Protostellar cores in Sagittarius B2 N and M

Budaiev et al., 2023

Summary by: Austin Rothermich

Many of the stars within our galaxy, as well as the galaxies in our local universe, were formed ∼10 Gyr ago during a time known as "Cosmic Noon". Conditions within this period of our universe's history were much different than we observe for most galaxies today, with a higher gas content creating dense star forming regions with a much higher star formation rate. If we want to better understand how the average star in the Milky Way formed, we therefore need to study current star forming regions which more closely resemble those which we believe existed in cosmic noon. That is exactly what the authors of this paper set out to do.

Budaiev et al 2023 were studying a region in the Milky Way known as the Central Molecular Zone (CMZ), a local analogue to the conditions of cosmic noon. Specifically, they were studying the Sagittarius B2 cloud (Sag B2), which despite only constituting only ∼10% of the CMZ's mass, accounts for ∼50% of its total star formation. Sag B2 is further broken up into four distinct regions: North (N), Main (M), South (S), and Deep South (DS). As the majority of the star formation is contained within the N and M regions, the authors limit their study to these two regions alone. Budaiev et al 2023 sought to derive an initial mass function (IMF) estimate for Sag B2 through the identification of protostellar cores.

Budaiev et al 2023 used 1mm & 3mm observations from the Atacama Large Millimeter Array (ALMA) taken in September of 2017. The 1mm data covered an area of 1.75×3.75 pc with a resolution of ∼500 AU, while the 3mm data covered an area of 6.5 × 4.5 pc with a resolution of ∼700 AU. The data was cleaned using a modified procedure utilizing the program `tclean`. Once the data was cleaned, and artifacts removed, the next step was to identify the protostellar cores. This was done using an automated source-finding dendrogram algorithm. However, Budaiev et al 2023 made some modifications which included: the removal of H II regions by hand, correcting the noise of the image so it stays constant throughout the region, and cropping any region of an image which overlaps with another image. With these corrections done, and their source identification complete, Budaiev et al 2023 carefully inspected by eye all detected sources twice; one inspection zoomed in to investigate the close in details, and again zoomed out so as to place the source into context with the surrounding cloud structure. These sources were then ranked as either 0 (non-core), 1 (core-candidate), or 2 (core). Their final catalog of protostellar cores within Sag B2 N & M contained 410 unique sources which received a score of 1 or 2. Some caveats exist, however. First, while the authors excluded as many artifacts from the data as possible, there still exist some artifacts which may create false positives/negatives. Second, while protostellar cores are not thought to exist within H II regions, the removal of these regions may still have removed some real cores from the analysis, as they may appear to coincide with H II regions though projection effects.

With the cores identified in Sag B2, Budaiev et al 2023 can use these to construct their IMF. First, they needed to calculate the masses of these cores. To do this, the authors used the equation:

$$M = \frac{T_b d^2}{\kappa_\nu T_{KE}} \tag{1}$$

where T_b and T_{KE} are the brightness and kinetic energy temperatures respectively, and d is the distance to the source. Budaiev et al 2023 adopt a uniform core kinetic temperature of $T_{KE} =$

50 K and a distance of 8.4 kpc. With these masses, Budaiev et al 2023 use the python algorithm `plfit` to fit a power law to their core mass function. In doing this, Budaiev et al 2023 find a power law with $\alpha = 2.4 \pm 0.1$. This value is in good agreement with the IMF power law of Kroupa, which has $\alpha = 2.35$. Finally, the authors wanted to take a look at the total stellar mass of the regions, along with their star formation rates. As the largest mass stars form quickly and become H II regions, the authors set an upper limit of 20 $M_{\odot}$ for all H II regions identified. The authors also used the Kroupa IMF to extrapolate the lowest mass end. Finally, Budaiev et al 2023 find a total inferred mass of 2,800 $M_{\odot}$ and 6,900 $M_{\odot}$ for the N and M regions respectively. This translates to a star formation rate of 0.0038 $M_{\odot}$ yr^{-1} for Sag B2-N 0.0093 $M_{\odot}$ yr^{-1} for Sag B2-M. Averaged together, this results in a total star formation rate of 0.013 $M_{\odot}$ yr^{-1}, which is consistent with estimates found for this region in previous studies.

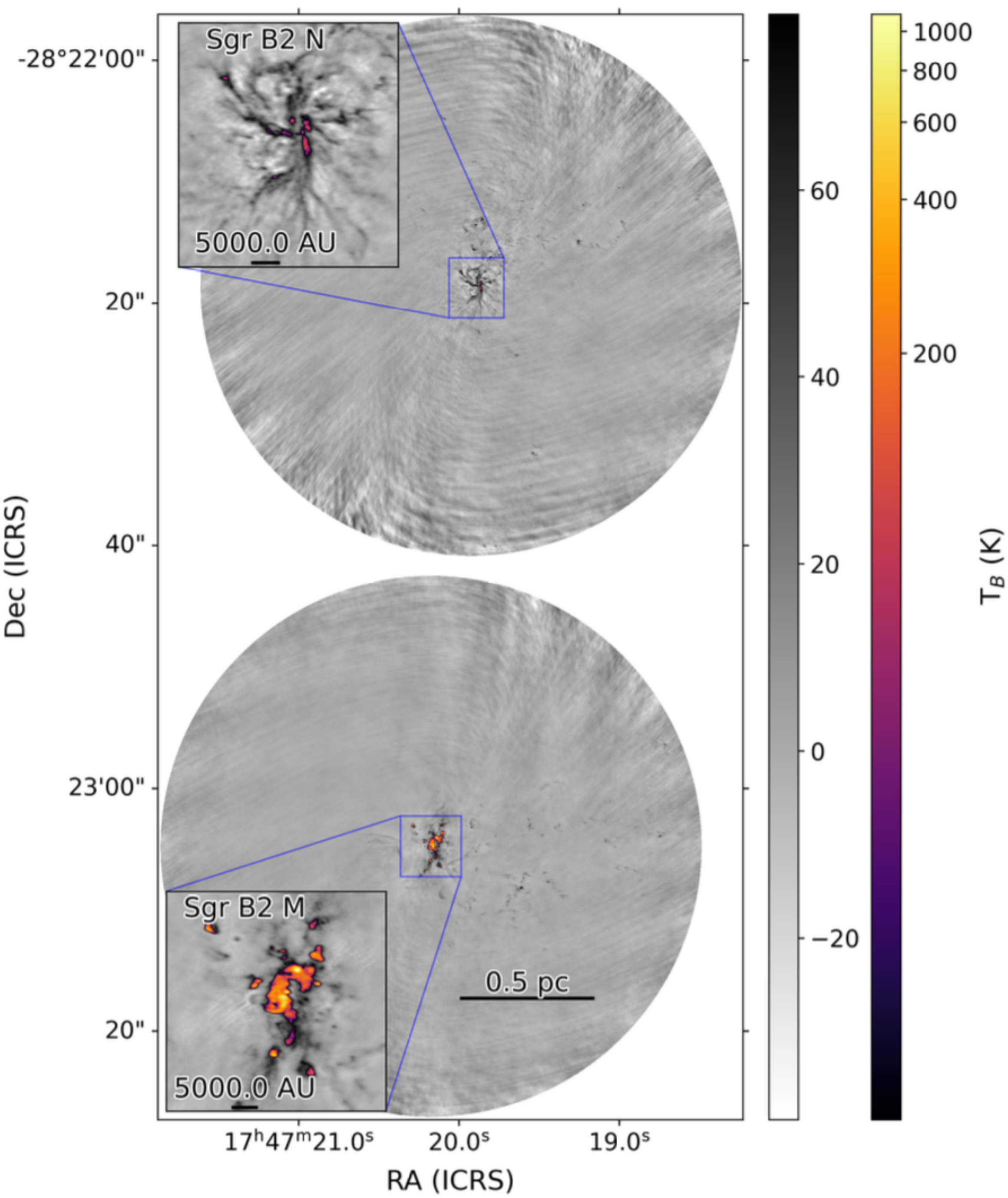

Figure 2. Band 6 (1 mm) continuum image of Sagittarius B2 N and M. Sgr B2 M appears to be hotter than Sgr B2 N. Due to the smaller field of view, H II regions Sgr B2 S and Z10.24 that are visible in Band 3 are not present here.

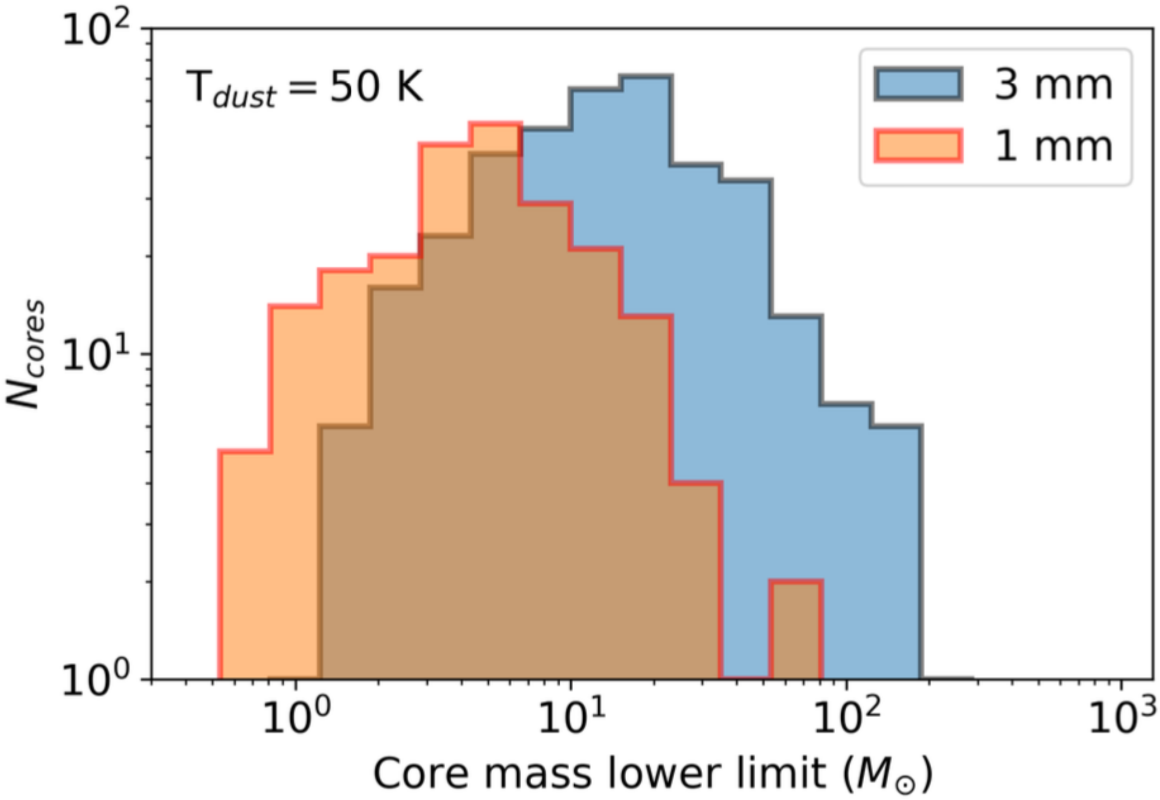

Figure 10. The inferred lower mass limit of the sources using the optically thin dust assumption for 1 mm and 3 mm data. 1 mm data has a higher mass sensitivity that is caused by the dust becoming more optically thick at higher frequencies and thus lower mass sources can be detected. We assume a uniform dust temperature of 50 K and a gas-to-dust ratio of 100. The turnover point at both wavelengths originates from the completeness limit over the whole imaged area.