated some issues with the DCS code. We think that time is handled the same for all instruments such that any time error would be seen on all K2 instruments. We verified that all relevant parameters for NIRSPEC pointing are treated as double precision numbers within the DCS code (see Appendix A for details).

This leaves us without an obvious solution.

Next Steps:
For all users who use NIRSPEC in PA mode and guide on the annular guider, we will ask them to take deep SCAM images simultaneous to their spectra. We will ask them to note the RA/Dec and Az/El compass roses and their telescope nudges, if any. We hope this data will shed light on the root cause.

We need to measure the NIRSPEC pointing origins on sky. This will require excellent seeing. There are no K2 engineering nights in January 2011 and no non-IF engineering nights before June 2011. I will submit an ETAC request on the chance that an engineering night becomes available. This will require us to take time from observers. In general, we try to avoid this as much as possible, then try taking time from observers who use the problem mode first. We must tread lightly: taking time from observers who do not use the problem mode strongly implies that their TAC-awarded science is not as important as the science of observers who use the problem mode.

We also need to define a work around. Other groups who use this mode, such as the Steidel group tend not to trust the NIRSPEC nodding. For this reason, they return to their offset star to nod the telescope along the slit. This gives them feedback whether the science object is in the slit, provided the offsets are correct. For an offset star with K=17, we can measure a centroid in about 20-30 seconds with a background-subtracted image. If we have a sky background on disk, the overhead to return to this offset star and take 2-3 images is less than 2 minutes. This seems a reasonable efficiency drop when taking 10-20 minute spectra. If the offset star happens to appear on SCAM when the object is on slit, we can take a couple of minutes at the beginning of the observation to determine the pixel location of the offset star in each nod position. Later, we can take SCAM images while taking spectra to verify the offset star remains at the correct pixel.

Efforts:
SA:
- JL defines engineering plans (T996, T1047) to measure/verify NIRSPEC pointing origins, no engineering time available or taken
- JL analyzes hundreds of SCAM images to measure drift
- RG, JL have multiple brainstorming sessions including other SAs
- JL explores drift on other instruments, specifically DEIMOS and LRIS
- JL communicates data analysis, brainstorming, etc. with interested parties
Software:
- SK verifies that DCS handles guide box position updates in affected guiding mode
- SK verifies that centroids measured by MAGIQ trace out an arc with a center that changes due to nodding along the slit
- JJ verifies that DCS code handles relevant variables as doubles

Timeline:
November 2010:
15-16: Observers (Ellis) see drift on NIRSPEC.
   o Guiding in PA mode on the annular (MAGIQ) guider.
   o Observers believe they understand the issue and can compensate.
   o Keck asks observers to save SCAM images for later analysis
19-20: Next observers see no drift on NIRSPEC
   o Guiding in PA mode on the annular guider
22: Later analysis of both observers’ SCAM images show drift of order 1 arcsecond per hour
22, 25: Next sets of observers see no drift
   o Guiding in stationary mode, both on-slit and on annular guider
25-27: JL on support over Thanksgiving
28-Dec 5: JL off island for family sick leave

December 2010
5-15: NIRSPAO run
   o Discuss issue with Blake group
     ▪ They have seen intermittent drift with NIRSPEC and NIRSPAO
     ▪ NIRSPAO drift also 1 arcsecond per hour
     ▪ NIRSPAO drift independent of sky PA
15: New info is very confusing. If true:
   o The drift is not due to the NIRSPEC rotator
   o The drift is not due to NIRSPEC pointing origins
   o The drift is not due to differential atmospheric refraction (DAR)
   o The drift is not due to MAGIQ
17: We decide data collection is our best way forward
17-20: Scoville run does not provide useful data
   o No objects in fields
   o Weather
23 8pm: Ellis email asking for update
27-28: JL LGS support
28-Jan 2: JL sick

January 2011
3: JL responds to Ellis email
6: Meeting to discuss
Appendix A: DCS Pointing Code (from JJ):
I haven’t gone through every line of code but from what I can see all the relevant pointing code is using doubles. The actual rotation is all using doubles and is very simple as shown below. This is used for the NIRSPEC NOGROT case but is also used elsewhere,. Normally dx and dy are used but in the NOGROT these are rotated 1st and then used.

```c
void
pntAutogRotate( double dx,    /* X correction */
                double dy,  /* Y correction */
                double angle,     /* Angle to rotate correction by */
                double *xrot,     /* Rotated X correction */
                double *yrot )    /* Rotated Y correction */
{
    double
        sinpa, cospa;

    /*
     * Rotate through specified angle
     */
    sinpa = sin( angle );
    cospa = cos( angle );

    *xrot =  cospa * dx + sinpa * dy;
    *yrot = -sinpa * dx + cospa * dy;
}
```

The only potentially interesting thing is that in the NOGROT case the angle of rotation is basically the rotator physical position but depending on a flag this can be ROTPDEST (rotator physical destination) or ROTPPOSN (rotator physical position). We are currently using ROTPDEST (this is determined by kN:dcs:pnt:fast.USED which is defaulted to 1, keyword USEDPNT (use pdest for pointing).