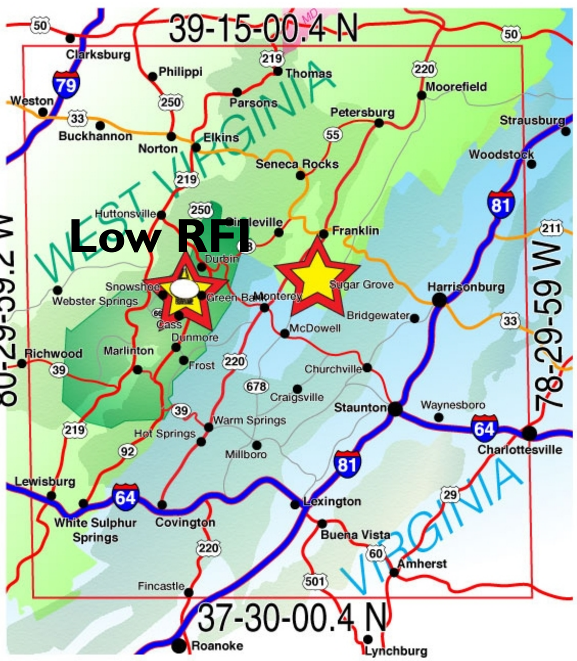
GBT Radio Cameras

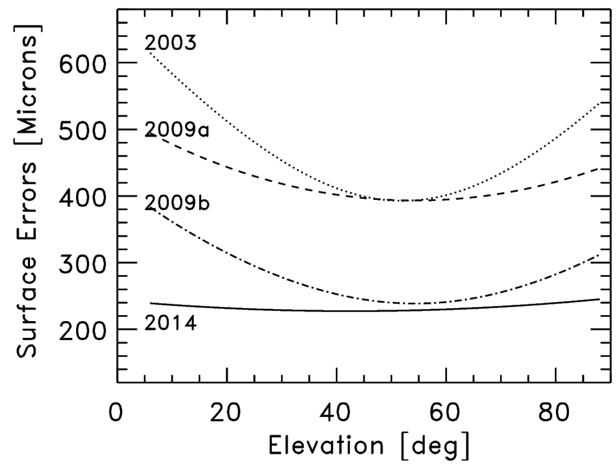
David Frayer (Green Bank Observatory)

Key Capabilities of the GBT

- Unblocked 100 meter diameter (low side-lobes providing unsurpassed sensitivity for extended objects)
- Active surface that enables efficient 3mm observations (GBT receivers cover 200 MHz to 116 GHz)
- Located within the National Radio Quiet Zone and protective measures to provide a low local RFI environment

clean beam





GBT high-frequency performance is improving over time.

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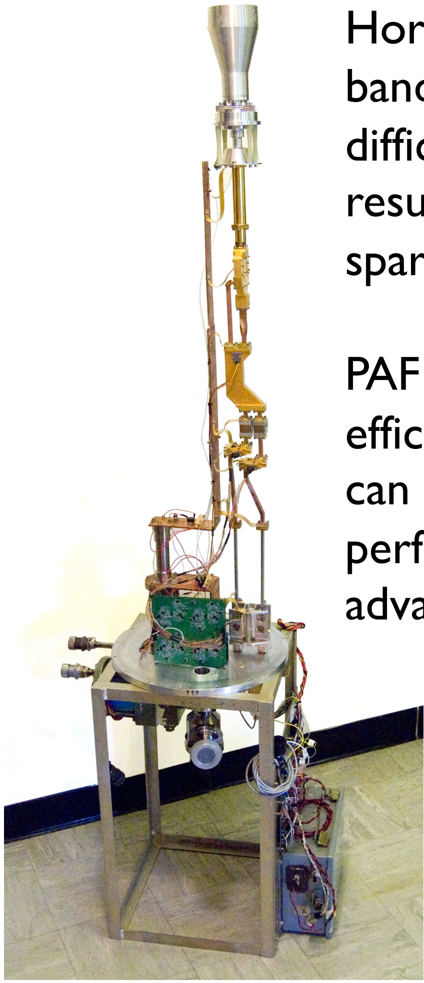
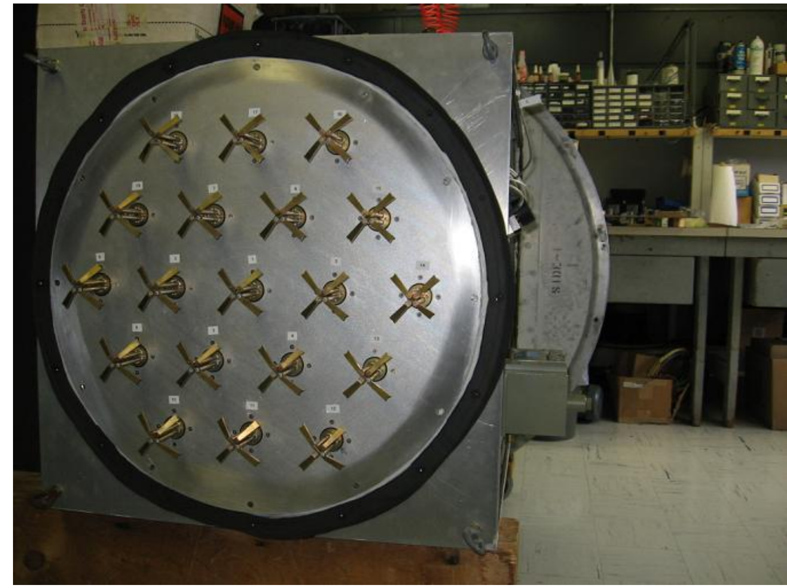
Radio Cameras

Traditional Feed Horns vs Phased Array Feeds (PAF), beam-forming arrays



Horns – High efficiency and large bandwidths, but horns are big and difficult to package electronics resulting in large feed spacing with sparsely sampled FOV (e.g., left).

PAF – Historically have had lower efficiency and limited bandwidths, but can fully sample the FOV andthe performance has been improving with advancing technologies (e.g., right).



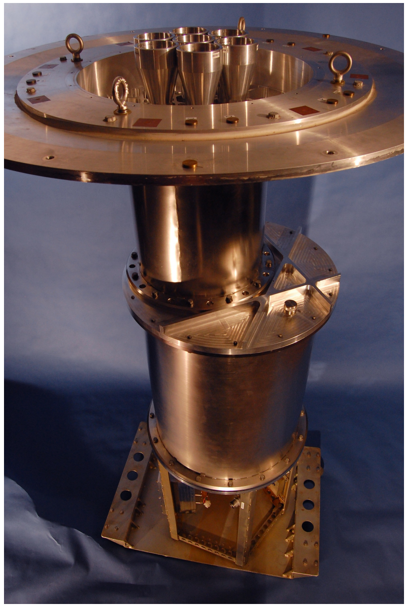
Mapping Speed $\propto N_{pix}\,(T_{sys}/\eta)^2$

Radio "cameras" with N_{pix}>>1 are a very cost effective solution to increase mapping speeds by orders of magnitude.
Want large N_{pix} without sacrificing T_{sys} or η.

Current GBT Cameras

KFPA

7 element (18-26 GHz) K-band Focal Plane Array [GBO/NRAO]

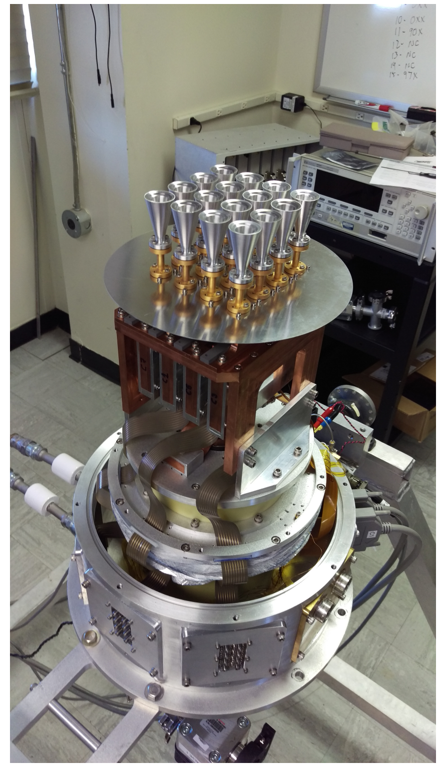


FLAG

19-element phased-array feed [PAF] (7beams) at 21cm [BYU/WVU/ NRAO/GBO]

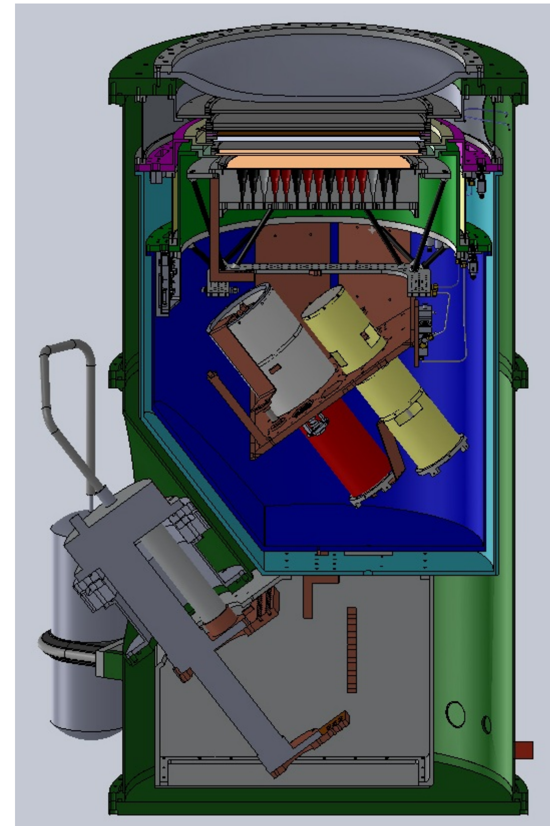
Argus

16 element 75-115 GHz FPA [Stanford/CIT-JPL/UMd/Miami/GBO]



Mustang-2

3mm 223 pixel bolometer camera [UPenn/GBO/NRAO]



- KFPA, Argus, and Mustang-2 are available for general use on the GBT.
- FLAG is currently an "expert user" instrument – contact D.J. Pisano (WVU) if interested.

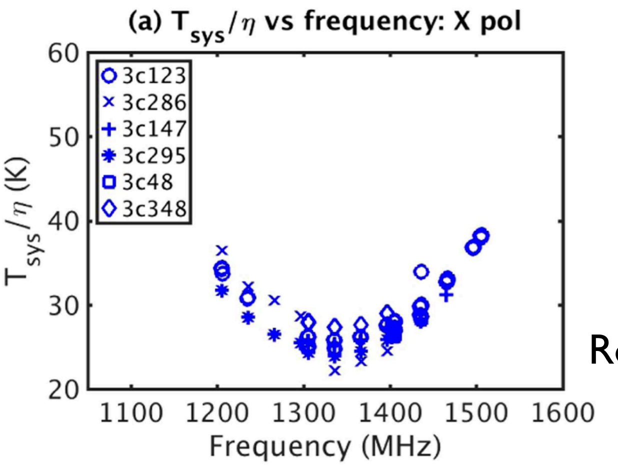
GBT Camera Development and Improvements

FLAG (Focal L-band Array for the GBT)

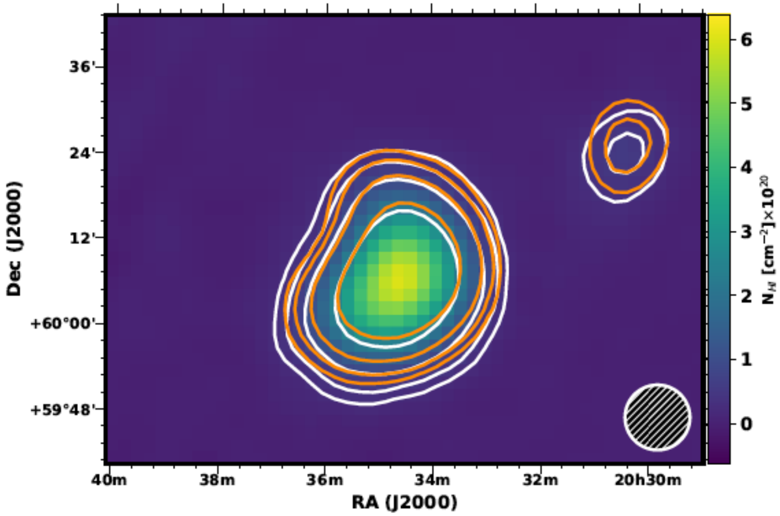
FLAG performance:

T_{sys}/η = 25.4+/- 2.5 K, 150MHz Bandwidth

which is similar to the optimized single L-band feed (T_{sys}/η =23 K)



Roshi et al. 2018



➔FLAG has successfully demonstrated the technology and would need additional resources to transition FLAG/FLAG2 into a general user instrument.

Pingel et al. 2020 (in press): 1st FLAG map showing the ability to reproduce the total HI intensity map of NGC 6946 (Pisano 2014)

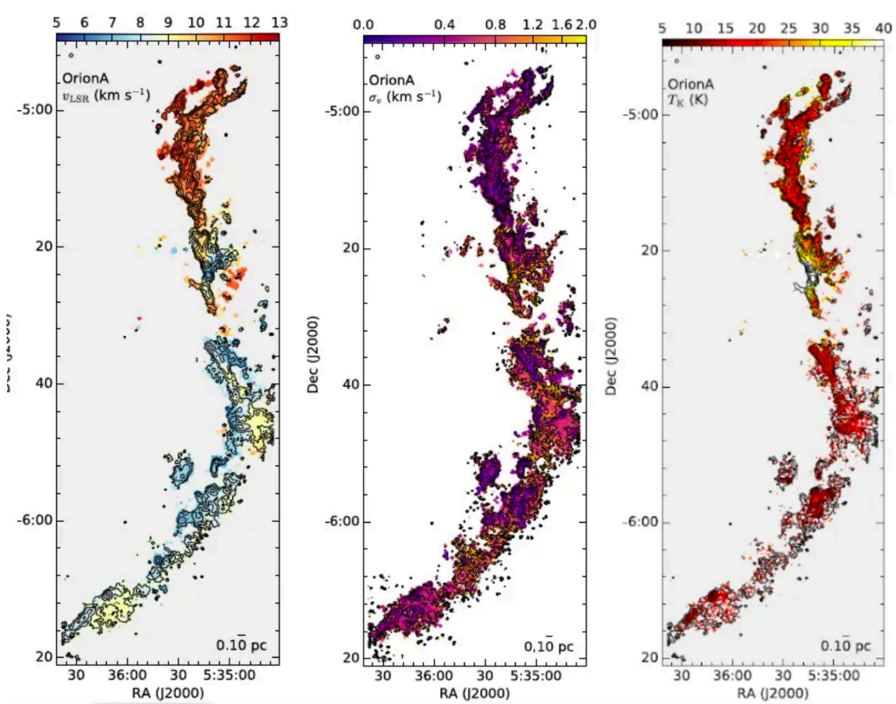
KPAF (K-band Phased Array Feed) (Future Plans)

23 GHz Beamforming Array

- 225 beams, single polarization
- 32 arcsec resolution with 4′ FOV
- 10x increase in mapping speed over current KFPA

Table 1: Performance Specifications.

Number of Feed-horns	256
Number of Beams	225
Instantaneous Bandwidth	400 MHz
Tunable Frequency Range	18 - 26 GHz
Fine Frequency Resolution	30 kHz
System Temperature	50 K
Sky Sensitivity (T_{sys}/η_{beam})	$<$ 85 K



Green Bank Ammonia Survey (GAS) image of Orion A (Friesen et al. 2017)

➔**would need funding ($2-5M)**

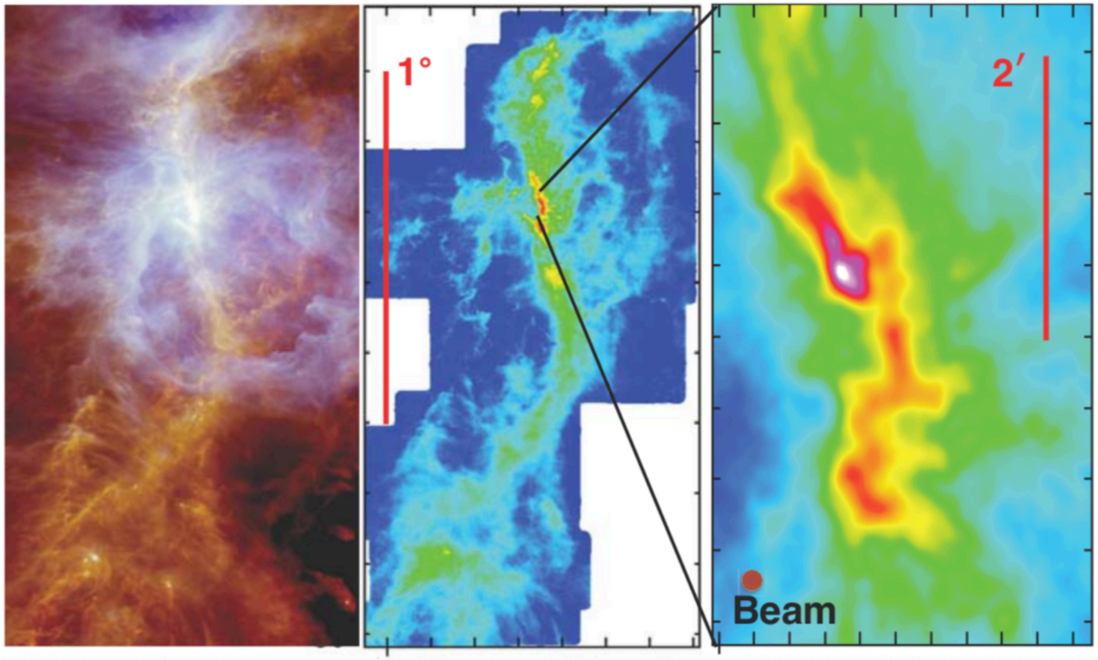
https://greenbankobservatory.org/wp-content/uploads/2019/09/MorganLawrenceK.pdf

Argus144 (Argus+) (Future Plans)

Wide-Field, High Resolution 3mm Molecular Imaging

- 144 feed horns operating from 75-116 GHz
- 7-9 arcsec resolution with 6 arcmin FOV
- 10x the mapping speed of Argus (in terms of sensitivity) and 50x the current mapping speed for area coverage (when including GBT LO upgrade)
- >10x faster than ALMA for mapping wide areas

➔**would need funding ($10-15M)**



Herschel infrared continuum image (left) with $^{13}CO(1\text{-}0)$ image from CARMA+NRO of Orion (right). Argus144 would enable wide-area molecular images over several sq-degree.

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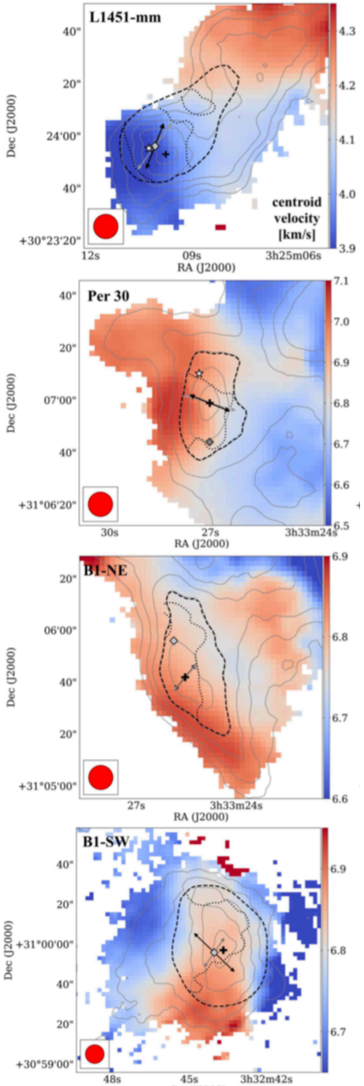
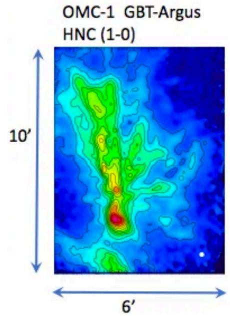
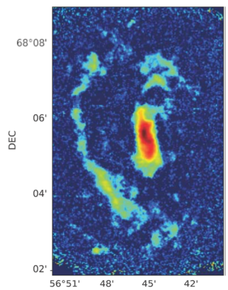
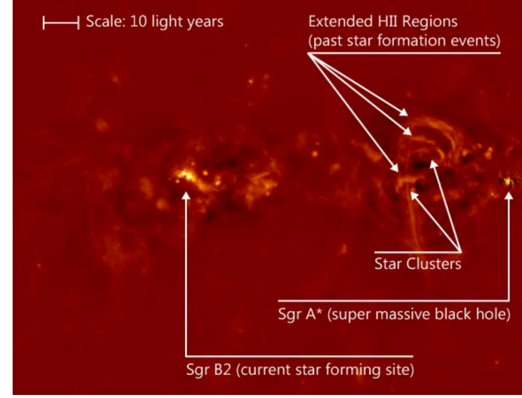


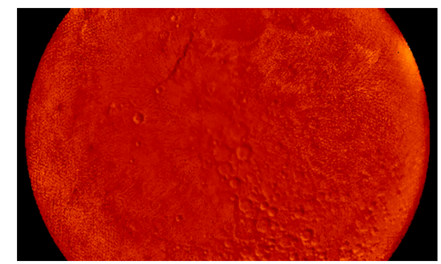




Argus images



Mustang images



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