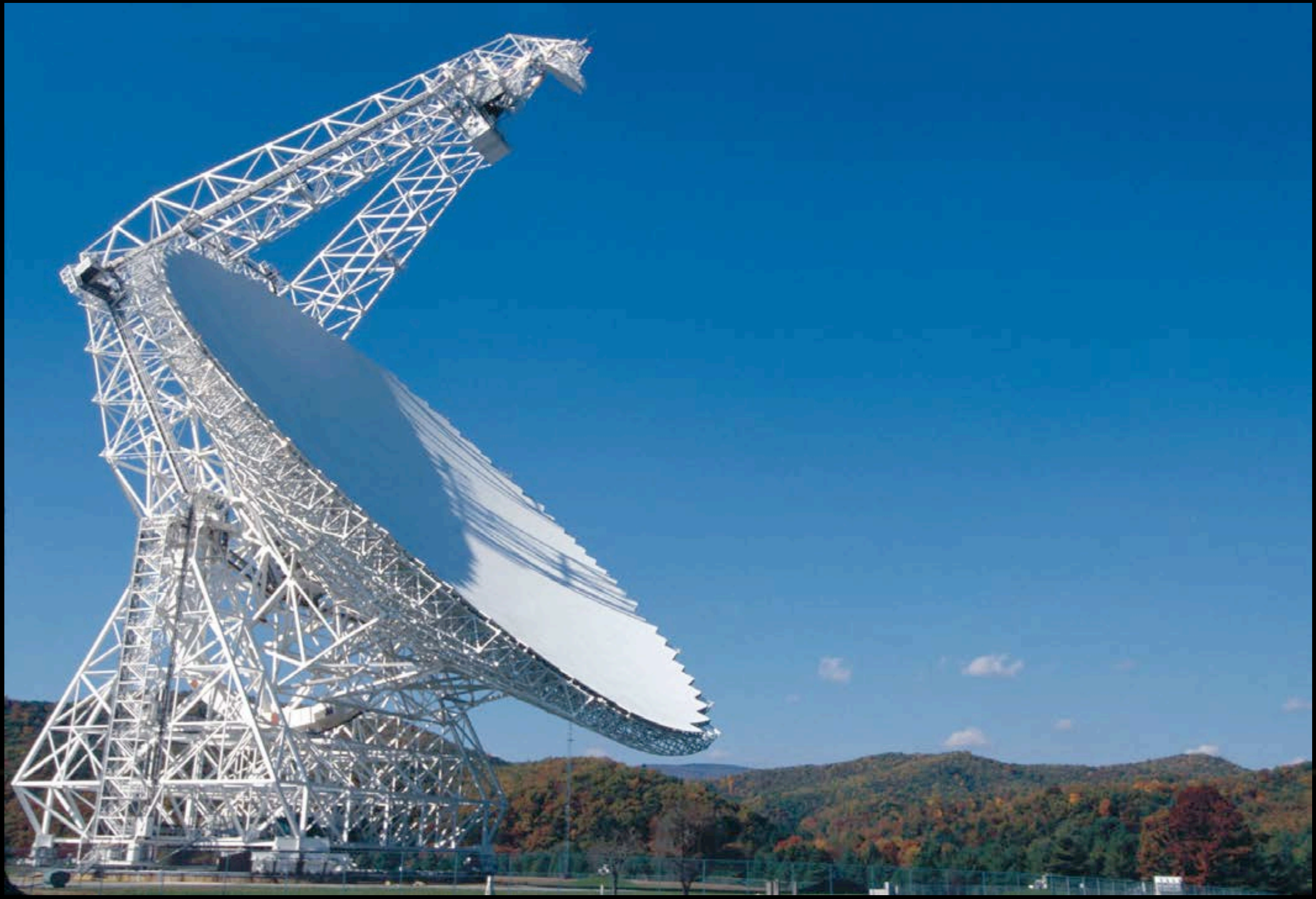
THE GREEN BANK TELESCOPE AT HIGH FREQUENCIES

THE WORLD'S LARGEST SINGLE DISH FACILITY OPERATING AT 20-115 GHZ



NEW HIGH FREQUENCY CAPABILITIES OF THE GBT SINCE THE PORTFOLIO REVIEW

- Improved performance at high frequencies
- Array receivers at 23 and 90 GHz
- Bolometer array at 90 GHz
- Routine operations at 3 mm

THE GBT TODAY IS A DIFFERENT FACILITY THAN THE 2005-2011 ONE REVIEWED

KEY SCIENCE AT 23 TO 115 GHZ

Star formation

- Fragmentation and collapse of clumps and cores
- Filaments and turbulent structure in molecular clouds
- Changing dust properties within molecular clouds

Galaxy formation & evolution

- Physical conditions and star formation rates in galaxies
- Surveys of high-redshift galaxies

Cluster structure via the Sunyaev Zeldovich effect

Comets

AGN and Blazars

THE CRUCIAL ROLE OF A LARGE SINGLE DISH

Mapping Speed

- Many-pixel receivers and bolometers cover large areas quickly with good surface brightness sensitivity
- Whole GMCs, large parts of the Galactic Plane, entire galaxies, and clusters
- Bandwidth

Spatial Dynamic Range (context)

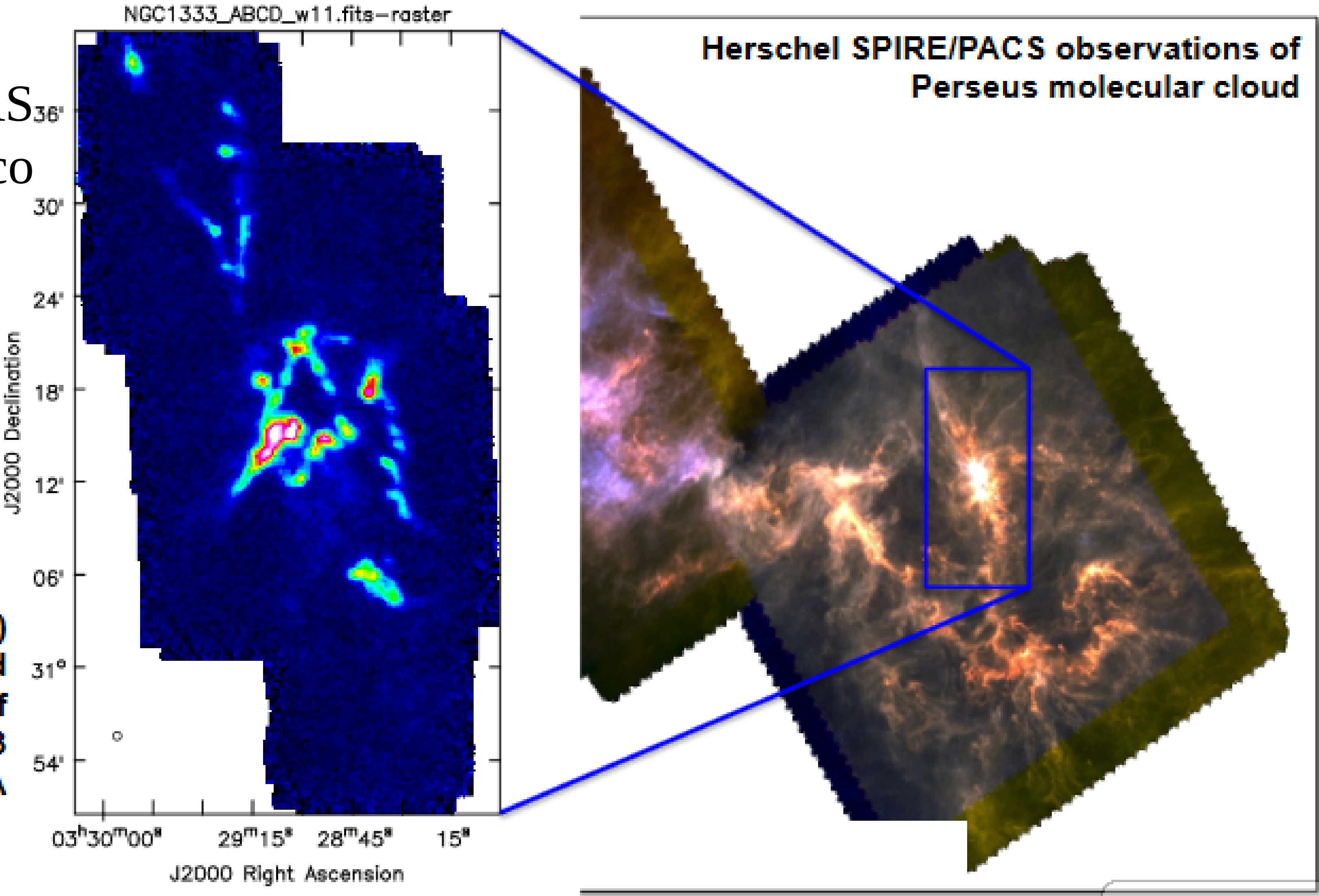
- In the Milky Way, the single dish captures spatial scales from ~0.1 to >100 pc, essential to understand SF and ISM structure
- Resolve substructure while covering entire clusters, whole galaxies and CGM

Exploration

- New instruments, speculative projects, and big, wide-area surveys are all well-matched to the single dish

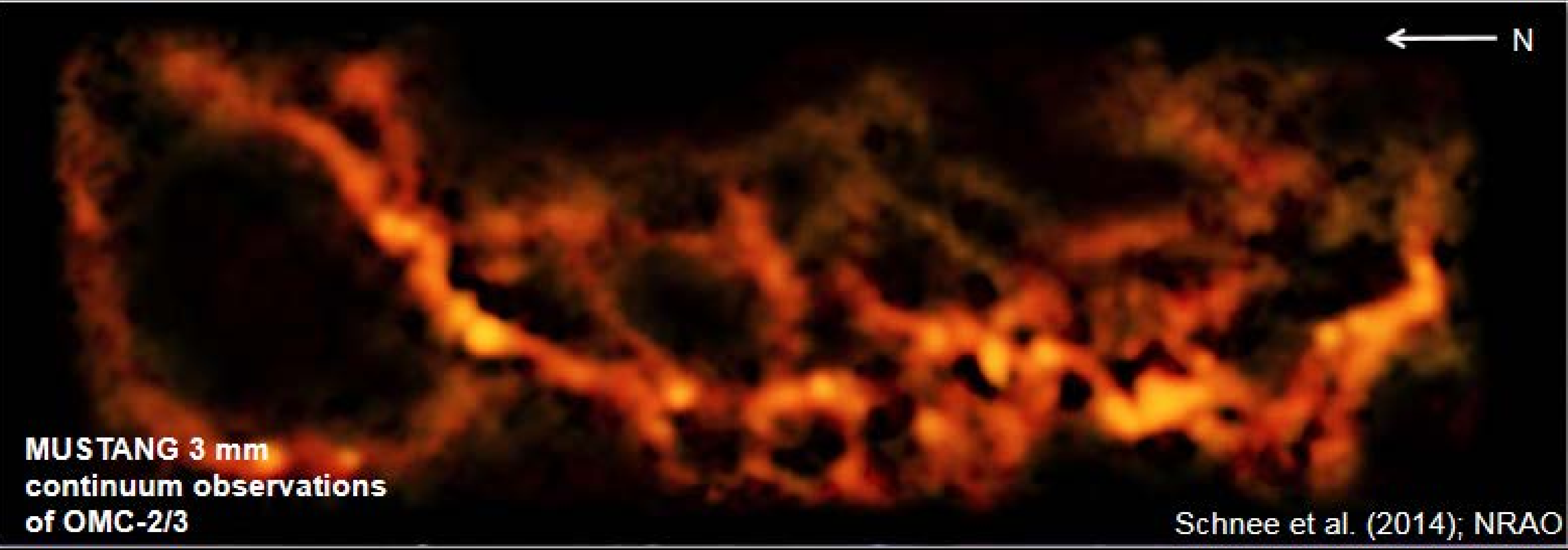
STAR FORMATION:
LINES: GAS DYNAMICS, TEMPERATURE, CHEMISTRY

GBT GAS
di Francesco



NH_3 (1,1) integrated intensity of NGC 1333 with KFPA

STAR FORMATION:
CONTINUUM: FILAMENTS AND DUST PROPERTIES



mm-cm sized dust; GBT: 9’’ resolution

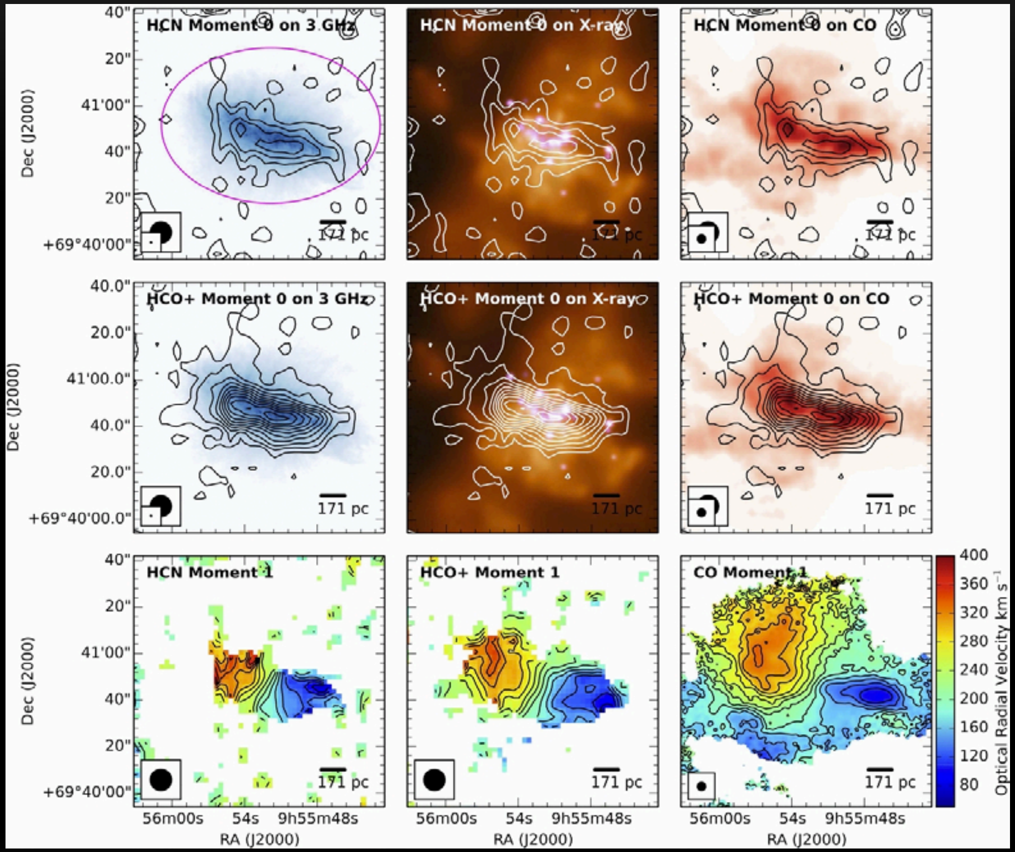
FAINT LINES IN NEARBY GALAXIES

Sensitivity to map faint lines that trace star-forming, dense gas.

Trace gas density, star formation rate of dense gas across galaxies.

Resolution of a 100-m dish.

ARGUS multiplies the speed of such mapping by a factor of 8.



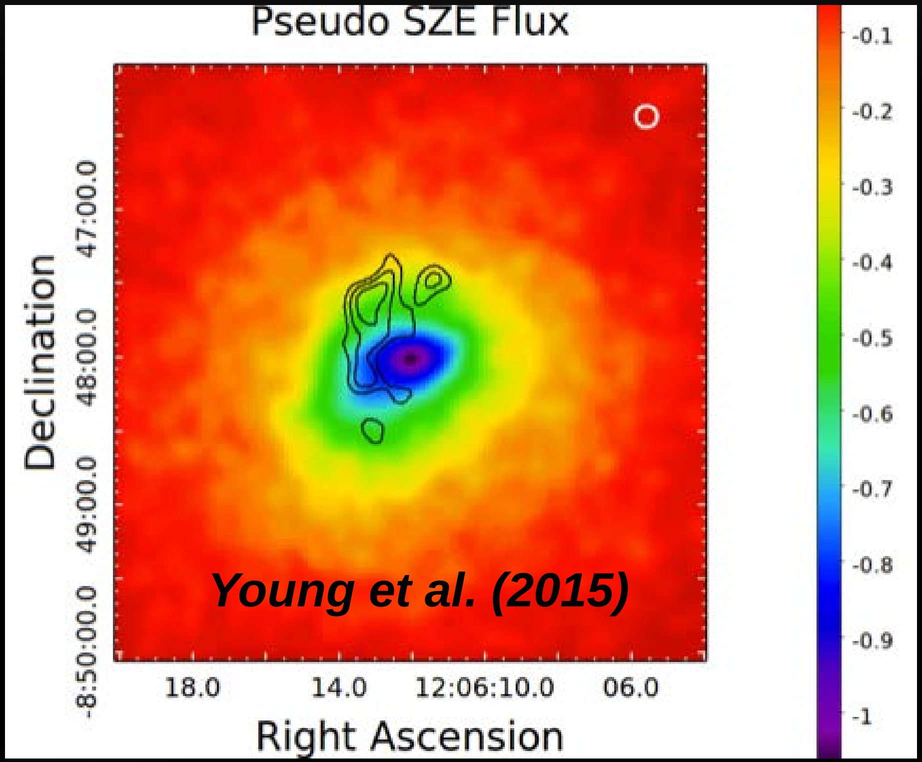
Single pixel HCN and HCO+ maps of M82 using GBT (Kepley et al. 2014).

SUNYAEV-ZEL'DOVICH EFFECT

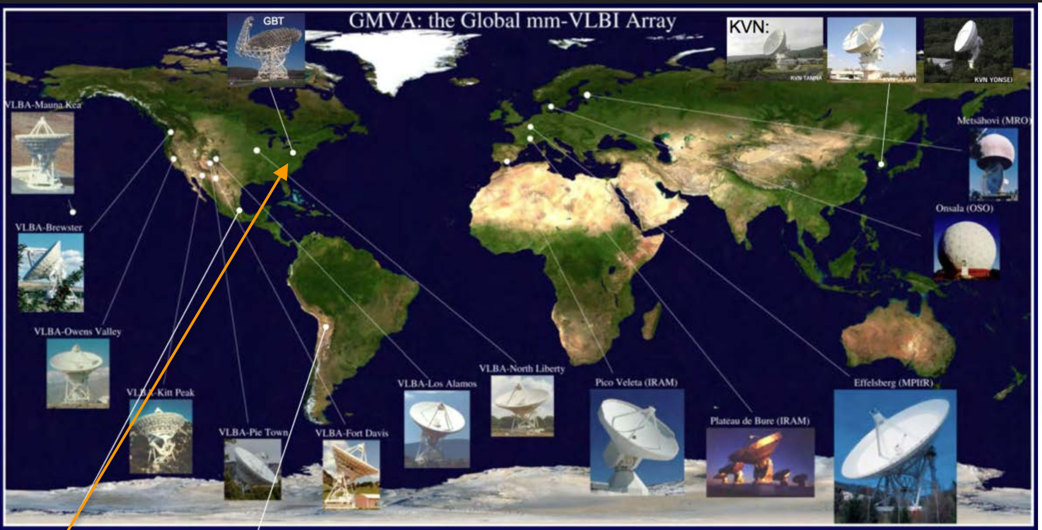
MUSTANG observations of MACS 1206-0847

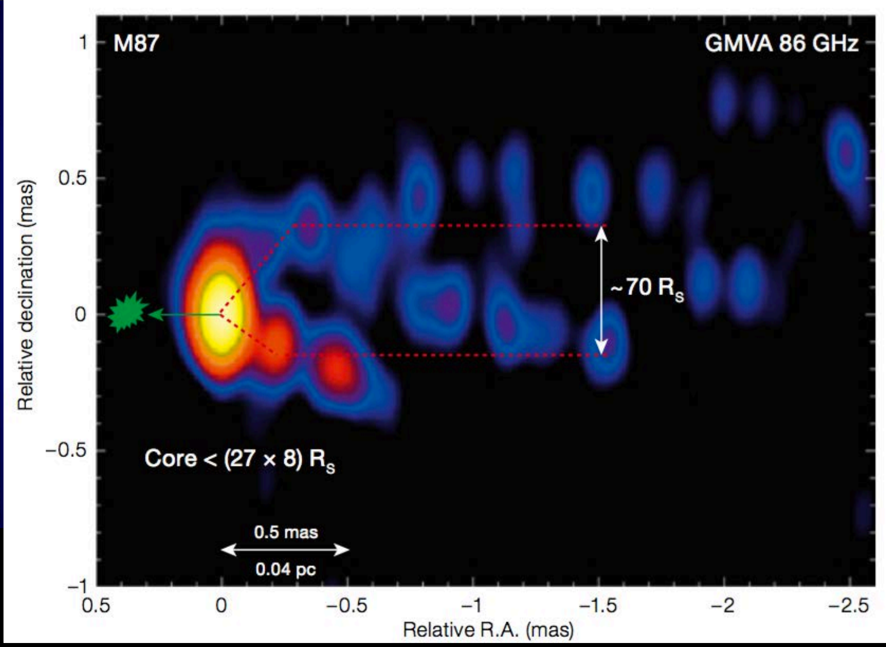
SZ effect reveals high-pressure structure not seen in existing X-ray data

May be evidence for material infalling into the cluster



A CRITICAL ELEMENT OF MM-WAVE VLBI





GBT provides enormous sensitivity at a crucial position for good UV coverage

Science apps: resolve 100 μarcsec-scale structure of:

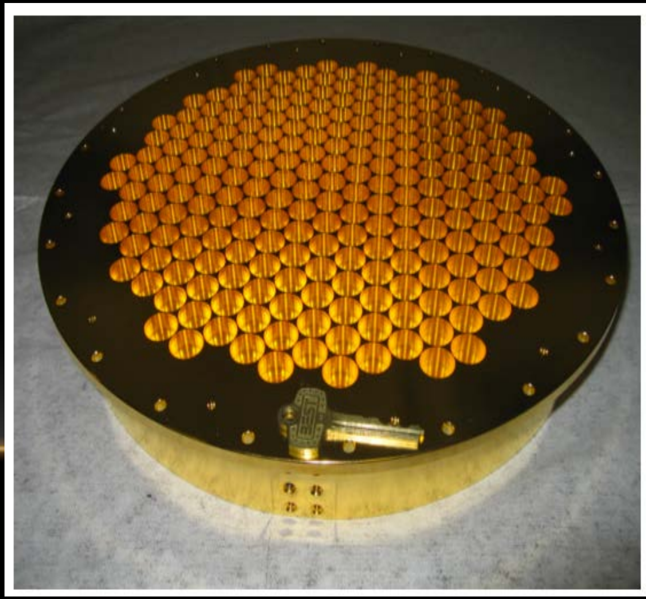
- Acceleration & collimation of relativistic jets (e.g., M87)
- Magnetic field structure near near base of relativistic jets & in young stellar objects
- Faraday rotation maps to probe interstellar medium in galactic nuclei
- Water, etc. masers in star-forming regions & evolved carbon stars
- Masers in accretion disks to measure black hole masses

GBT: UNIQUE COMBINATION OF LARGE COLLECTING AREA + FOV

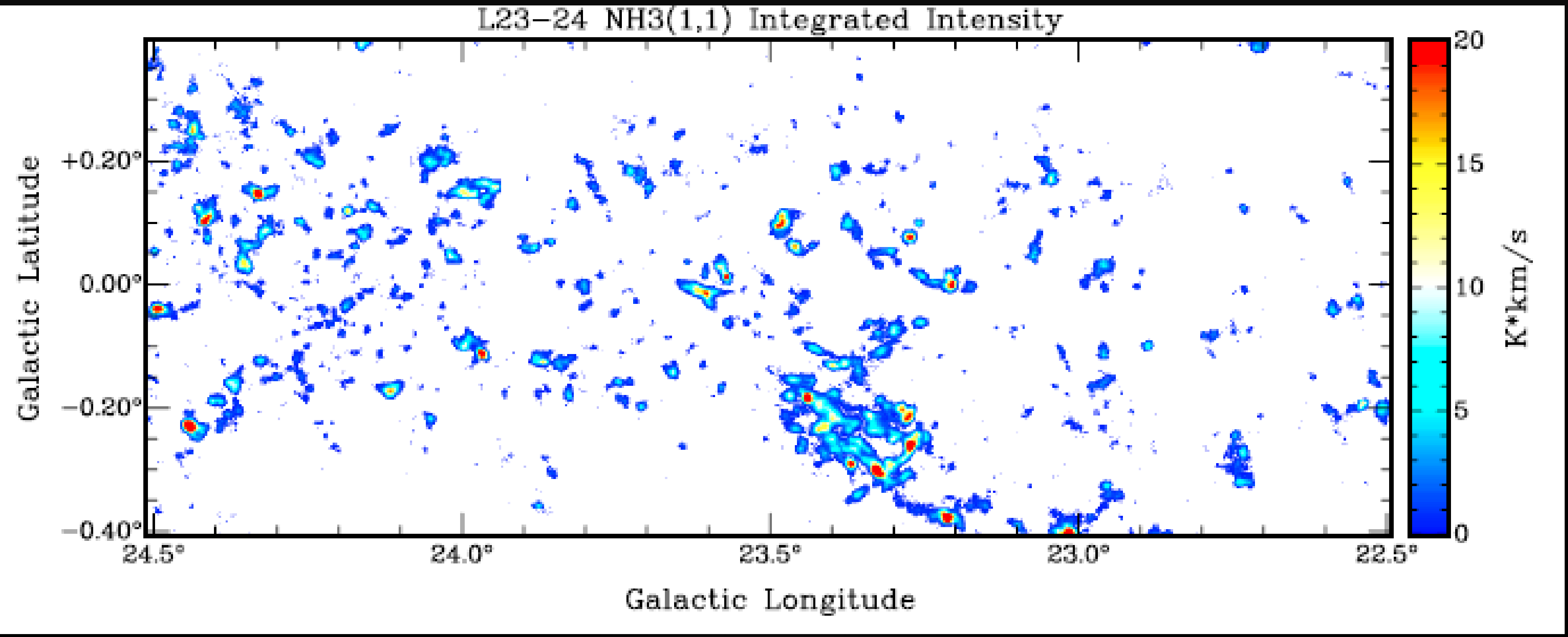
- Superb platform for array receivers
- Key science:
  - Large-scale and multi-line surveys
  - Sensitivity to faint extended emission

CURRENT GBT ARRAYS

- KFPA: ~23 GHz, 7-elements heterodyne
- ARGUS: ~90 GHz, 16-elements heterodyne
- MUSTANG-2: ~90 GHz, 223-elements bolometer

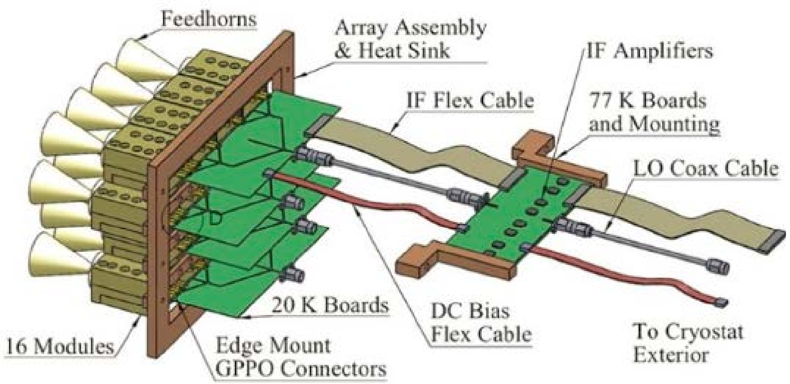


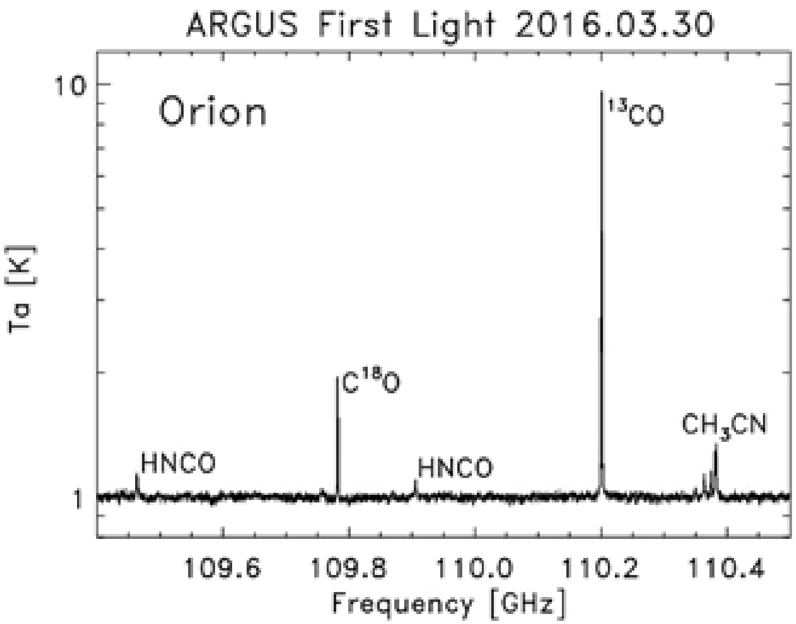
K-BAND FOCAL PLANE ARRAY (KFPA) NH_3 MAPPING

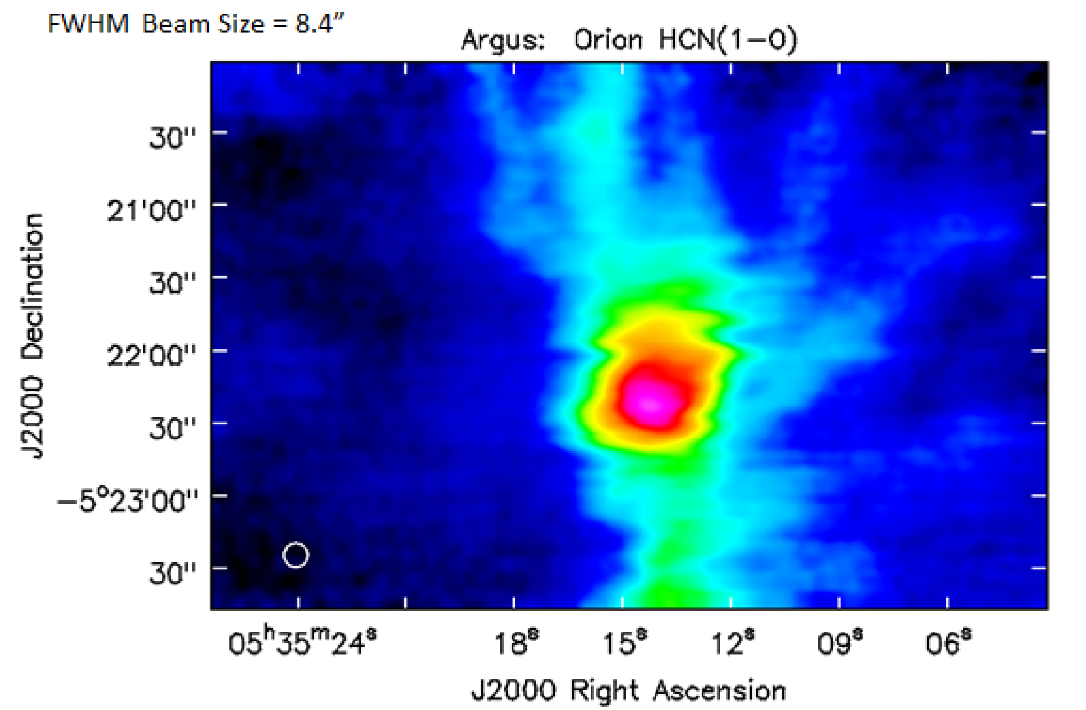


NH_3 (1,1); RAMPS survey

ARGUS: 75 – 115 GHZ SPECTROSCOPY

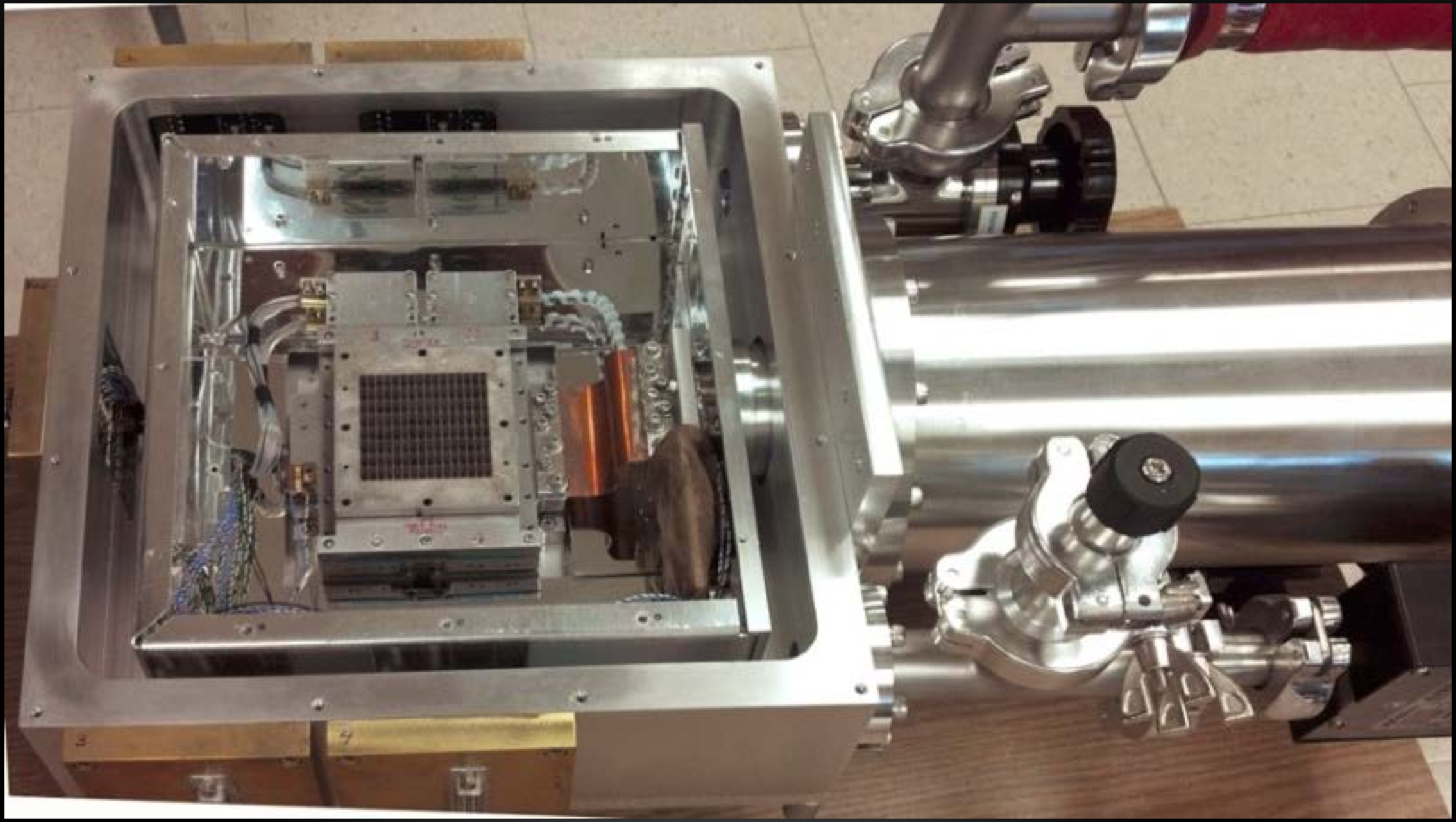






ARGUS: PI Church
First light images and spectrum toward Orion

FUTURE ARRAYS:
SCALABLE PHASED ARRAY FEEDS



64 element 3-mm PAF (UMass; Erickson)

GBT: EFFECTIVE AREA FOR MAPPING

$$A_{eff} = \eta \, \pi \, r^2 \, N_{ant} \, N_{elem}$$

	46 GHz		90 GHz	
	Rx elements	Eff. Area (m^2)	Rx elements	Eff. Area (m^2)
ALMA	1	4,927	1	4,927
GBT	1	4,791	16	47,752
GBT	500	2,395,464	900	2,387,610

GBT already achieves ~10x more collecting area for large scale mapping than ALMA at 90 GHz

Maximal arrays could have 500x larger A_{eff}

THE GBT HAS EXTRAORDINARY SENSITIVITY: COMPETITIVE WITH ANY WORLD FACILITY

Time to map 3’x3’ region at 3mm to T_A*=20 mK

GBT 2015 1 Pixel 8”	ARGUS 2016 16 Pixels 8”	GBT 2020 50 Pixels 8”	ALMA 50x12m 3”	ALMA 50x12m 1”	ALMA 10x7m 23”	ngVLA 500x18m 1”
21h	3.3h	<1h	19h	1,500h	0.5h	17,500 h

Declination 0°, 1 km/s velocity resolution, Ta, GBT 2000h/yr opacity*

SUBSTANTIAL GBT OBSERVING TIME IS AVAILABLE AT HIGH FREQUENCIES

HOURS AVAILABLE PER YEAR

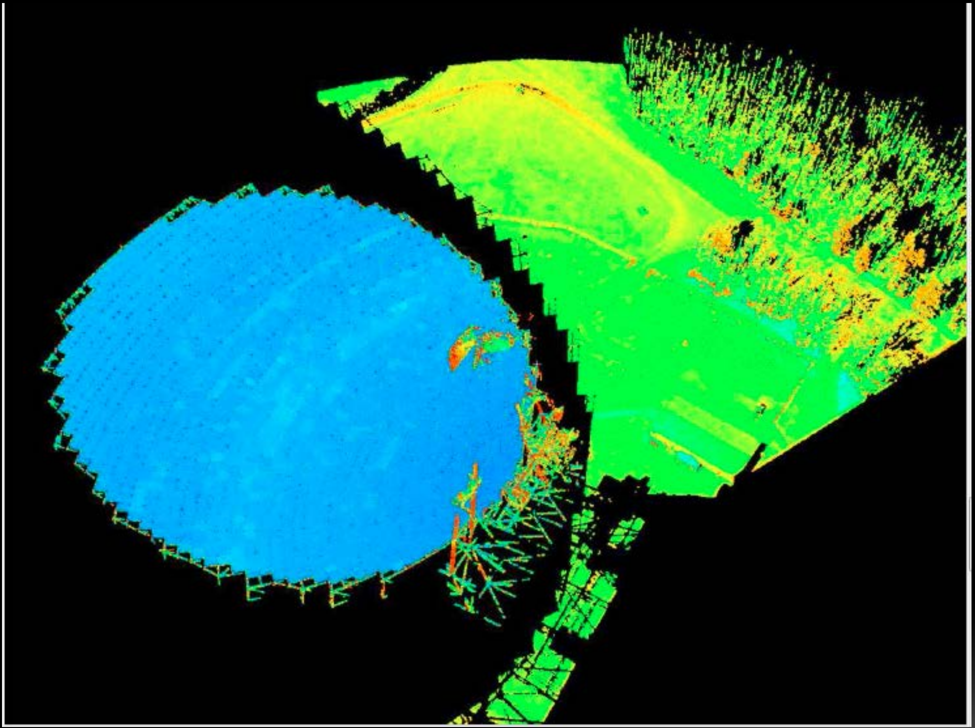
Frequency	tau < 0.1	tau < 0.2
22 GHz	2600 h	4000 h
45 GHz	---	2800 h
86 GHz	975 h	2100 h

MID-SCALE NEAR-TERM IMPROVEMENTS

- POINTING
- SURFACE
- INSTRUMENTS

POINTING AND EFFICIENCY

RANGE FINDING LASER IMAGE



Substantial improvements can be achieved by real time monitoring of surface and feed arm position with off-the-shelf technology.

~0.5$M

INSTRUMENTATION

- LARGER ARRAYS can take advantage of recent advances in technology
  - Correlators
  - Multi-pixel highly integrated receivers
  - Phased array feeds

~few $M

SUMMARY

- Large scale/bandwidth mapping and low surface brightness are the province of a single-dish, and the GBT is a very large single-dish
  - Interferometers are not the end-all
- The GBT is well-placed to be at bleeding edge of 20 – 115 GHz science
  - It is a much improved facility
- With modest investment it will be a incredibly powerful and complementary national facility with unique strengths available to US astronomers