High-Mass Star Formation and the Origin of the Stellar Initial Mass Function

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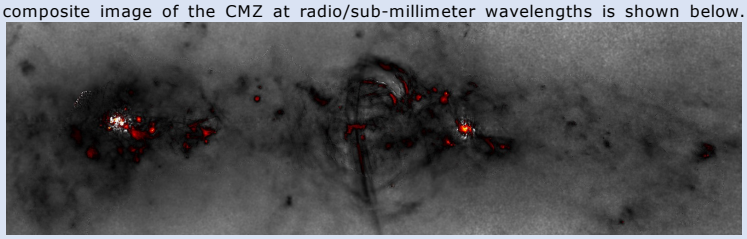
Solving mysteries of star formation in the Milky Way and beyond

The Ginsburg group studies how stars form in a variety of Galactic and extragalactic environments using **observational** (radio, mm/sub-mm, and infrared), **theoretical**, and **simulation-based** techniques. The following are some guiding questions in astronomy and star formation we strive to answer to better understand the Universe:

1. What role does environment play in star and planet formation?
2. How does the stellar initial mass function (IMF) vary?
3. How does stellar clustering affect star and planet formation?

A common subject of our research is the Milky Way's Central Molecular Zone (**CMZ**) located at the Galactic Center (GC). The CMZ contains the most extreme conditions for star formation in the galaxy due to its high density and complicated kinematics. A composite image of the CMZ at radio/sub-millimeter wavelengths is shown below.



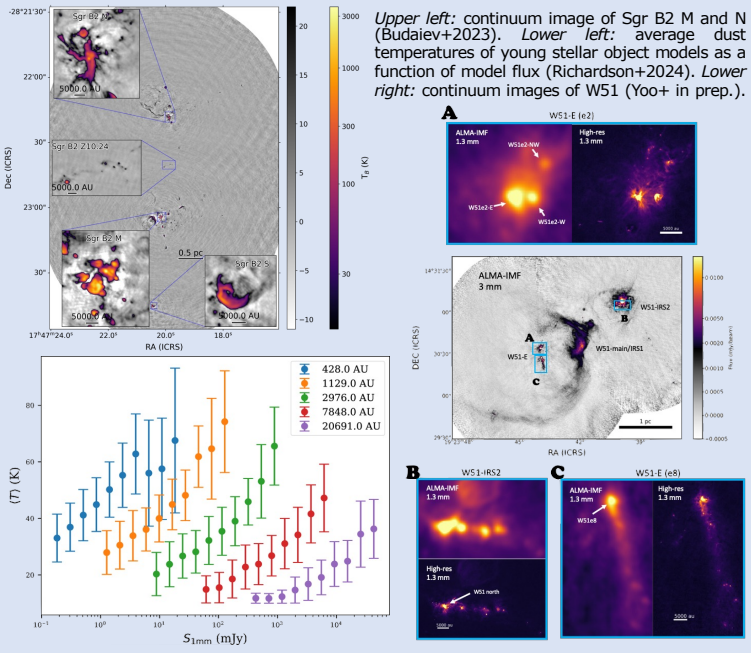
Ginsburg group circa summer 2024 (not including postbacs, undergrads)

We use world-class facilities to study never-before seen environments

Our group has two successful **JWST** Cycle 3 programs and one Cycle 1 program. One C3 program is led by Nazar Budaiev to map the star-forming GC molecular cloud Sgr B2; the other is led by Taehwa Yoo to measure the (pre)IMF in W51, a region of SF in the MW disk. The C1 program is focused on gas and dust in two quiescent GC clouds, The Brick and Cloud c.

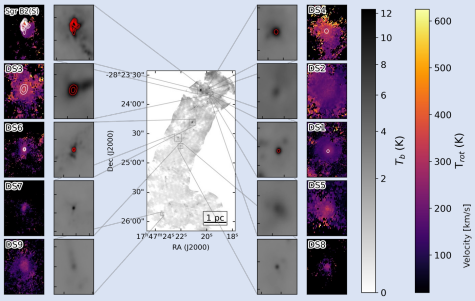
The Atacama Large Millimeter/submillimeter Array (**ALMA**) is a powerhouse facility for our research group. Our group has led a multitude of projects using data from ALMA, targeting sources of high-mass star formation in the GC (Sgr B2 N, M, S, and DS) and the Galactic disk (W51, Orion KL), as well as sources that show little to no evidence of star formation (The Brick, G5). In addition to obtaining time on competitive instruments, the Ginsburg group has secured computing space on HiPerGator, UF's supercomputer. We have led the data processing effort for two ALMA Large Programs, ALMA-IMF and ACES, which take up a total of 500 TB of storage on **HiPerGator**. Our group also consistently dominates the Astronomy department's usage of computing cores on HiPerGator, usually from running radiative transfer simulations on model grids of protoplanetary disks.

From cores to protostellar objects to stars (Budaiev, Richardson, Yoo)



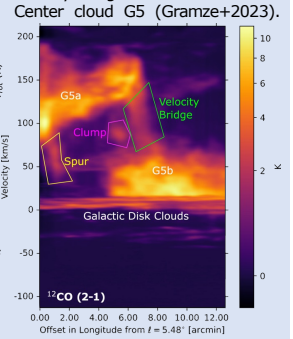
Upper left: continuum image of Sgr B2 M and N (Budaiev+2023). *Lower left:* average dust temperatures of young stellar object models as a function of model flux (Richardson+2024). *Lower right:* continuum images of W51 (Yoo+ in prep.).

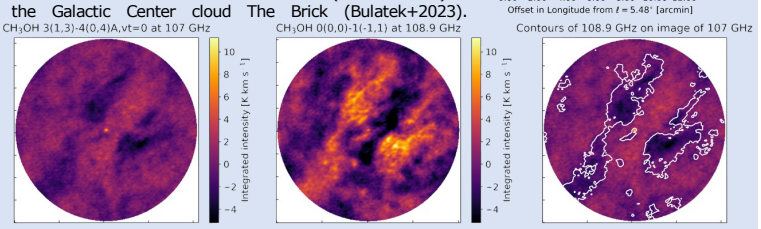
Chemistry and kinematics (Bulatek, Garcia Santa-Maria, Gramze, Jeff)



Left: dust continuum image of Sgr B2 DS surrounded by images and temperature maps (derived from methanol) of hot cores embedded in the cloud (Jeff+2024). *Below:* integrated intensity maps showing two methanol transitions and the detection of a methanol "dasar" (anti-inversion) in the Galactic Center cloud The Brick (Bulatek+2023).

Above: integrated intensity maps of NaCl (salt) in disk candidates (Ginsburg+2023). *Right:* position-velocity diagram of the Galactic Center cloud G5 (Gramze+2023).





Observing programs and software design engage global collaborators

The **ALMA-IMF** Large Program targets 15 high-mass protoclusters in the Galactic disk, from young (having only a few stars) to old (blowing out gas). There have been 15 papers published so far (plus 3 more that are in the submission phase) using data from the ALMA-IMF program.

The **ACES** ALMA Large Program provides the largest mosaic ever made of the Galactic Center/CMZ and it covers the entire bandwidth of ALMA Band 3. Two complementary surveys (**JACKS** on the VLA and **TENS** on the GBT) are providing crucial measurements of the large-scale structure of gas and dust in the footprint of the ACES survey. Group members are involved in each of these three projects.

Dr. Ginsburg is a co-founder of, and several group members are contributors to, The **Astropy** Project, which is an ecosystem of core Python packages for use by all astronomers. The first Astropy paper has over 10,000 citations!