The Fossil Nuclear Outflow in the Central 30 pc of the Galactic Center

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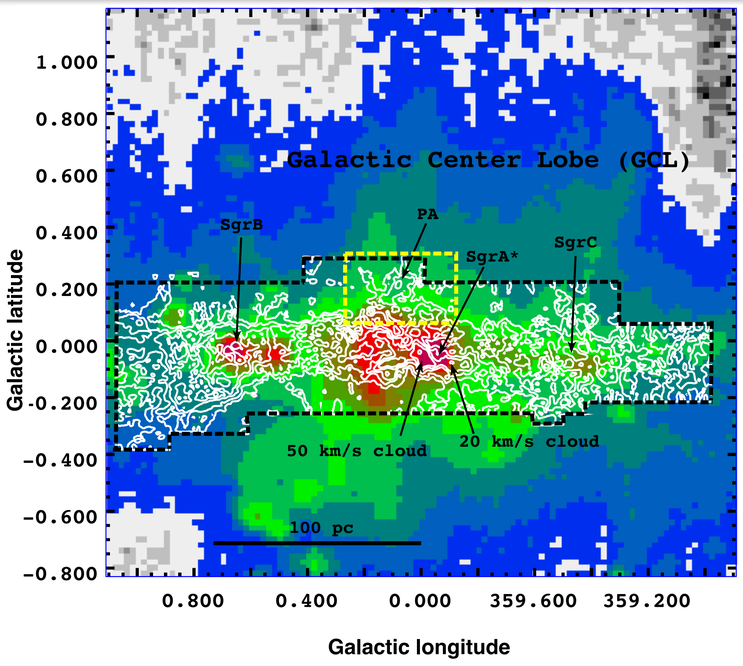
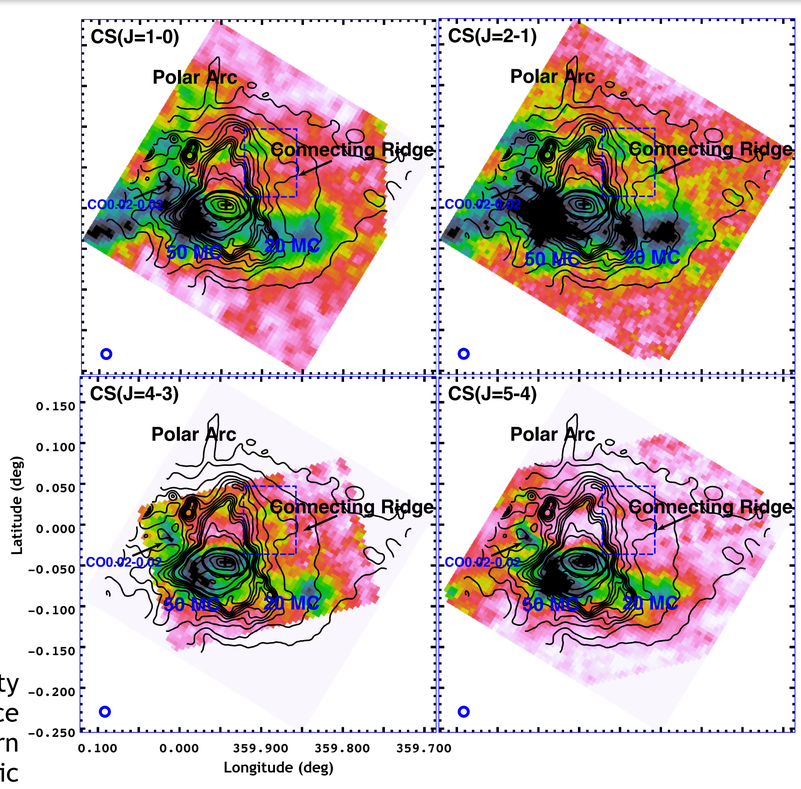
Hsieh et al. 2015 ApJ , 811, 142; Hsieh et al. 2016 ApJ, accepted (astro-ph->arXiv:1607.03673)

Dense Molecular Gas in the Galactic Center

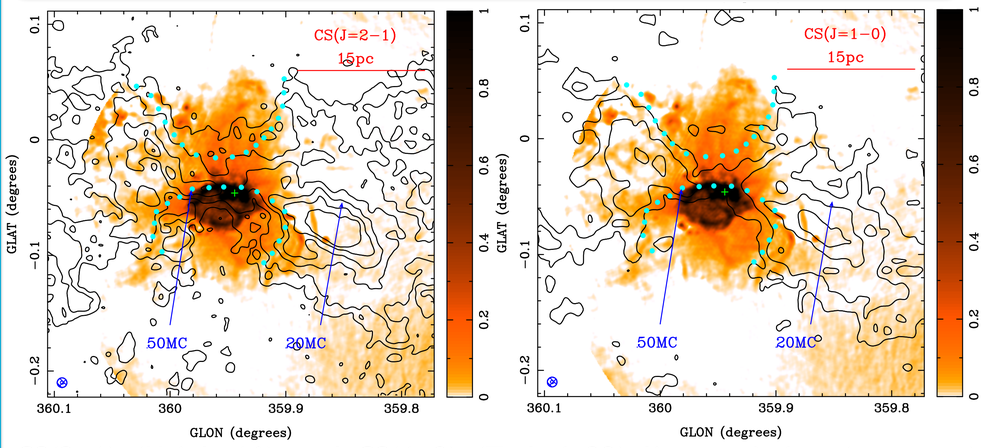


Dense Gas and Infrared Emission: CS(1-0) integrated intensity map (Tsuboi+99; contours) overlaid on the MSX E-band map (Price +01; color). The Galactic Center Lobe (GCL) (e.g., Bland-Hawthorn +03, Law+09) is a double-horn feature that straddles the Galactic Plane.



We present the dense gas maps in the central 30 pc of the Galactic Center (GC). We observed the CS(Ju=5,4,2) lines with the Nobeyama 45m (NRO 45m) and the Caltech Submillimeter Observatory (CSO) (Hsieh+15,16). Our goal is to obtain reliable maps less affected by the foreground/ambient cold gas in the GC. We focus on the complex activities and physical conditions in the nuclear region probed by the dense gas. The archival CS(1-0) line map (Tsuboi+99) is also shown in the left figures for comparison. We reported a new feature called the connecting ridge (CR) which was detected with the CS(4−3) line. The CR has a velocity gradient perpendicular to the disk rotation. It is physically associated with the extraplanar polar arc (PA) (Bally 88; Henshaw+16). The PA extends from north of the SgrA* region at a 40 deg and shows a large velocity gradient from (l, b, Vsys) =(0 , 0.05, 70 km/s) to (0.2, 0.25, 140 km/s) and becomes confused with the molecular clouds in the SgrA* region. We find that the kinematic and spatial structures connect the Galactic disk, the CR, and the PA. These results suggest that the molecular gas might be lifted out of the Galactic plane. We, thus, propose the idea of a molecular outflow in the central 30 pc of the GC and suggest that the PA is pushed away, possibly by the energy of 8-80 supernovae explosions (Hsieh+15). We also confirmed the PA belongs to the eastern protrusion of the GCL.

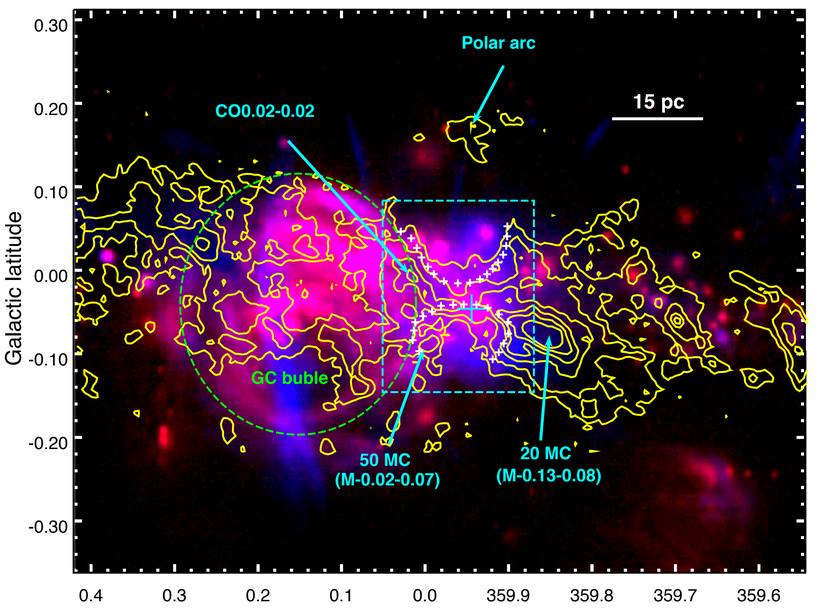
Shell-Like Molecular Feature



CS(2−1) (Hsieh+16) and CS(1−0) (Tsuboi+99) line emission (contours) integrated from −10 km/s to 10 km/s overlaid on archival VLA 20-cm continuum (color). The resolution is 30″ (1.1 pc) for both images (blue circles in lower left corners). The molecular gas associated with the molecular cloud called 20 MC and 50 MC shows an hourglass-shaped feature (hereafter HG-feature), with a northwest-southeast orientation perpendicular to the Galactic disk, with the openings or cavities that surround the radio halo (Pedlar 89; Zhao+14). **The HG-feature is marked with cyan dots.** The HG-feature has a size of ~13 pc.

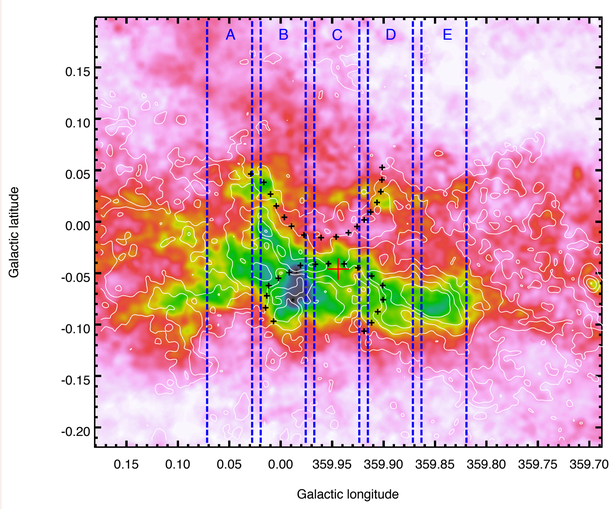
Molecular Shell and Bipolar Outflow

We display the color-composite map of the 20-cm (Yusef-Zadeh+04) and the MSX E-band 21-μm map (Price+01; Simpson+99, 07). We compare the low velocity CS(2−1) line emission (same as left panel) with the dust (21 μm) and the emission from free electrons (20 cm). The map shows that the low-velocity gas roughly surrounds the infrared/radio features. The 21 μm emission shows the prominent Galactic center bubble (Simpson+07) (GC bubble, or arc bubble in Ponti+15) near the SgrA radio halo/arc. The northern part of the GC bubble has a radio feature known as the “radio arc” (e.g. Serabyn & Guesten 1987; Lang+99). The GC bubble could be produced by the starbursts in the past (Simpson+07; Sofue 03). We show the low-velocity CS(J = 2−1) line map spatially coincides with the infrared/radio features. The HG-feature seems to surround the warm dust and the free-electron emission.

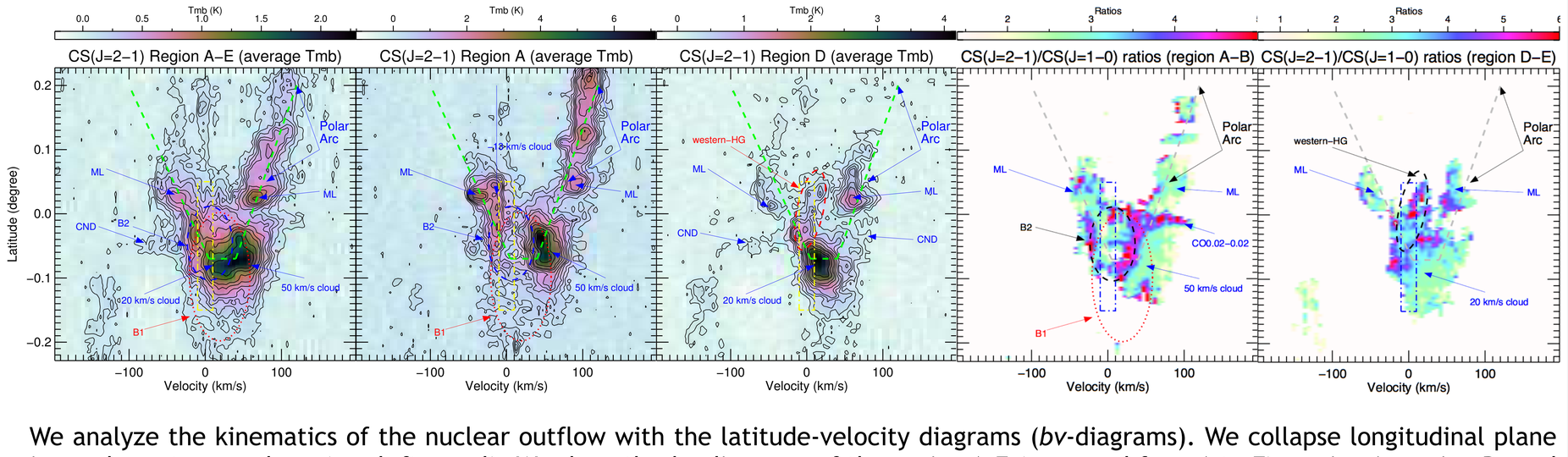


Outflow and GC bubble: CS(2-1) integrated intensity map (contours) overlaid on the VLA 20 cm (blue) and the MSX E-band maps (red).

The Fossil Nuclear Outflow



Regions of the latitude-velocity diagrams (right panels) are shown. Each region covers a width of 2.6′ in longitude. Color map shows the CS(2-1) integrated intensity map from -197 km/s to 197 km/s and the contour map shows the CS(2-1) map integrated form -10 km/s to 10 km/s. Regions A, B, C, D, E are marked. The central large red cross marks the position of SgrA*. Small black crosses mark the HG-feature. The spacing between regions corresponds to the convolved beam size of 30″.



We analyze the kinematics of the nuclear outflow with the latitude-velocity diagrams (*bv*-diagrams). We collapse longitudinal plane in a cube onto one plane (see left panel). We show the *bv*-diagrams of the region A-E (averaged from A to E), region A, region D, and the CS(2-1)/CS(1-0) ratios for averaging region A/B and C/D, respectively. The yellow/blue rectangles mark the HG-feature. The 50/20 MC are located in the Galactic disk. The PA extends out of the Galactic disk to b~0.23 deg with increasing velocity and connects to the Galactic disk via the molecular loop ((ML; see Hsieh+15). The B1/B2 labels show the position of an expanding bubble south of the Galactic disk. Other known features of the CND and the HVCC CO0.02-0.02 are labeled. We find that the PA can be traced back to the Galactic disk. This provides clues of the launching point of the PA , roughly 6X10^6 years ago. Implications of the dynamical time scale of the PA might be related to the GCL at parsec scale. The *bv*-diagrams show that the eastern edge of the HG-feature is associated with expanding bubble B1, ~7 pc away from SgrA*. The dynamical time scale of bubble B1 is ~ 3X10^5years. The bubble B1 is interacting with the 50 MC. Part of the molecular gas from the 50 MC was swept away to the bubble B1 to b = −0.2. The western edge of the HG-feature seems to be the molecular gas entrained from the 20 MC towards the north of the Galactic disk. Our results suggest a fossil explosion in the central 30 pc of the GC a few 10^(5-6) years ago. More information please see Hsieh+16.