A Possible Detection of Ionized Gas Orbiting around an IMBH embedded in the Galactic Center IRS13E Complex; The Second Galactic Center Black Hole?

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The Galactic Center is the nuclear region of the nearest spiral galaxy, the Milky Way, and contains the supermassive black hole with $M \sim 4\mathrm{x}10^6\ M_\odot$, Sagittarius A*(Sgr A*) . One of the basic questions about the Galactic Center is whether or not Sgr A* is the only "massive" black hole in the region.

The IRS13E complex is a very intriguing IR object that contains a large dark mass comparable to the mass of an intermediate mass black hole (IMBH) from the proper motions of the main member stars. However, the existence of the IMBH remains controversial. There are some objections to accepting the existence of the IMBH.

In this study, we detected ionized gas with a very large velocity width ($\Delta V_{\mathrm{FWZI}} \sim 650$ km s^{-1}) and a very compact size (r ~ 400 au) in the complex using ALMA. We also found an extended component connecting with the compact ionized gas. The properties suggest that this is an ionized gas streamer on the Keplerian orbit with high eccentricity. The enclosed mass is estimated to be $M \sim 6\mathrm{x}10^4\ M_\odot$ by the analysis of the orbit. The mass does not conflict with the upper limit mass of the IMBH around Sgr A*, which is derived by the long-term astrometry with VLBA. In addition, the object probably has an X-ray counterpart.

Consequently, a very fascinating possibility is that the detected ionized gas is rotating around an IMBH embedded in the IRS13E complex.

Please see Tsuboi et al. APJL, 850, id. L5, (2017)

We observed the continuum emission of Sgr A* and the Mini-spirals at 340 GHz as an ALMA Cy.3 program (2015.1.01080.S. PI M.Tsuboi). The angular resolutions using "natural weighting" and "uniform weighting" are 0".14X0".13 and 0".10X0".09, respectively. The sensitivities are 0.10 and 0.18 mJy/beam, respectively. Sgr A* and the Mini-spirals are clearly detected at 340 GHz in figure 1 (upper panel). The flux density of Sgr A*is = 2.8 Jy at 340 GHz.

We analyzed the DDT observation toward the Galactic Center with ALMA, which was released in the autumn of 2016 (2015. A.00021.S). Figure 1(lower panel) shows Integrated intensity (moment 0) map of the H30α recombination line. The angular resolutions is 0".41X0".30 using "natural weighting". The recombination line emission associated with Sgr A* is not detected. Famous IR objects are detected in the continuum map. Most of them are WR stars except for IRS7, which is a cool star. Some clusters are prominent both in the maps, for example, IRS13E and IRS21.

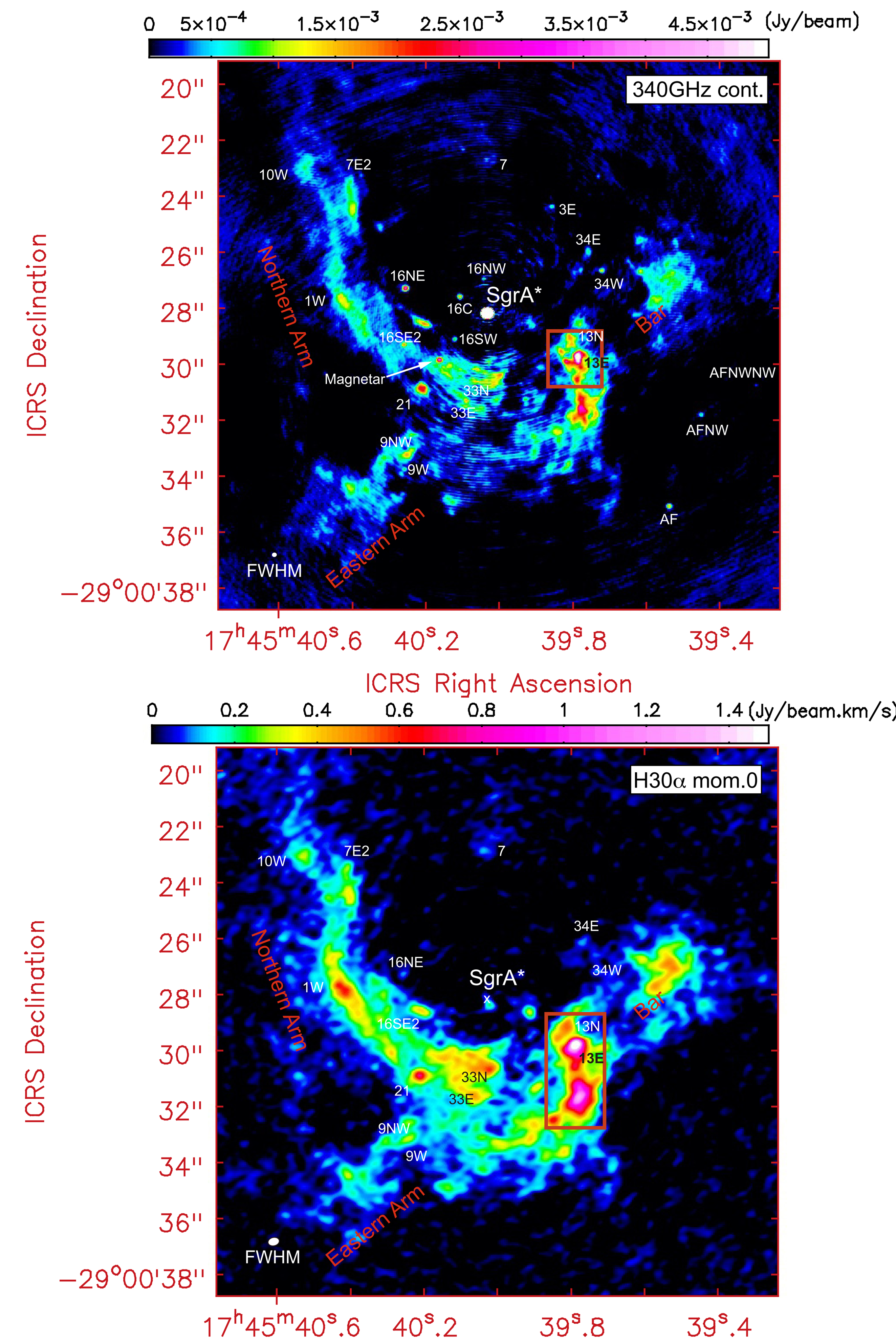

Figure 1
upper panel: Continuum map of Sgr A region at 340 GHz. The angular resolutions is 0".14X0".13. **lower panel:** Integrated intensity (moment 0) map of the H30α recombination. The angular resolutions is 0".41X0".30.

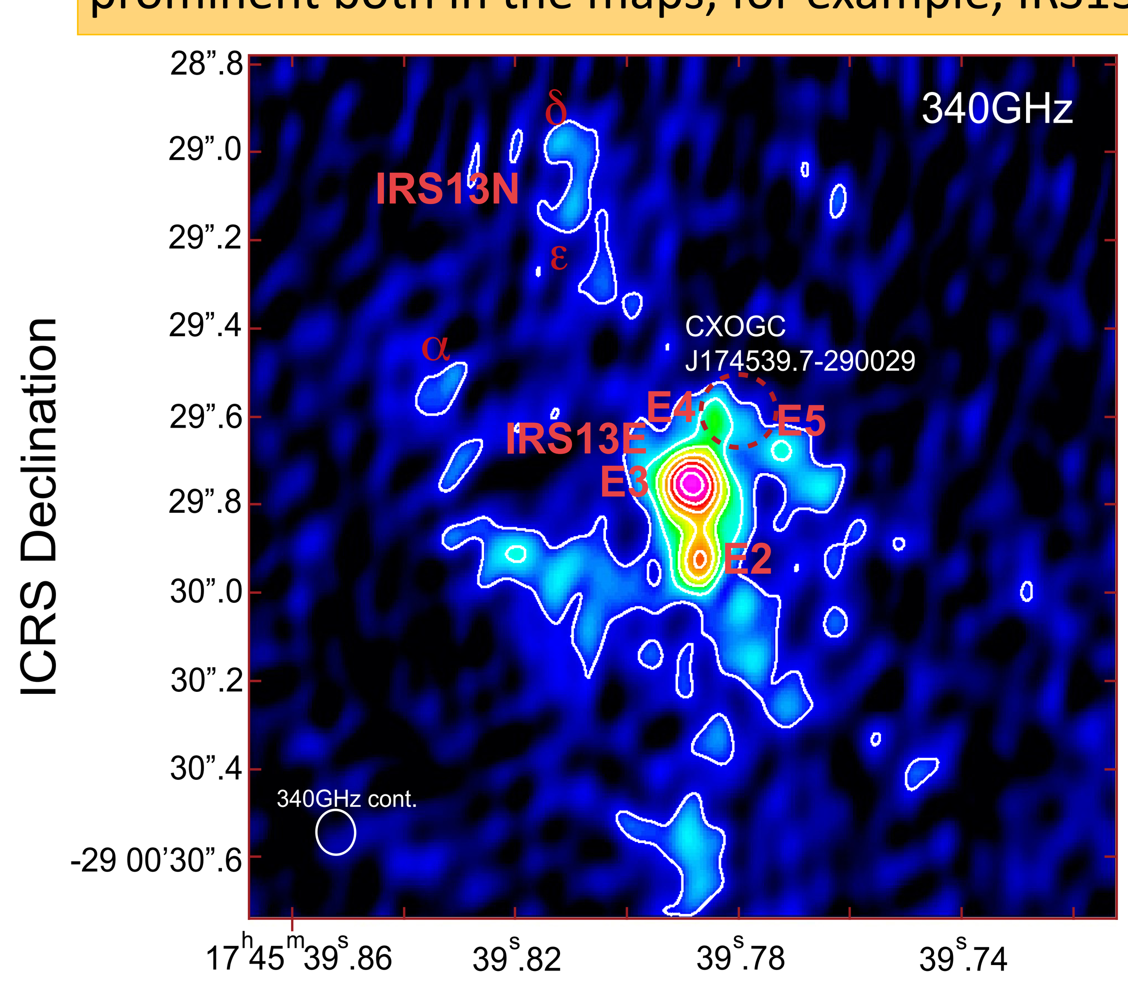

Figure 2
Close-up continuum map of IRS13E at 340 GHz. The angular resolutions using "uniform weighting" is 0".10X0".09.

Figure 2 shows the close-up continuum map of the IRS13E complex at 340 GHz. The IRS13E complex is resolved into a group of compact objects in the map. Most of these are the IR identified objects (e.g., Maillard et al. 2004 ; Schödel et al. 2005 ; Paumard et al. 2006), including IRS13E3 which is a main member of the IRS13E complex but an ionized gas blob (Fritz et al. 2010). The angular sizes of these objects are estimated by the 2D Gaussian fit. The beam-deconvolved angular size of IRS13E3 is derived to be 0."102 x 0."090, corresponding to the physical size of 800 au x 700 au at the Galactic Center distance. Because the spectra of IRS13E3 is flat, the emission is an optically thin free–free emission and the sign of dust thermal emission is not clear.

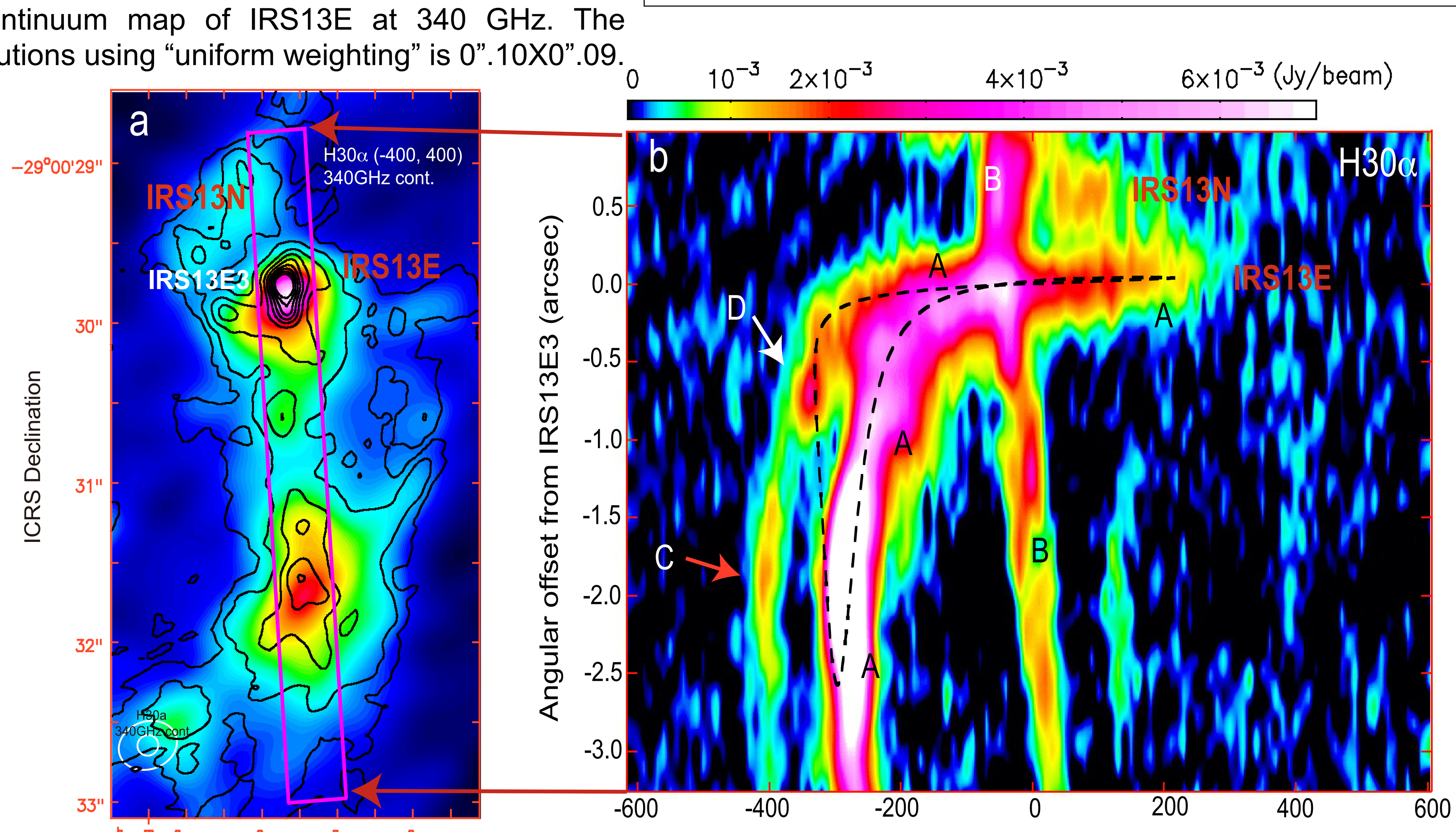

Figure 3
Position–velocity diagram of H30α recombination line. The velocity width toward IRS13E3 is very large, up to 650 km/s. The IRS 13E complex is connected to the southern extended component by a curved ridge. The ionized gas can be described by a Keplerian Oribit (broken curve).

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From the Keplerian orbit, the semi-major axis, eccentricity, orbital period and enclosed mass are estimated to be $a \sim 1.5\mathrm{x}10^{17}$ cm,; $e \sim 0.97$, $T \sim 4000$ yr, and $M_{\mathrm{IRS13E}} \sim 6\mathrm{x}10^4\ M_\odot$, respectively. The enclosed mass is as large as 1% of Sgr A* mass, $M_{\mathrm{IRS13E}} \sim M_{\mathrm{SgrA*}}\mathrm{x}10^{-2}$.

The ionized gas mass is estimated to be $M \sim 6\mathrm{X}10^{-3}\ M_\odot$ assuming the electron temperature of $T_e \sim 1\mathrm{x}10^4$ K (Tsuboi+2017). If the efficiency is assumed to be 1% as a conservative value, the mass accretion rate, $dM/dt \sim 1\mathrm{x}10^{-8}$, would be comparable to the mass accretion rate of Sgr A* ($10^{-9} \sim 10^{-6}$ Mo/yr, e.g. Genzel 2010).

The positional difference between the peak positions of the integrated H30α recombination line and X-ray continuum emission (CXOJ174539.7-290029; 0.5-7 keV) is $\Delta\alpha = 0.35''$, $\Delta\delta = 0.03''$. This difference is as small as the positional accuracy of these. These positions are identical. This object has a X-ray Counterpart.

Using VLBA, the position of Sgr A* had been monitor for 15 years (Reid&Brunthaler 2004). The position change vertical to the galactic plane was as small as 0.4mas/yr, the upper limit mass of the IMBH is ~10^4Mo at the physical distance of 10^3~10^5 AU. Our result is consistent with this upper limit mass.

This object is probably an IMBH with 10^4Mo.