The CARMA Orion Survey
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Abstract
Here we present the initial results from the CARMA Orion survey. The survey includes degree-size mosaics of molecular line emission from both the Nobeyama 45m single-dish telescope and the CARMA interferometer. The mosaics cover a number of famous regions, including the integral-shape filament, the Orion KL region, the Orion Bar, L1641-N, L1641-C, etc. We combine the single-dish data and the interferometer data in the uv-plane, producing an unprecedented view of the molecular gas distribution, kinematics, excitation, etc. Practical details of the data combination method are given in the paper. Here we show a brief introduction to the data qualities and statistics, with the aim of fostering follow-up scientific studies.

Introduction
Star formation (SF) in the Milky Way takes place in giant molecular clouds (GMCs) that can contain 10^7 M⊙ of gas. A thorough understanding of GMCs has been a major goal in the subject of SF for decades. However, due to the complexity in GMCs, there are still many questions about the picture of SF process. One of them is rooted in the high dynamic range of SF, which spans from ~10 pc scale of GMCs all the way down to ~sub-AU scale of stars, corresponding to a factor of ~10^4 change in physical scales. Such high contrast in physical scales calls for high dynamic range observations. In this context, combining single-dish observations with interferometer observations can be very helpful for probing both large-scale structures of the GMC gas as well as small-scale details, thus providing a comprehensive picture of the GMC and SF therein. The CARMA Orion project provides such a large-scale, high dynamic-range observation of CO isotopologues (Figure 1). The project includes 12CO, 13CO, and C18O in 1-0 maps of a 1x2 deg2 region in Orion A using the Combined Array for Research in Millimeter Astronomy (CARMA) and the Nobeyama Radio Observatory 45 m telescope (NRO45). The broad goal of our program is to trace the gas kinematics from a scale of 7.2 pc down to about 0.02 pc (~4000 AU). Never before have images with such a large spatial dynamic range (~400) been obtained with a spatial resolution that can resolve individual protostellar envelopes.

Observations
The CARMA mosaic was carried out between 2013 to 2014 under the key project: c1061 (PI: Carpenter). Molecular lines 12CO(1-0, 115 GHz), 13CO(1-0, 110 GHz), and C18O(1-0, 109 GHz) were included in the spectral setup. In total, the mosaic footprint covers the Orion A cloud between RA(J2000) = (05:33:07, 09:38:46) and DEC. (J2000) = (07:12:40, -48:27'). The total project time amounts to roughly 650 hours. The observation used the CARMA 15-element array which includes six 10m antennas and nine 6m antennas. We applied the standard calibration procedures. Two array configurations (DE) were adopted in the project, with a uv-coverage encompassing 3-40 kλ (λ being 2.6 mm at 115 GHz), corresponding to angular scales 2-70". The resulting synthesized beam size using the data from these two CARMA configurations is ~6".

Between December 2007 and February 2017, we carried out mapping observations in 12CO(1-0, 115 GHz), 13CO(1-0, 110 GHz), and C18O(1-0, 109 GHz) toward the Orion A GMC with a 25-beam receiver, BEARS, and new 4-beam receiver, FOREST, which is a dual-polarization sideband separating SIS receiver on the NRO45 telescope. The telescope beam size is ~14" at 115 GHz. Due to the gridding of the OTF mapping, the final imaging resolution is ~21".

Results and Summary
Figure 2 shows the observation coverage (Left) and resulting combined images for 12CO(1-0) data (peak intensity image in the middle and velocity-range integrated intensity on the right). The map extends from the OMC-3 and OMC-2 regions in the north (at a declination of ~5°) to the V880 Ori Group (i.e., NGC 1999) and L1641-C region in the south, spanning about 2 degrees in declination. Widespread, complex structures can be seen in the maps. The false color image shows a combination of three velocity-range integrated intensity maps (4.8 - 7.1 km s⁻¹ in blue; 7.3 - 9.6 km s⁻¹ in green; 9.8 - 12.1 km s⁻¹ in red). At the same time, we also have the combined data for 13CO(1-0) and C18O(1-0). We will use these data to study the turbulence, outflows, shells, bubbles, filamentary structures, etc. We will also compare the gas kinematics provided by the molecular line cubes with the kinematics of the star clusters. We expect a fruitful outcome of scientific results to be obtained from the dataset.

Figure 3: flux density ratio between CARMA and NRO45 images.

Figure 4: NRO45 Gaussian uv-sample with a FWHM ~3.5 kλ.

Figure 5: CARMA uv-coverage (configurations D55).

Figure 1: Left: NRO45 12CO(1-0) observations in the Orion KL region. Middle: CARMA observations in the same region. Right: combined data in the same region.