# Preliminary Report on GISMO Run #2

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The GISMO instrument was assembled in the main building lab and installed on the telescope for observations beginning Tuesday, October 21, 2008.

In this year's observing run we encountered significantly worse weather conditions than in last year's run. Despite the fact that (as of the current state of the data reduction) the bad weather did not allow us to demonstrate integrations to sub-mJy levels, we were able to investigate the properties of the atmosphere under poor conditions and to test the ability of our data reduction algorithms for astronomical observations under these conditions.

The yield of working detectors is close to 100%, and more than 80% can be biased and read out under most conditions. However, we detected a ground loop problem which caused a crosstalk of the first stage SQUID feedback of column 1 into the second stage feedback of columns 2 & 3. The resulting crosstalk from column 1 into 2 and 3 is significant, and therefore we decided to observe without using column 1.

The detector noise spectra we obtained in the lab with the dewar window closed are very good, as is the case in our lab at GSFC. We see only a 50/60 Hz spike with notable power.

We moved GISMO to the receiver cabin the Monday prior to observations. During the optical adjustment with the IRAM laser setup we detected a tilt in M6 that was corrected by IRAM staff. We also detected a problem with the optical bench. It turned out that the pistons for the air pressure control were defective and thus they were inactivated by the IRAM staff. We wrapped the dewar stand with eccosorb sheets and the LOs in the cabin were turned off by IRAM staff. Initially, there was no pneumatic isolation for the optical bench, which resulted in vibrations of our dewar that resulted in increased noise. On the following day, the bench was pressurized again and the noise spectra were significantly better than in the year earlier (see Fig. 1). Note the physical units shown in the figure. Meanwhile we revised the noise density conversion factor shown in the figure (derived from two independent methods that both require the knowledge of the exact shunt resistor value) to be about 20% higher (this was determined from statistical analysis of phi_0 jumps which does not require any knowledge about passive elements in the circuit). Few prominent lines can be seen, one at 11 Hz, which were measured as vibrations present in the receiver cabin by reading out the accelerometers of an iPhone. The observed noise density at frequencies > ~3 Hz are very consistent with the expected fundamentally limited noise levels (see ref. Staguhn et al.).

The most important aspect of Figure 1 is to notice the total sky noise (red) and correlation-removed sky noise (yellow), both of which are significantly above the noise floor provided by the GISMO instrument (green/blue). This demonstrates that GISMO is entirely photon-noise limited in the conditions shown here.

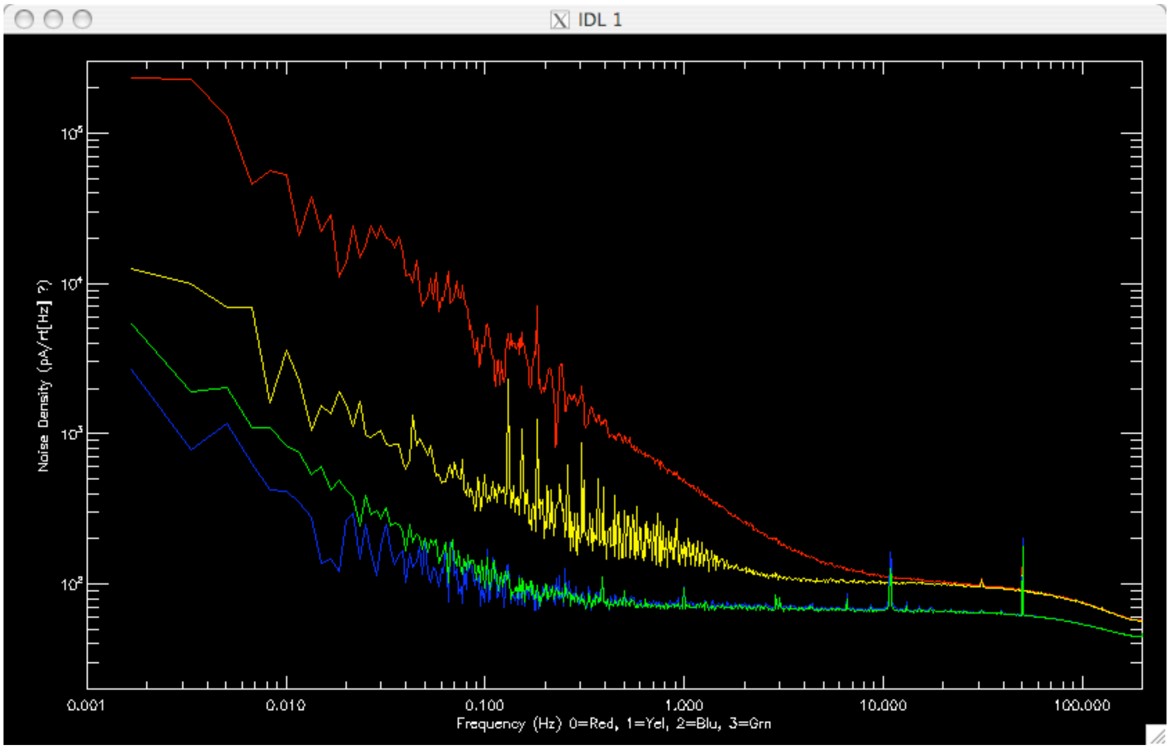


Fig. 1: Current noise density spectrum measured for 64 GISMO pixels.
Red: raw spectrum on sky (during observations of quasar J1849+670); Yellow: sky spectrum with common mode subtracted; note the quasar's signal in the signal band between 0.1 and 1.5 Hz. Green: raw spectrum with shutter closed; Blue: shutter-closed spectrum with common mode removed.

The hot spillover observed during the last observing run was not present. This is a result of the redesign of GISMO's cold baffles.

Some reduced maps are shown in Figures 2 (the quasar J1849+670, as in Figure 1) and 3 (Cygnus A). These demonstrate that we have adequate software tools to process these images in near-real time, and that the resulting images have few spurious features after sufficient cleaning.

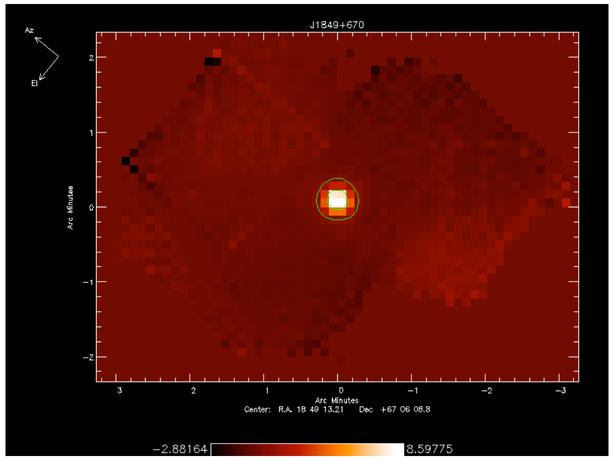


Figure 2: Image of J1849+670 from dataset shown in Fig. 1. A Gaussian fit yields a beam size of 15.8”x16.2”, as expected.

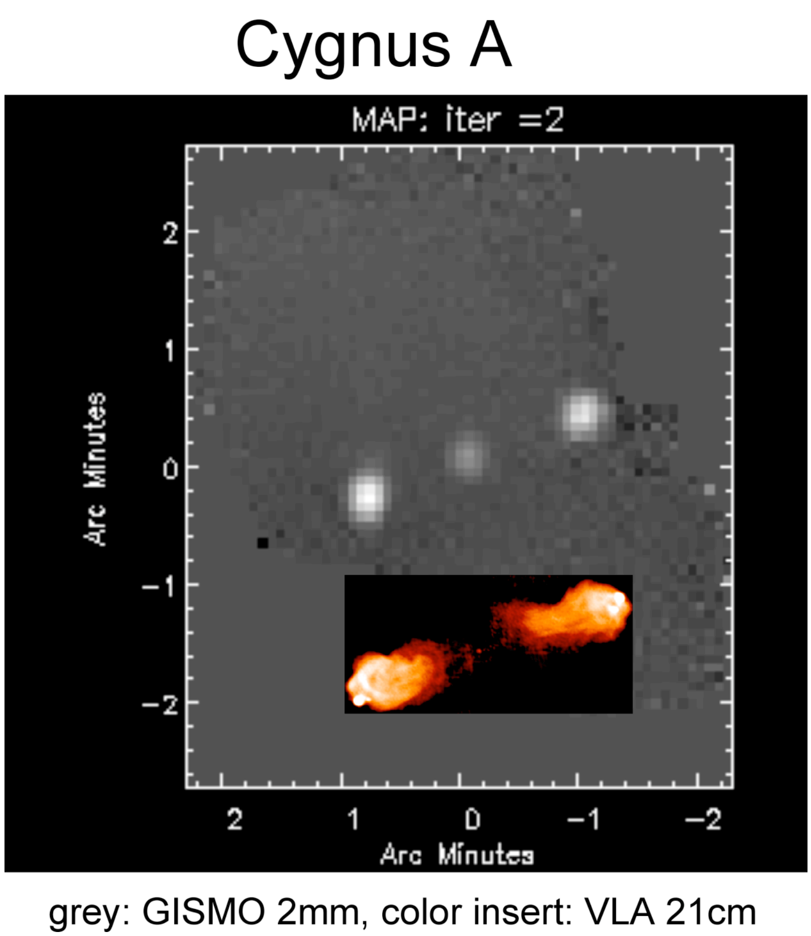


Figure 3: Composite picture showing Cygnus A at 2mm (grey) and at 21 cm.

**Observed Flux Density Noise/Sensitivity Considerations:**

There is a discrepancy (a factor of ~ 5) in the noise seen in our source maps and what is seen in the time streams of individual pixels at short (~1 to 5 sec) time streams, e.g. shown in Figs. 4 and 5. The lower noise from the time streams is also implied in the spectral noise density shown in Fig. 1. Our currently best explanation for this discrepancy is a problem in the determination of the pixel gains in our data reduction. This will be investigated more in the future. We believe that we have ample data in hand to perform the necessary analyses to solve this problem, and have some ideas of approaches to use to achieve sky-photon-noise-limited mapping.

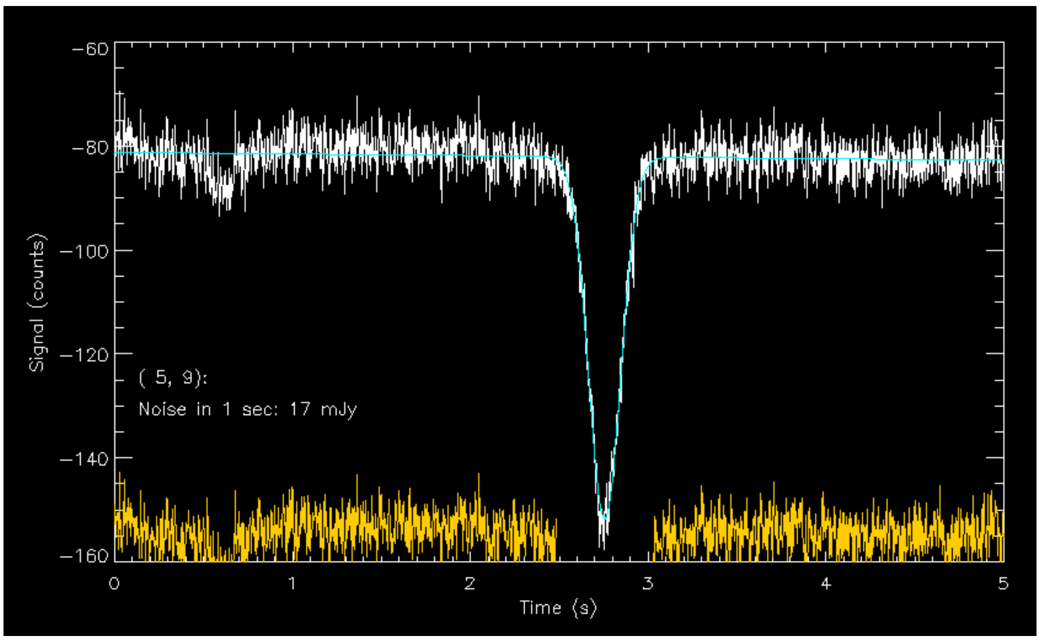


Fig 4: Time sequence showing the readout from a single pixel during a scan on 3C454. The source can be seen crossing the pixel. The flux from 3C454 is assumed to be 7 Jy at 2mm. The corresponding noise fit is shown, yielding 17mJy/rt(s). This value is very close to the photon noise limit for the observing conditions (the 225 GHz zenith tau during this observation was ~ 0.2).

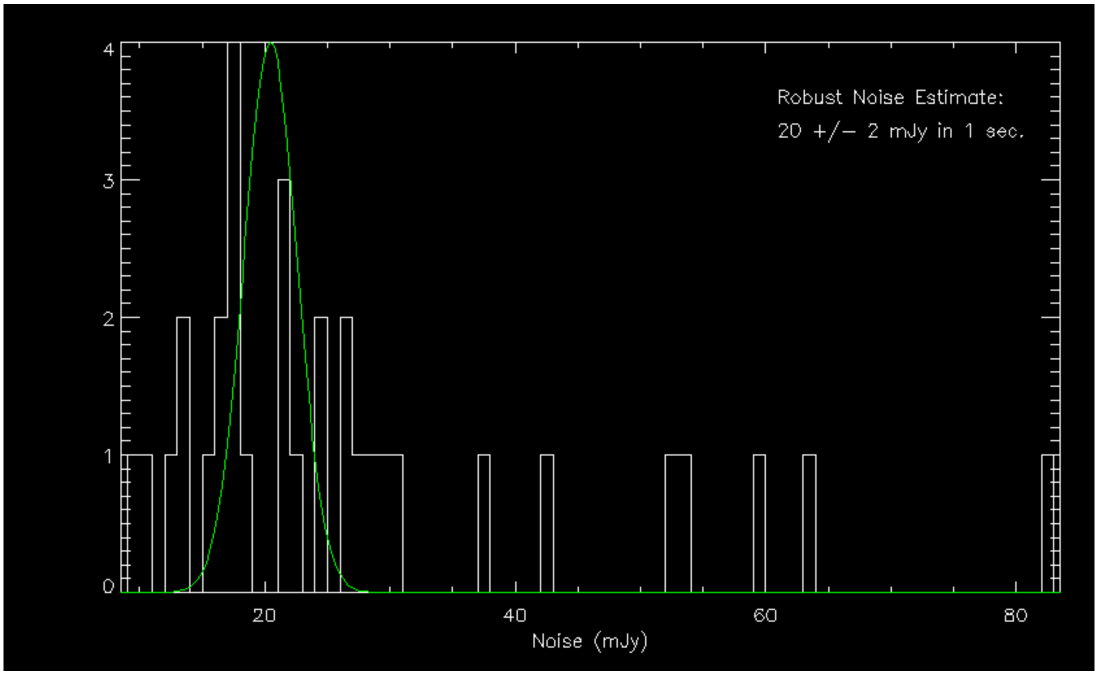


Fig. 5: Histogram showing the noise derived from 32 pixels during the same observation shown in Fig. 4. Only pixels with response to the source about a given threshold (i.e. which were centrally crossed by the source) were selected, resulting in the number of 32. The centroid of the histogram is at 20mJy/sqrt(s).

**Magnetic fields:**

We swept the telescope around 12 degrees near Az=125, recording three-axis magnetic fields with the GISMO window shutter blanked. The resultant pickup of the Earth's magnetic field is easy to see in the attached sample of five channels, and somewhat hysteretic due to instrument drifts during the 10 minute scan. After comparing all channels and selecting out those with the cleanest signal, a net pickup of 95.5 counts per microTesla is seen. No pickup significantly in excess of this is present in any valid channel. We convert this to an approximate pickup during scanning of around 0.3 counts per arcminute of azimuthal slew. Typical GISMO scans move only 2 arcminutes, and so the total effect of magnetic field pickup at this azimuth should be around 0.6 counts. This can be contrasted with typical sky noise variations of hundreds of counts during a typical scan. At this level, magnetic field pickup will likely be subsumed in the overall atmosphere model.

In summary: We observe very low magnetic field pickup this year. One reason is probably the better shielding provided by the niobium foil under the SQUID chips.

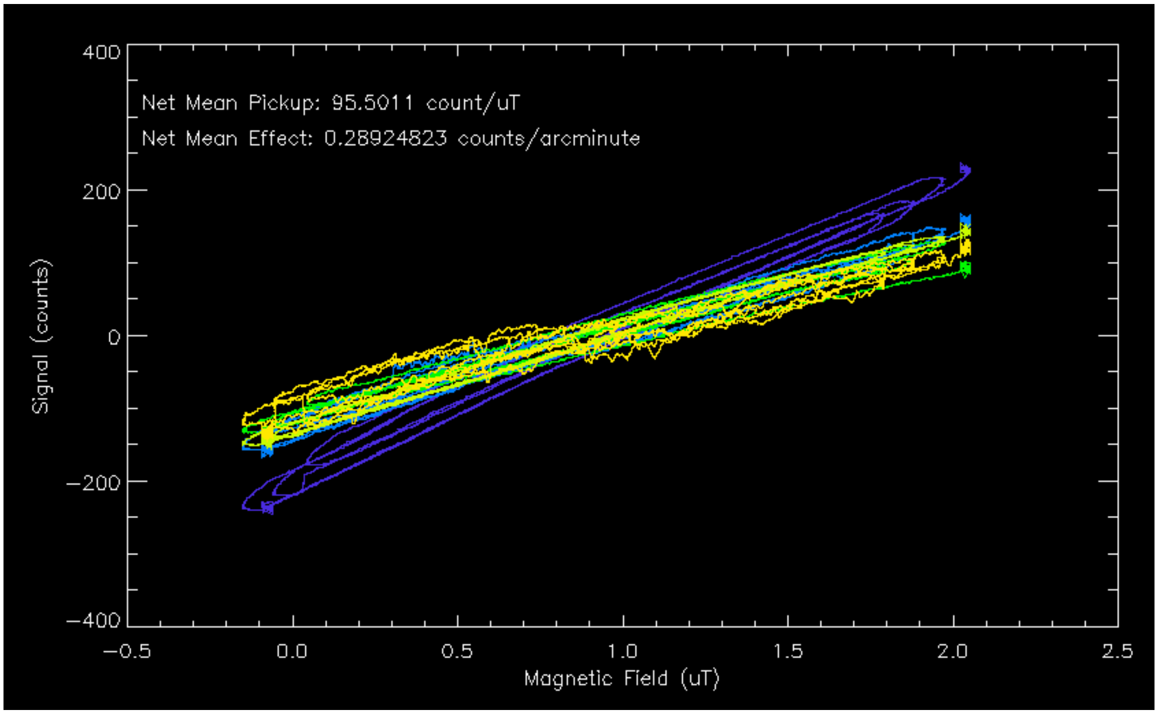


Fig. 6: Recording of three-axis magnetic field measurements when the telescope was swept around 12 degrees near AZ=125. The detected signal from the GISMO detectors is displayed vs. the measured change in the magnetic field.

**Internal calibration source**

GISMO has an internal calibration source, consisting of an encased LED with fiber optic that (is supposed to) point towards the detector. We have electronics that pulse the fibre for lock-in detection. Due to a misalignment of the fiber optic we did not achieve the required illumination for sufficient signal strengths. The power required for a sufficient illumination of our pixels resulted in too much radiative heat from the LED to use it in routine mode. This can be easily fixed.

**Conclusion**

The following improvements of GISMO (after the Local Oscillators in the receiver cabin were turned off and optical bench was fixed) as compared to last year’s observing run were obtained:

- We observed a significant decrease in pickup noise in our data, resulting in much lower noise floor for the instrument.
- The detector pixel yield is significantly improved.
- Stray beam (hot spillover) is eliminated, consequently we have a greater saturation power range.

- Blackening of many cold components, including inside of detector package lid, additionally reduces load on detectors and improves stray light response.
- Opto-isolators for all external signals allow for only one ground reference for the dewar and electrical signals entering and exiting the dewar. The resulting improvements are demonstrated in Figure 1.
- Greatly enhanced tunability of SQUIDs and detectors, resulting in more optimal instrument performance during observing. The tuning processes are significantly more automated than before, making the user interface to GISMO more accessible to the novice.
- Greatly reduced magnetic field pickup, essentially eliminating this as a source of concern.
- Improved mapping efficiency using the IRAM Lissajous scan pattern.
- Greater data processing automation through a standard pipeline that is run automatically via triggering from the IRAM messaging system.

The results from this observing run include:

- A demonstration that GISMO achieves approximately photon-noise-limited performance on short timescales, to the extent this can be determined.
- High-quality image of Cygnus A, where new data at 350μm will be combined to measure the AGN-heated dust emission in the central galaxy.
- An image of Mon R2 IRS 2 to use in combination with short wavelength data to provide a complete far-IR through millimeter SED.
- Data that should yield flux measurements to several high redshift sources, include APM08279+5255, SDSS J1148+5251, and PKS 2322+1944.
- Data to constrain the cold dust content of NGC 660, NGC 1068 and NGC 891, Arp220.
- Extended mapping of Orion molecular cloud to include OMC-2, OMC-2, and OMC-4, and the IR dark cloud IRDC30.
- Numerous quasars and stars as system characterization.

A remaining discrepancy is the method-dependent derived signal to noise ratio for astronomical observations with GISMO. A possible explanation for the observed difference in the S/N seen in individual pixels around source transients and in reduced maps: uncertainty in gains (note: very high accuracy required).

Possible implications for a fix:

- different data reduction methods?
- Internal calibrator flashing all the time?