EVIDENCE OF SHORT TIMESCALE FLUX DENSITY VARIATIONS OF UC H II REGIONS IN SGR B2 MAIN AND NORTH

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ABSTRACT

We have recently published observations of significant flux density variations at 1.3 cm in H II regions in the star-forming regions Sgr B2 Main and North. To further study these variations, we have made new 7 mm continuum and recombination line observations of Sgr B2 at the highest possible angular resolution of the Karl G. Jansky Very Large Array (VLA). We have observed Sgr B2 Main and North at 42.9 GHz and at 45.4 GHz in the BnA configuration (Main) and the A configuration (North). We compare these new data to archival VLA 7 mm continuum data of Sgr B2 Main observed in 2003 and Sgr B2 North observed in 2001. We find that 1 of the 41 known ultracompact and hypercompact H II regions in Sgr B2 (K2-North) has decreased \approx 27\% in flux density from 142 \pm 14 to 103 \pm 10 mJy (2.3\sigma) between 2001 and 2012. A second source, F3c-Main, has increased \approx 30\% in flux density from 82 \pm 8 to 107 \pm 11 mJy (1.8\sigma) between 2003 and 2012. F3c-Main was previously observed to increase in flux density at 1.3 cm over a longer period time between 1989 and 2012. An observation of decreasing flux density, such as that observed in K2-North, is particularly significant since such a change is not predicted by the classical hypothesis of steady expansion of H II regions during massive star accretion. Our new observations at 7 mm, along with others in the literature, suggest that the formation of massive stars occurs through time-variable and violent accretion.

Key words: H II Regions – radio continuum: ISM – stars: formation

1. INTRODUCTION

Accretion flows onto massive stars are so dense that they may become internally gravitationally unstable, leading to the formation of strong density fluctuations in the flows. The interaction of these fluctuations with the ionizing radiation from the massive stars at the centers of the flows may cause stochastic variations in the total mass of ionized gas (the H II regions) around the stars (Keto 2002, 2003; Keto & Wood 2006). In high-resolution, radiation-hydrodynamic, and magnetohydrodynamic simulations (Peters et al. 2010a, 2010b, 2011), the developing H II region surrounding a young high-mass star flickers between hypercompact (HC, \textit{d} < 0.05 pc, EM > 10^6 pc cm^{-6}) and ultracompact (UC, \textit{d} < 0.1 pc, EM > 10^7 pc cm^{-6}) states throughout the main accretion phase.\footnote{There are a number of definitions of UC and HC H II regions; here we use the criteria of Kurz (2002).}

Theories that describe the evolution of H II regions around non-accreting stars embedded in a homogeneous medium would predict monotonic expansion. The small size of HC H II regions, together with radio recombination line (RLR) widths indicating velocities of a few tens of kilometers per second (De Pree et al. 2011), suggest timescales on the order of 100 years, in agreement with the predictions of the simulations (Galván-Madrid et al. 2011). The timescale on which we can expect notable changes in the ionization state in the absence of an ionizing flux is the recombination timescale, which is defined as the inverse of the recombination rate. For 10^4 K hot gas, \textit{t}_{\text{rec}} = (2.59 \times 10^{-11} n_e)^{-1} \text{s}, when the electron number density \textit{n_e} is given in \text{cm}^{-3}. For an ultracompact H II region with \textit{n_e} = 10^6 \text{cm}^{-3}, this gives \textit{t}_{\text{rec}} = 12 \text{years}, and for a hypercompact region with \textit{n_e} = 10^8 \text{cm}^{-3} we have \textit{t}_{\text{rec}} = 0.12 \text{years}. In reality, of course, the ionizing flux is not shielded perfectly in all directions, the density and temperature in the H II region are inhomogeneous, and collisional ionization also contributes, leading to an order of magnitude estimate of 10–100 years. Thus, flux density variations might be detected on observable timescales (10 years) as changes in the brightness or sizes of the H II regions.

Sgr B2 is one of the most luminous star-forming regions in the Milky Way and is associated with a massive giant molecular cloud (\textapprox 10^5 \text{M}_\odot). The star-forming region contains 49 H II regions (Gaume et al. 1995), of which 35 are ultracompact and 6 are hypercompact. As the resolution of radio frequency observations has improved, Sgr B2 has been divided up into ever smaller sub regions. Sgr B2 is broadly separated into two areas: Sgr B2 Main, and Sgr B2 North (\textapprox 1’ north). As sub-sources were detected, they were given letters in order of increasing R.A., and then numbers (e.g., F1a). In this paper, we use the existing naming schemes of Gaume et al. (1995) and De Pree et al. (1998), additionally noting whether the source is located in Main or North (e.g., K2-North). The large number of UC and HC sources within a small field of view makes Sgr B2 ideal for testing theories of UC H II region evolution. Consequently, it has been a frequent target of...
interferometric observations at radio wavelengths (Gaume et al. 1995; De Pree et al. 1998, 2011, 2014; Qin et al. 2011). Gaume et al. (1995) published high-resolution ($\theta_{\text{beam}} = 0^\circ 25, \sim 2000$ AU) 1.3 cm radio images of the Sgr B2 Main and North star-forming regions taken in 1989 with the Very Large Array (VLA). De Pree et al. (1998) made the first high-resolution VLA 7 mm continuum observations of Sgr B2 in 1996/7 ($\theta_{\text{beam}} = 0^\circ 065, \sim 600$ AU), and high-resolution 7 mm line and continuum observations followed in 2003 (De Pree et al. 2011).

Fluctuations in radio brightness have been detected in several ionized sources with multi-epoch VLA observations (e.g., Cep A, Hughes 1988; NGC 7538 IRS1, Franco-Hernandez & Rodriguez 2004; MWC 349A, Rodriguez et al. 2007; G24.78+0.08, Galván-Madrid et al. 2008, Orion BN/KL, Gómez et al. 2008; Dzib et al. 2013; Rivilla et al. 2015). Our previous paper in this investigation (De Pree et al. 2014) presented the changes detected in Sgr B2 Main and North from observations of the 1.3 cm continuum emission between 1989 and 2012. At 1.3 cm, we detected four sources that changed in peak intensity over 23 years. K3-North was observed to decrease in peak intensity by 7%, and sources F1, F3, and F1a were observed to increase in peak intensity by 7%, 5%, and 16% respectively.

In this paper, we report new 7 mm continuum observations of Sgr B2 Main and North. We give 7 mm continuum parameters for all detected sources, including a newly identified 7 mm source in Sgr B2 North (K7-North). Archival observations of Sgr B2 Main and North at 7 mm have allowed us to search for changes in flux density between 2001 and 2012. In comparing our new observations with archival data, we detect significant changes in flux density from two sources: F3c-Main and K2-North. Simultaneous VLA 7 mm RRL observations will be introduced along with new VLA 1.3 cm RRL data from the same regions in a subsequent paper.

2. VLA OBSERVATIONS AND DATA REDUCTION

2.1. 2012 Sgr B2 Main and North 7 mm Line and Continuum

Sgr B2 Main was observed with the VLA at 7 mm on 2012 September 21 (during the move from the BnA to the A configuration), and Sgr B2 North was observed at 7 mm on 2012 October 28 (A configuration) under program name 11B-058. Each observation was for a total of four hours, with $\sim 2.5$ hr on source, and the balance of time for flux density, phase, and bandpass calibrators. Observations were made at 45.4 and 42.9 GHz, separated into 16 Intermediate Frequencies (IFs). One of the central IFs at each frequency was centered on an RRL (H52$\alpha$ at 45.4 GHz and H53$\alpha$ at 42.9 GHz) with $\sim 450$ km $s^{-1}$ bandwidth in each IF. The key observational parameters are summarized in Table 1.

For the Sgr B2 Main data, the basic calibration was carried out with the new VLA data pipeline, which flags frequencies and antennas with interference and determines and applies bandpass, phase, and amplitude calibrators. The calibrated continuum data were then self-calibrated and imaged using the Common Astronomy Software Applications. Basic calibration was also carried out for the Sgr B2 North observations using the VLA data pipeline, and self-calibration and imaging were done with the Astronomical Image Processing System (AIPS). The two continuum uv-data sets at 7 mm (42.9 and 45.4 GHz) were averaged and then imaged to make a single 44.2 GHz continuum image for Sgr B2 Main and North. Hereafter these 44.2 GHz images are referred to as Main-2012 and North-2012.

2.2. Archival Data (Sgr B2 Main)

Our previous 7 mm continuum observations of Sgr B2 Main from 1996/7 (43.3 GHz) and 2003 (45.4 GHz) were reported in De Pree et al. (1998, 2011; respectively). In order to compare images between epochs with matched uv-coverage, bandwidth, and restoring beams, we reprocessed the 1996/7 and the 2003 observations with AIPS. In order to compare source flux densities, it was important to make sure that the uv-coverage and bandwidth were as well-matched as possible, and that the comparison images were made with matched restoring beams.

In order to have matched uv-coverage between the 1996/7 and the 2012 data, we needed to severely restrict the number of antennas to only the seven pads that overlapped between the two observations. The 2012 observations were made in the BnA configuration, and the 1996/7 observations were made with the antennas located in a “spiral” pattern. However, the resulting images were too low-quality to make detailed comparisons in the complex region around the F sources.

We had more success making comparison images for the 2012 and the 2003 data sets. Sgr B2 Main was observed with the VLA in the BnA configuration on 2003 October 4. The uv-coverage was well-matched between these two observations, as the VLA was in its BnA configuration at both times. To compare the 2003 and the 2012 data, we made an image of the Sgr B2 Main region from a single line-free (32 MHz bandwidth) IF from the 2012 data, and used the same restoring beam for the two images (0$''$12 $\times$ 0$''$09, BPA = 60$'$). In the

| Parameter | Sgr B2 Main | Sgr B2 North |
|-----------|-------------|--------------|
| Program   | 11B-058     | 11B-058      |
| Observe Date | 2012 Sep 21  | 2012 Oct 28  |
| Configuration | BnA $\rightarrow$ A$^*$ | A |
| Observing Frequencies (GHz) | 42.9, 45.4 | 42.9, 45.4 |
| Averaged Frequency (GHz) | 44.2 | 44.2 |
| Total Observing Time (Time on source) | 4 hr (2$^3$30$''$) | 4 hr (2$^3$30$''$) |
| Flux Cal. | J1331+305   | J1331+305    |
| Phase Cal. | J1733–130  | J1733–130    |
| Bandpass Cal. | J1733–130 | J1733–130    |
| Continuum rms noise (mJy beam$^{-1}$) | 0.14 | 0.16 |
| Total Continuum Bandwidth (MHz) | 1024 | 1024 |

Note. $^*$ These observations were made while the VLA was being moved from the BnA to the A configuration.
discussion that follows, the matched-resolution images of Sgr B2 Main are referred to as Main-2003 and Main-2012m.

2.3. Archival Data (Sgr B2 North)

Sgr B2 North was observed with the VLA in the BnA configuration on 2001 February 12 (45.7 GHz). These data were edited and calibrated using standard techniques in AIPS, selecting only line-free channels to make the continuum image. In order to compare the 2001 and the 2012 images of Sgr B2 North, we had to restrict the uv-coverage of the 2012 data (which was observed in the A configuration). We set a uv-range when imaging the 2012 data that matched the uv-range in the 2001 data (with a maximum telescope separation of ~2.5 MA). We also imaged only a single IF from the 16 IFs of the 2012 data to match the bandwidth in the 2001 data. The resulting images were made with a matched restoring beam of (0.013 × 0.010, BPA = 0°). In the discussion that follows, the matched-resolution images of Sgr B2 North are referred to as North-2001 and North-2012m.

3. RESULTS

3.1. 7mm Continuum in Sgr B2 Main and North (2012)

The central region of the full bandwidth image (Main-2012) is presented in Figure 1 ($\theta_{\text{beam}} = 0''12 \times 0''10$, BPA = 73°, contours). The rms noise in the full resolution image is 0.14 mJy beam$^{-1}$. The dashed box in Figure 1 indicates the region of detail shown in Figure 4. Sources are labeled using the naming conventions of De Pree et al. (1998), with sub-sources labeled in Figure 4.

Figure 2 shows the full bandwidth image (North-2012; $\theta_{\text{beam}} = 0''11 \times 0''05$, BPA = 3°). The rms noise of the image is 0.16 mJy beam$^{-1}$. Sources are labeled using the naming conventions of Gaume et al. (1995). The sources in Sgr B2 North have unique morphologies, apparent for the first time in this high-angular-resolution image. K1-North has a cometary morphology, with a sharp cutoff in surface brightness on its western edge. K2-North consists of a bright, compact source, with a region of more diffuse, extended emission to the northwest. Source K3-North is shell-like ($D \sim 0''25$, 0.01 pc), with breaks in the edge-brightened shell to the north and southeast. K7-North is double-peaked, with the brighter of the two peaks located to the southeast. Finally, K4-North is a larger, shell-like source, with a diameter of ~1'' (~0.04 pc). The dashed box indicates the region of detail in Figure 3.

For each source above the 3σ noise level in the continuum images for Sgr B2 Main and North, we report the following parameters from 2D Gaussian fits (numbers in square brackets indicate column number): position [1, 2], fitted source size [3], peak intensity (mJy beam$^{-1}$) [4], and flux density (Jy) [5]. Table 2(a) shows these parameters for Main-2012 and Table 2(b) shows them for North-2012.

3.2. 7mm Difference Images

In order to search for flux density changes in Sgr B2 Main and Sgr B2 North, we compared source flux densities in the matched-resolution images. The analysis in Sgr B2 North was considerably simpler, so we begin with this region.

3.2.1. Sgr B2 North

Sgr B2 North contains a smaller number of well-isolated sources, so the comparison between epochs was more straightforward. In order to look for flux density changes in Sgr B2 North, we first normalized the two matched-resolution North images (North-2001 and North-2012m), aligned the two images, and then subtracted the two matched data sets. To determine the normalization factor, we took the ratio of the fitted flux densities of sources K1-North, K2-North, K3-North, and K7-North. The ratio was ~1.3 for sources K1, K3, and K7,
and 0.85 for source K2. To normalize the flux density between the images, we multiplied 2001-North by a factor of 1.3 (in AIPS) so that the flux density ratios for sources K1, K3, and K7 would be 1 between the two epochs.

Figure 3 shows the results of the difference image in Sgr B2 North. Figure 3(a) shows North-2012m in grayscale, and the difference between the two images is indicated as contours. The dashed box indicates the region of detail shown in Figure 3(b) and (c). Figure 3(b) shows the continuum in detail around source K2-North and the difference image between the normalized, matched-resolution images North-2012m and North-2001 (contours). Finally, Figure 3(c) shows the 7 mm continuum from K2-North as contours, showing the extension of emission to the northwest of the region of flux density change. Table 3 presents the fits to the North-2001 and North-2012m data sets. Continuum source parameters were determined for the sources in Sgr B2 North using the JMFIT task in AIPS. For each source above the 3σ noise level in the continuum images for Sgr B2 North, we report the following parameters from 2D Gaussian fits (numbers in square brackets indicate column number): position [1, 2], fitted source size [3], peak intensity (mJy beam$^{-1}$) [4], and flux density (Jy) [5]. Table 3 shows these parameters for North-2012m and North-2001. The reported size of K4-North is the average of two perpendicular slices made across the source in AIPS. K4-North was too faint to be fitted in the 2001 data.

In Table 3, there are two additional columns that list the ratio of the fitted peak intensities between the most recent observations (North-2012m), the oldest archival data available for those sources (North-2001) [6], and the ratio of flux densities for the same two epochs [7]. Values from Tables 3 were used to look for changes in peak intensity and flux density discussed below. K2-North is observed to decrease in both peak intensity and flux density. The other three detected continuum sources (K1, K3, and K7) are relatively constant. Source K7, newly discovered in the 2012 data, is also detected in the 2001 data presented here.

In order to check that the normalization described above has not spuriously introduced the change detected in K2-North, we note that the flux density ratios of pairs of sources within a single epoch give the same result as the comparison of the normalized images. That is, the flux density ratio of the K7/K3 sources does not change between 2001 and 2012, with K7/K3$_{2001}$ = 0.14 ± 0.1 and K7/K3$_{2012}$ = 0.13 ± 0.1. The ratio of the K7/K1 sources is also constant (within the errors of the ratio), with K7/K1$_{2001}$ = 0.20 ± 0.03 and K7/K1$_{2012}$ = 0.22 ± 0.03. By contrast, the ratio between K2-North and its companion sources in Sgr B2 North within the same epoch does change between 2001 and 2012. K2/K7$_{2001}$ = 4.7 ± 0.7, but this ratio falls to 3.3 ± 0.4 by 2012. Likewise, the ratio K2/K3$_{2001}$ falls from 0.66 ± 0.10 to 0.43 ± 0.06 in 2012. As a result, we conclude that making difference images of the normalized, matched uv-coverage, and matched bandwidth images is a valid method for looking for individual source flux density changes. Table 3 indicates that source K2-North is the only source in Sgr B2 North that shows a decrease in both peak intensity and flux density between 2001 and 2012.

3.2.2. Sgr B2 Main

The crowded field in the boxed region shown in Figure 1 of Sgr B2 Main made Gaussian source fitting more difficult than it was in Sgr B2 North. In Sgr B2 Main, we chose a slightly different method to look for flux density changes. We normalized the 2003-Main image in the same manner, choosing the ratio of the G and F10.37 sources (well-isolated, high signal-to-noise sources) to determine the normalization factor. For these two sources, the ratio of the 2012 to the 2003 flux density was 0.72 ± 0.02, so we multiplied the Main-2003 image by 0.72 and then aligned and subtracted the two images.

Figure 4 shows the region of detail from Figure 1 of the sources in Sgr B2 Main. Figure 4(a) shows the Main-2012 data as contours, with sub-sources named as in De Pree et al. (1998). Figure 4(b) shows the Main-2012m image (grayscale) and the difference image between Main-2012m and Main-2003...
as contours. The difference image highlights two regions where flux density appears to have increased between 2003 and 2012: F3c-Main and F1f-Main. Only the increase in peak intensity in F3c-Main is greater than 2σ (see below).

3.3. Sources with Flux Density Changes

In the current data, we have observed significant flux density changes in two sources: K2-North and F3c-Main. These two sources represent ~5% of the known UC and HC H II regions in Sgr B2. F3c-Main has increased by ~30% in flux density, from 82 ± 8 to 107 ± 11 mJy (1.8σ). In the Sgr B2 North region, K2-North has decreased by ~29% in peak intensity from 40.7 ± 2.0 to 28.9 ± 0.3 mJy beam⁻¹ (5.9σ) and by ~27% in flux density from 142 ± 14 to 103 ± 10 mJy (2.3σ).

We note that a flux density increase in F3c-Main has also been detected at 1.3 cm (De Pree et al. 2014). In K2-North, the decrease in flux density is slightly offset from the continuum peak. Based on the simulations of (Peters et al. 2010a, 2010b, 2011), the detected variations are not expected to necessarily be centrally peaked. The location of the variations depends on the interaction of the radiation with the complex accretion flow (Keto 2002, 2003; Keto & Wood 2006).

To provide an additional way to view the changes over time in Sgr B2 North, the source flux densities of the individual sources in North-2001 and North-2012m are shown in Figure 5. Note that only source K2-North appears to have a significant change in flux density between the two epochs. The other sources are consistent with level flux densities between the two epochs.

3.3.1. Observations at Different 7 mm Frequencies

The observations at 7 mm were all made at slightly different frequencies, ranging from 44.2 GHz (Main-2012) to 45.4 GHz (Main-2003) to 45.7 GHz (North-2001). Using the relationship \( S_{\nu} \propto \nu^{\alpha} \) (where \( S_{\nu} \) is continuum flux density and \( \alpha \) is spectral index), we can examine whether any of the flux density changes detected at 7 mm could result from comparing observations at different 7 mm (Q-Band) wavelengths. The range in spectral index values possible in UC and HC H II regions is from \(-0.1\) (optically thin) to 2 (optically thick), though at 7 mm, few sources are optically thick. The largest known spectral index values in sources in Sgr B2 Main are the “rising spectral index” sources with \( \alpha \sim 1.0 \) (Gaume et al. 1995; De Pree et al. 1998). But, using these two extreme spectral index values (\(-0.1\) and 2), and the range of observed frequencies, we can determine that in Sgr B2 Main, observations at different frequencies (45.4 GHz in 2003 and 44.2 GHz in 2012) would result in flux density differences at the <1% level for \( \alpha \sim 0.1 \) (optically thin source) and at the <6% level for \( \alpha \sim 2 \). In Sgr B2 North, observations at different frequencies (45.7 GHz in 2001 and 44.2 GHz in 2012) would result in flux density differences at the <1% level for \( \alpha \sim 0.1 \) (optically thin source) and at the <7% level for \( \alpha \sim 2 \).
Thus, we conclude that our observed flux density changes in F3c-Main (flux density increase of $\sim$29%) and K2-North (flux density decrease of $\sim$27%) cannot be the result of observations made at slightly different frequencies. The detected decrease in flux density of K2-North, for example, is a factor of $>4$ larger than one would expect from a decrease resulting from a change introduced by observations made at slightly different frequencies.

4. DISCUSSION

Galván-Madrid et al. (2011) used simulations by Peters et al. (2010a, 2010b, 2011) to predict that an individual source observed at 2 cm has a 5% chance of experiencing more than a 50% change in flux density over a 20-year baseline and a 14% chance of experiencing a change larger than 10%. Consequently, we also expect variations of the observed 7 mm flux. However, the actual percentages are highly model-dependent, although they are likely of the correct order of magnitude. Furthermore, they will depend on whether the region is optically thick or optically thin, and on the relative contribution of thermal emission from dust. Since the optical depth of the free–free emission decreases with increasing wavelength, the predictions for the observed variations at 7 mm should be smaller than those estimated by Galván-Madrid et al. (2011) at 2 cm. Furthermore, dust emission contributes more at 7 mm than at 2 cm. These two effects act together to decrease the possible variability at 7 mm. In addition, these two competing factors are likely to be dominated by the sensitivity of the observations. As a result, we expected the “flickering” effect might be less at 7 mm than predicted at 2 cm, simply because of the lower signal-to-noise in the archival data (2003-Main and 2001-North).

Comparison with 1.3 cm Results: We find significant changes in flux density of the 7 mm continuum emission from two sources in our sample: K2-North (between 2001 and 2012) and F3c-Main (between 2003 and 2012). In comparison, at 1.3 cm we detected four sources in the same field that changed in peak intensity over 23 years (between 1989 and 2012; De Pree et al. 2014). K3-North was observed to decrease in peak intensity by 7%. Sources F1-Main, F3-Main, and F1a-Main were detected to increase in peak intensity by 7%, 5%, and 16% respectively over the same period.

These requirements suggest that flux density variations may occur in a small subset ($<10\%$) of sources on timescales of only a few years. Indeed, such rapid changes have already been found in Orion BN/KL (Gómez et al. 2008; Rivilla et al. 2015) and W3(OH) (Dzib et al. 2013). These recent observations and our observations of Sgr B2 Main and North indicate that short-timescale monitoring of source flux densities in crowded fields of UC and HC H II regions may identify other variable sources. Our difficulty in isolating and fitting the sources in Sgr B2 Main in the current investigation indicates that the technique

| Source Name | R.A. (1$^{\text{h}}$0$^{\text{m}}$) | decl. ($^\circ$) | Size, PA | Peak Intensity (mJy beam$^{-1}$) | $\delta_0$ (mJy) |
|-------------|----------------------------------|----------------|----------|---------------------------------|----------------|
| B           | 19.94 s                          | 03:00          | $\sim$0$^\circ$9 | 10.9                            | 80 $\pm$ 8     |
| B10.06      | 19.87 s                          | 01:22          | 0$^\circ$29 $\times$ 0$^\circ$18, 55$^\circ$ | 2.0 | 9 $\pm$ 0.9 |
| E           | 20.11 s                          | 08:38          | $\sim$0$^\circ$65 | 4.8 | 63 $\pm$ 6 |
| F1a         | 20.12 s                          | 03:36          | 0$^\circ$18 $\times$ 0$^\circ$15, 54$^\circ$ | 30.2 | 71 $\pm$ 7 |
| F1c         | 20.13 s                          | 03:38          | 0$^\circ$23 $\times$ 0$^\circ$19, 165$^\circ$ | 25.6 | 92 $\pm$ 9 |
| F1d         | 20.13 s                          | 04:22          | 0$^\circ$15 $\times$ 0$^\circ$13, 145$^\circ$ | 9.1 | 15 $\pm$ 2 |
| F1h         | 20.15 s                          | 03:59          | 0$^\circ$32 $\times$ 0$^\circ$16, 67$^\circ$ | 34 | 153 $\pm$ 15 |
| F1h         | 20.12 s                          | 04:22          | 0$^\circ$14 $\times$ 0$^\circ$10, 59$^\circ$ | 10.2 | 16 $\pm$ 1 |
| F2          | 20.18 s                          | 03:55          | 0$^\circ$24 $\times$ 0$^\circ$23, 76$^\circ$ | 12.2 | 56 $\pm$ 6 |
| F3a         | 20.17 s                          | 04:22          | 0$^\circ$22 $\times$ 0$^\circ$15, 74$^\circ$ | 13.7 | 38 $\pm$ 4 |
| F3c         | 20.17 s                          | 04:24          | 0$^\circ$24 $\times$ 0$^\circ$16, 112$^\circ$ | 33 | 107 $\pm$ 11 |
| F3d         | 20.18 s                          | 04:25          | $\sim$0$^\circ$35 | 51.4 | 560 $\pm$ 60 |
| F3e         | 20.23 s                          | 04:26          | 0$^\circ$22 $\times$ 0$^\circ$19, 156$^\circ$ | 5.7 | 21 $\pm$ 2 |
| F4          | 20.22 s                          | 04:22          | 0$^\circ$25 $\times$ 0$^\circ$17, 139$^\circ$ | 25.4 | 92 $\pm$ 9 |
| F10.27      | 20.09 s                          | 05:22          | 0$^\circ$12 $\times$ 0$^\circ$10, 76$^\circ$ | 3.8 | 4 $\pm$ 0.4 |
| F10.37      | 20.19 s                          | 05:28          | 0$^\circ$15 $\times$ 0$^\circ$12, 101$^\circ$ | 23.6 | 38 $\pm$ 4 |
| F10.39      | 20.21 s                          | 06:55          | 0$^\circ$13 $\times$ 0$^\circ$11, 83$^\circ$ | 15.1 | 18 $\pm$ 2 |
| G           | 20.30 s                          | 02:59          | 0$^\circ$26 $\times$ 0$^\circ$19, 54$^\circ$ | 25.5 | 109 $\pm$ 11 |
| G10.44      | 20.26 s                          | 03:22          | 0$^\circ$12 $\times$ 0$^\circ$10, 64$^\circ$ | 6.0 | 6 $\pm$ 1 |
| I           | 20.39 s                          | 05:00          | $\sim$0$^\circ$9 | 4.1 | 318 $\pm$ 32 |
| I10.52      | 20.34 s                          | 08:00          | 0$^\circ$16 $\times$ 0$^\circ$14, 51$^\circ$ | 4.1 | 7 $\pm$ 0.7 |

Note.  
* The source size measurement for the shell-like source K4-North is described in the text.
Table 3
Sgr B2 North 7 mm Radio Continuum Parameters—Matched uv-coverage

| Source | R.A. | decl. | Size, PA | Peak Intensity | S, | Peak Intensity | Flux Density |
|--------|------|-------|----------|----------------|----|----------------|-------------|
| Name   | 17h47m | -28° 22′ | θmaj × θmin, BPA° | (±0.01 s) | [1] | [2] | [3] | [4] | [5] | [6] | [7] |
| North-2012m | | | | | | | | | | | |
| K1     | 19.77 s | 20°6′ | 0″47 × 0″30, 40° | 13.6 | 143 ± 14 | 0.99 ± 0.15 | 0.95 ± 0.13 |
| K2     | 19.87 s | 18°4′ | 0″30 × 0″15, 157° | 28.9 | 103 ± 10 | 0.71 ± 0.05 | 0.73 ± 0.10 |
| K3     | 19.90 s | 17°2′ | 0″30 × 0″28, 139° | 37.5 | 239 ± 24 | 1.06 ± 0.06 | 1.11 ± 0.15 |
| K4     | 19.99 s | 04°8′ | ~0″9″ | 4.1 | 139 ± 14 | ... | ... |
| K7     | 19.90 s | 13°5′ | 0″16 × 0″14, 130° | 18.0 | 31 ± 3 | 0.78 ± 0.09 | 1.03 ± 0.14 |
| North-2001 | | | | | | | | | | | |
| K1     | 19.79 s | 20°5′ | 0″51 × 0″28, 15° | 13.8 | 151 ± 15 | ... | ... |
| K2     | 19.89 s | 18°3′ | 0″30 × 0″15, 163° | 40.7 | 142 ± 14 | ... | ... |
| K3     | 19.91 s | 17°0′ | 0″30 × 0″27, 168° | 35.1 | 216 ± 22 | ... | ... |
| K4     | ... | ... | ... | ... | ... | ... | ... |
| K7     | 19.91 s | 13°3′ | 0″14 × 0″12, 165° | 23.2 | 30 ± 3 | ... | ... |

Note. a The source size measurement for the shell-like source K4-North is described in the text.

Figure 4. Both (a) and (b) show the same region of detail from the image of Sgr B2 Main in Figure 1. (a): Contours show continuum emission from Sgr B2 Main in 2012. The first negative and positive contours are at the 7σ (1 mJy beam⁻¹) level in the 2012 image. Successive positive contours are at 2, 4, 8, 16, and 32 times the 7σ level. A slightly higher contour cutoff was chosen for this image to make source labels easier to read. Sources are labeled as named in De Pree et al. 1998. (b): The difference image shows the 2012-Main (grayscale), with the difference image between 2012 and 2003 overlaid (contours). The uv-coverage, bandwidth, and restoring beam were matched between these two epochs as described in the text. Both of the images used to make the difference overlay were made with a restoring beam of θbeam = 0″12 × 0″09. BPA = 60°. In the difference image (contours), the first negative and positive contours are at the 5σ level of the 2003 image (4 mJy beam⁻¹). The beam size is indicated in the lower left corner of each image.

used at 1.3 cm (precisely matched configurations and bandwidths) makes the job of comparing flux densities between two epochs much simpler.

Submillimeter Array (SMA) 850 μm Observations: Qin et al. (2011) have published SMA observations of the 850 μm continuum in Sgr B2 Main and Sgr B2 North (Sgr B2-M and Sgr B2 N in their paper). They have reported detections of 2 peaks in Sgr B2 North and 12 in Sgr B2 Main, and discussed the coincidence between their continuum peaks and the known source positions of ultracompact regions in Sgr B2 Main and Sgr B2 North. The brightest continuum peak [Sgr B2(M)-SMA1, 2.39 ± 0.138 Jy beam⁻¹] is located near the position of F3c-Main, one of the two sources reported in this paper to change in flux density at 7 mm between 2003 and 2012.
Their second brightest continuum source [Sgr B2(N)-SMA1, 1.79 ± 0.039 Jy beam⁻¹] lies at the position of K2-North, the other source in which a significant change in 7 mm peak intensity and flux density has been recorded. These observations are consistent with the theoretical suggestion that flickering is caused by strong accretion flows (Peters et al. 2010a).

**New Source K7-North:** We have detected a new continuum source to the north of the well-known K1-K3 sources at R.A. 17°47′19″895, decl. −28°22′13″47. The location of this source has not been previously published to our knowledge, though Qin et al. (2011) mention that a nearby source was detected in the 7 mm continuum observations reported by Rolffs et al. (2011). The source (which we designate K7-North) is visible in both the 2012 data presented here, and the 2001 data of Martín-Pintado (2015). The source parameters at both epochs are presented in Table 3, and flux density is constant over the 11 year time span observed (2001–2012). This source was not reported in the 1.3 cm observations of Gaume et al. (1995), most likely because it is located in the midst of diffuse, patchy emission associated with two shell-like sources (K5-North and K6-North). The current high-resolution 7 mm image (North-2012) has filtered out most of the diffuse emission from the shells, highlighting this point source. K7-North lies within 0′′2 in both R.A. and decl. from the position of Sgr B2(N)-SMA2, one of two continuum peaks in Sgr B2 North detected in the 850 μm continuum (Qin et al. 2011).

**5. CONCLUSIONS**

New 7 mm continuum observations with the VLA indicate that two of the ultracompact H II regions in Sgr B2 (F3c-Main and K2-North) have experienced changes in flux density over short timescales (9 years and 11 years, respectively). The detection of source variability (and in particular decreases in both peak intensity and flux density in K2-North) support the hypothesis that UC and HC H II regions may be located in dynamically and morphologically complex and time-variable environments during the first 100,000 years of their evolution, producing short-timescale variability. We are undertaking similar observations of other crowded massive star-forming regions to further test this hypothesis.

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