Argus144

Wide-Field, High Resolution 3mm Molecular Imaging of Star-Forming Regions

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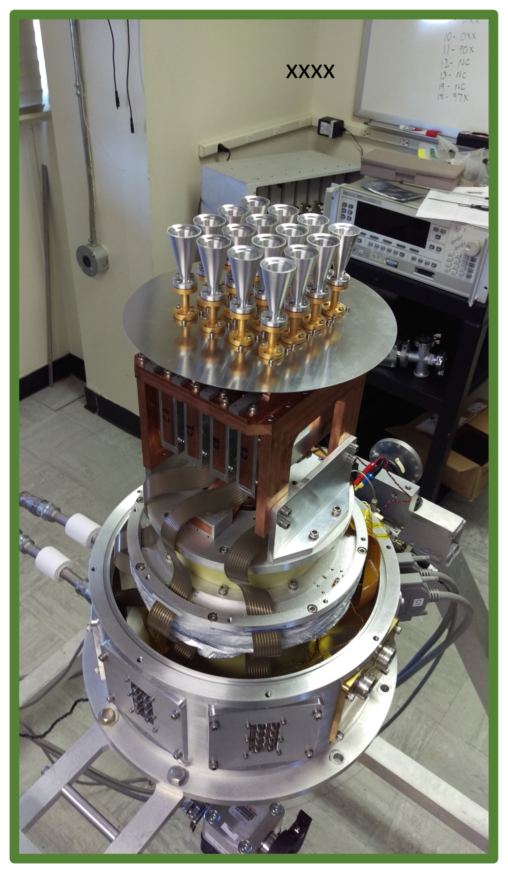
Green Bank Telescope

Abstract

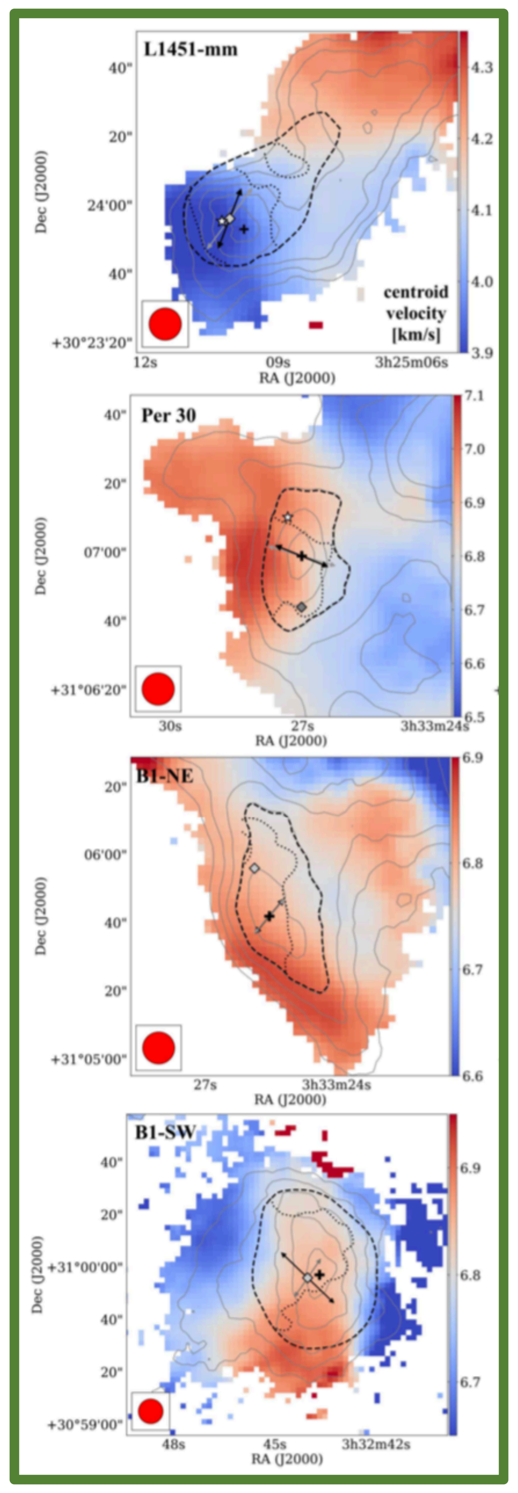
The Green Bank Observatory plans to construct a 144-element radio camera for spectroscopic studies in the 3mm band (74-116 GHz) to operate as an open skies instrument on the Green Bank Telescope (GBT). The new camera, called Argus144, will increase mapping speeds tenfold over that of Argus, a 16-element pilot version of the instrument. Combining the 6'x6' field of view of Argus144 with the 8 arcsec beam of the 100m GBT will provide high spatial dynamic range maps of interstellar molecules that are crucial in understanding the physical processes and astrochemistry associated with star formation, from the scale of entire galactic disks to the sub-parsec scale of interstellar filaments and dense molecular cloud cores. The GBT with Argus144 will be unmatched worldwide for wide-area 3mm spectroscopic mapping, and will be a critical complement to ALMA, which has high angular resolution but a small field of view.

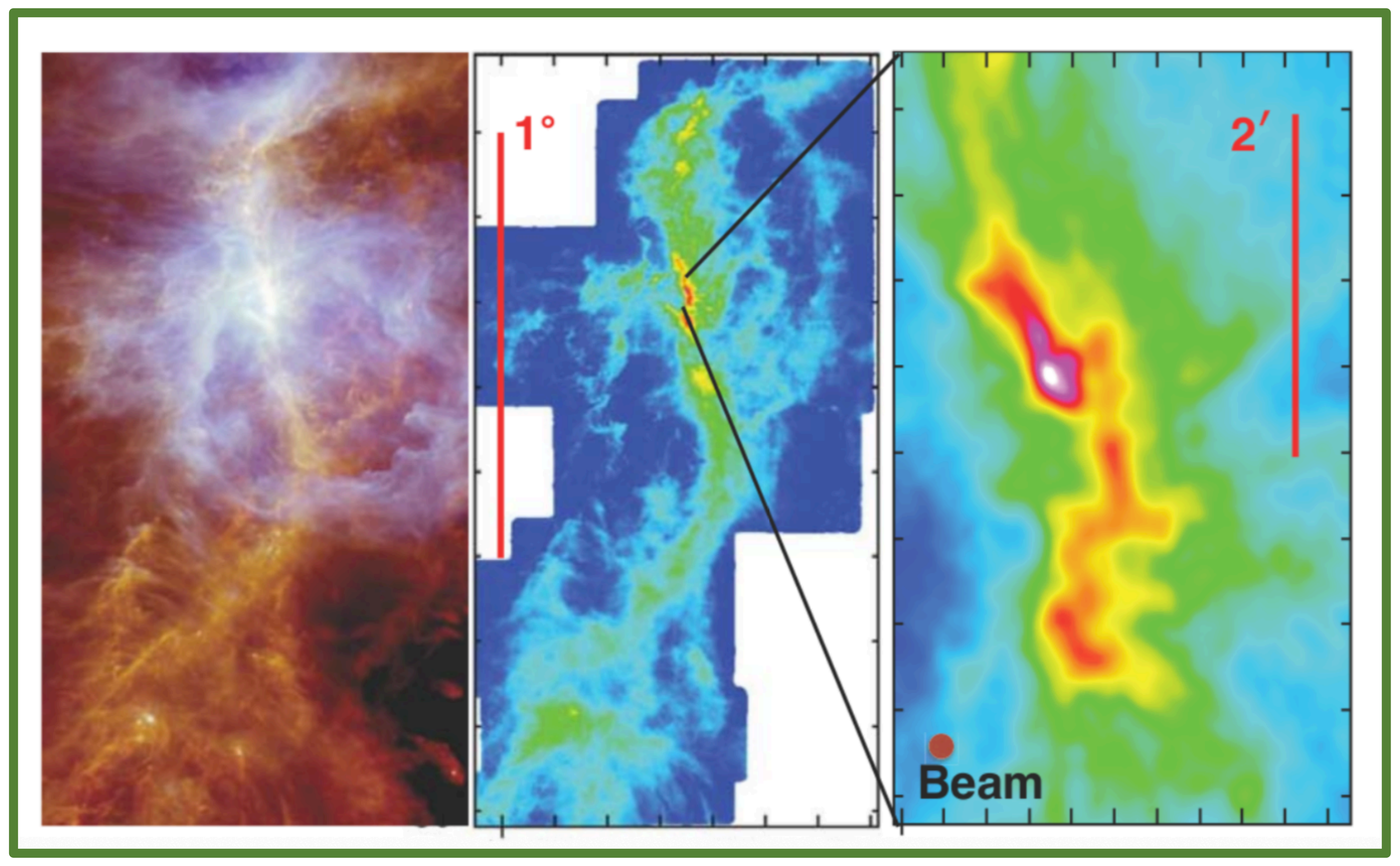


(**Above**) Argus uses a scalable architecture. The Argus144 camera will use 9 copies of Argus in a single dewar, with a footprint of 6′ × 6′ on the sky, increasing the mapping speed by a factor of 10 (Table 1).

Argus144 will produce large-area maps of nearby star-forming molecular clouds with ~0.01–0.1 pc resolution, which are key to understanding dense cores, filaments, and the factors that regulate star formation.

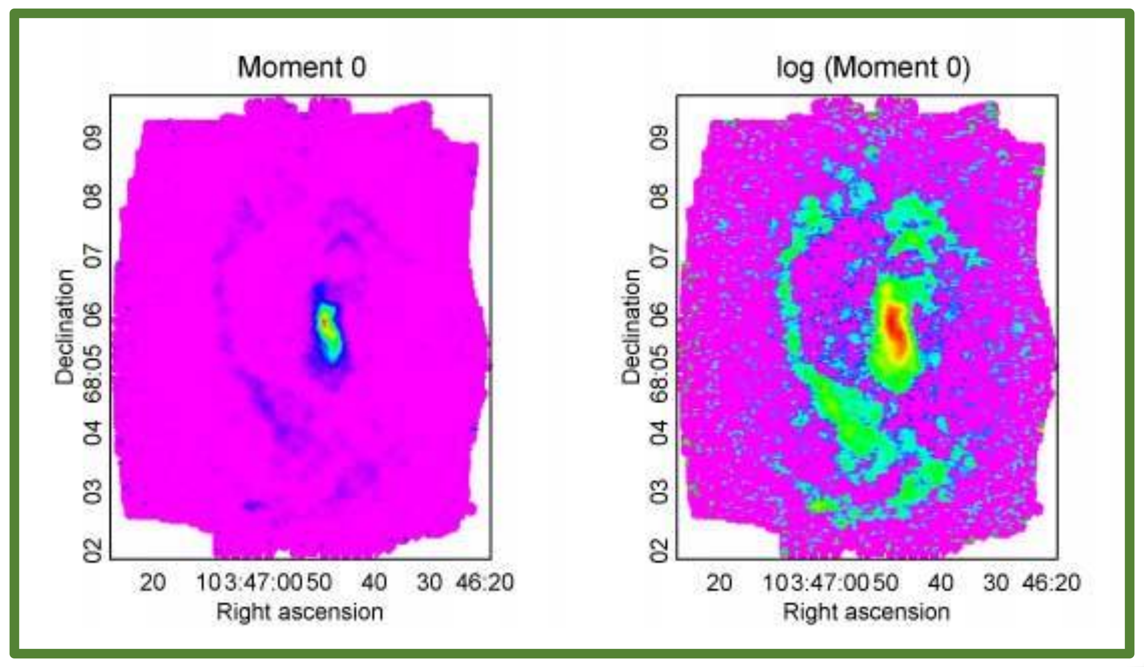
(**Right**) Shows the velocity fields of 4 dense molecular cloud cores measured in N_2H^+ with Argus (Chen et al. 2019). These observations motivated the large program DiSCo Gas (Dynamics in Star-forming Cores: a GBT-Argus Survey) which seeks to characterize the internal velocity structures of 108 young cores for range of star forming environments.



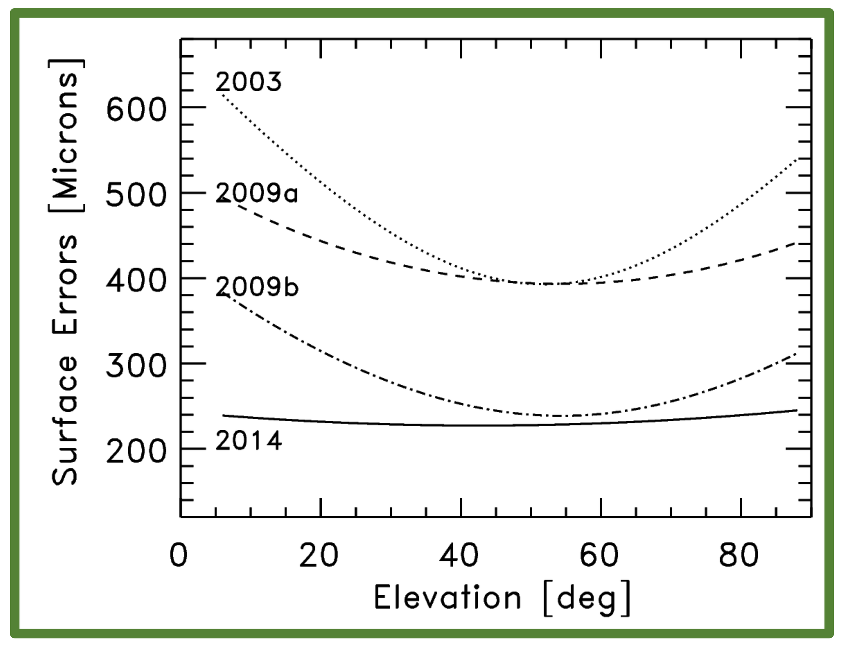


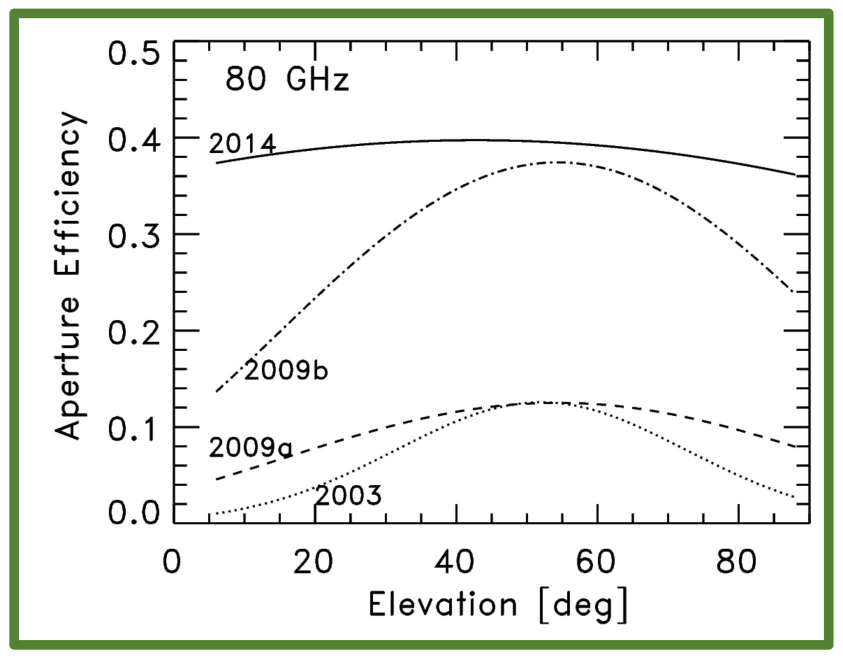
(**Left**) Herschel infrared continuum image with $^{13}CO(1\text{-}0)$ image from CARMA+NRO of Orion (**Right**). Argus144 would enable wide-area molecular images over several sq-degree (Table 1).

$^{12}CO(1\text{-}0)$ image of the galaxy IC342 made with Argus (Jialu Li and the Argus team). This galaxy is part of the large Dense Extragalactic GBT and Argus Survey of nearby galaxies (PI Amanda Kepley).



GBT High-Frequency Performance





(**Left**) The effective surface errors as a function of elevation based on the measured 43 GHz gain-curves over the history of the telescope. (**Right**) The corresponding 80 GHz aperture efficiency. The telescope was not efficient for 3mm observations before 2010 **(see GBT Memo #301).**

(see GBT Memo #302)

Table 2: 86GHz GBT Efficiency and Calibration Parameters

Dish Diameter	D	100 m
RMS Surface Accuracy	ϵ	$235 \pm 15\,\mu$m
Beam Size Parameter	κ	1.20 ± 0.02
Aperture Efficiency	η_a	0.347 ± 0.032
Main-Beam Efficiency	η_{mb}	0.442 ± 0.043
Corrected Main-Beam Efficiency	η_M^*	0.465 ± 0.035
Jupiter Beam Efficiency(43″diameter)	$\eta_{\rm Jupiter}$	0.53 ± 0.05
Moon Beam Efficiency (32′ diameter)	$\eta_{\rm Moon}$	0.814 ± 0.029
Rear Spillover Efficiency[a]	η_l	0.985 ± 0.015
Forward Spillover Efficiency[b]	η_{fss}	0.965 ± 0.020

[a]Power in the forward 2π direction. [b]Factional power in the forward direction inside the $\sim 1^\circ$ diameter error pattern.

Table 1: **Large Area Mapping Time**

Map Size, Frequency, and Sensitivity	ALMA	ACA	TP	Argus	Argus+
(1) 1 sq-deg, 110 GHz, $\sigma = 1$ K, 1 km s^{-1}	35hr	310hr	660hr	10hr	1hr
(2) 1 sq-deg, 110 GHz, $\sigma = 0.2$ K, 1 km s^{-1}	190hr	1760hr	2940hr	170hr	17hr
(3) 1 sq-deg, 93 GHz, $\sigma = 0.1$ K, 0.1 km s^{-1}	3.9khr	32khr	55khr	2khr	0.2khr
(1) 1000 sq-deg, 110 GHz, $\sigma = 1$ K, 1 km s^{-1}	35khr	310khr	660khr	10khr	1khr
(2) 100 sq-deg, 110 GHz, $\sigma = 0.2$ K, 1 km s^{-1}	19khr	176khr	294khr	17khr	1.7khr
(3) 10 sq-deg, 93 GHz, $\sigma = 0.1$ K, 0.1 km s^{-1}	39khr	320khr	550khr	20khr	2khr

The above mapping times (in hr and khr [10^3hr]) to reach the listed sensitivity levels in Kelvin [Tmb] at 110 GHz and 93 GHz (the frequency of ^{13}CO and the dense core tracer N_2H^+, respectively). The ALMA (12m Array), ACA (7m Array), and TP (ALMA Total Power Array) values were derived using the Cycle-7 ALMA Observing Tool based on the most compact ALMA configuration (C43-1), while the values for Argus and Argus+ include all the extra overheads required for accurate calibration and temperature corrections for high-frequency GBT observations. Large area mapping projects that take ~1–2 khr with the GBT/Argus+ would be possible if carried out over multiple years, while the corresponding time needed to reach similar sensitivities and mapped areas for ALMA+ACA/TP would be impossible.

NH_3 image of Orion (orange) from the GBT Ammonia Survey (GAS) of the nearby Gould Belt star-forming regions (Friesen+2017). Argus144 will enable surveys of 3mm molecular lines for the Gould Belt sample (~1000 sq-deg).

The Argus144 (Argus+) project is summarized in APC Astro-2020 White Paper (Frayer+2019, BAAS, 51g, 94F).

Green Bank Observatory: https://greenbankobservatory.org/

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