Discovery of a dwarf planet candidate in an extremely wide orbit: 2017 OF201

SIHAO CHENG (程思浩) <sup>(1)</sup>,<sup>1,2</sup> JIAXUAN LI (李嘉轩) <sup>(1)</sup>,<sup>3</sup> AND ERITAS YANG (杨晴) <sup>(1)</sup>

<sup>1</sup>Institute for Advanced Study, Princeton, NJ 08540, USA

<sup>2</sup>Perimeter Institute, Waterloo, N2L 2Y5, Canada,

<sup>3</sup>Department of Astrophysical Sciences, 4 Ivy Lane, Princeton University, Princeton, NJ 08540, USA

## Abstract

We report the discovery of a dwarf planet candidate, 2017 OF201, currently located at a distance of 90.5 au. Its orbit is extremely wide and extends to the inner Oort cloud, with a semi-major axis of 838 au and a perihelion of 44.9 au precisely determined from 19 observations over seven years. Assuming a typical albedo of 0.15, we estimate a diameter  $\sim$ 700 km, making it the second-largest known object in this dynamical population and a likely dwarf planet. Its high eccentricity suggests that it is part of a broader, unseen population of similar objects totaling  $\sim$ 1% of Earth's mass. Notably, the longitude of perihelion of 2017 OF201 lies well outside the clustering observed in extreme trans-Neptunian objects, which has been proposed as dynamical evidence for a distant, undetected planet.

Keywords: Solar system (1528) – Trans-Neptunian objects (1705) –Detached objects (376) – Dwarf planets (419)

## 1. INTRODUCTION

While the asteroid belt contains only ~0.04% of the Earth's mass  $(M_{\oplus})$ , the Kuiper Belt – home to Pluto and numerous icy bodies – harbors significantly more material, with an estimated total mass of 2%  $M_{\oplus}$  (Fraser et al. 2014; Pitjeva & Pitjev 2018). Even greater mass is believed to reside beyond the classic Kuiper Belt, in the scattering disk and Oort Cloud, which may together contain up to several  $M_{\oplus}$  (Gladman & Volk 2021). These distant reservoirs of comets, small bodies, minor planets and possibly undetected massive planets holds essential clues to the formation and evolution of the solar system.

After 30 years of the discovery of the first trans-Neptunian objects (TNOs) (Jewitt & Luu 1993) other than Pluto, various survey programs have been conducted to explore the vast region of outer solar system, and more than 5,000 TNOs have been discovered so far. Although the census of large TNOs near the ecliptic plane is nearly complete, it remains highly incomplete in regions that are beyond ~ 60 au or at high latitude, due to the challenging scaling relation that the brightness of reflected light drops steeply with distance as  $r^{-4}$ . Many dedicated solar-system surveys are thus either shallower wide-field surveys covering ~10,000 deg<sup>2</sup> (e.g., Trujillo & Brown 2003; Schwamb et al. 2010) or deeper but more focused surveys near the ecliptic plane or pencil-beam regions covering hundreds to a few thousand  $\deg^2$  (e.g., Elliot et al. 2005; Petit et al. 2011; Bannister et al. 2018; Sheppard & Trujillo 2016; Sheppard et al. 2019).

Fortunately, recent cosmological imaging programs, though not dedicated to solar-system science, offer a promising solution to this limitation. These surveys typically provide wide sky coverage, deep photometry, and multiple epochs that are well-suited for the detection of faint solar system objects. A prime example is the Dark Energy Survey (Dark Energy Survey Collaboration et al. 2016), whose main scientific goal lies in weak lensing cosmology but has already led to the discovery of ~ 800 TNOs (Bernardinelli et al. 2022).

In this letter, we report the discovery of a large and exotic TNO, 2017 OF201<sup>4</sup>, from a systematic search in the archival data of another extra-galactic survey similar to DES. This survey is called the Dark Energy Camera Legacy Survey<sup>5</sup> (DECaLS; Dey et al. 2019), which is a wide-field optical imaging survey covering mostly  $-15^{\circ} < \text{Dec} < +32^{\circ}$  in the *grz*-bands using the Dark Energy Camera (DECam) on the 4-meter Blanco telescope (Flaugher et al. 2015). To our knowledge, this dataset has not been previously searched for solar-

Email: scheng@ias.edu, jiaxuanl@princeton.edu, qy8274@princeton.edu

Corresponding author: Sihao Cheng

<sup>&</sup>lt;sup>4</sup> https://www.minorplanetcenter.net/mpec/K25/K25K47.html

<sup>&</sup>lt;sup>5</sup> https://www.legacysurvey.org/

system objects, possibly due to its sparse and irregular epoch sampling.

We shall describe the discovery of 2017 OF201 in Section 2, present its large size and wide orbit in Section 3, explore its possible migration history in Section 4, and finally discuss its interesting implications for the Planet X / Planet 9 hypothesis.

### 2. DISCOVERY

We performed our search in a similar way to Bernardinelli et al. (2020, 2022) and optimized it for the sparse epoch sampling of DECaLS. Details of the search algorithm will be described in a future paper. So far, 2017 OF201 is the most interesting object found in our search, with the largest distance and widest orbit.

After identifying ten detections of 2017 OF201 in three bands (g, r, z) of DECaLS span from 2014 to 2018 and connecting them with a tentative orbit, it became rather clear that they correspond to a single moving object that has an extremely wide and eccentric orbit. In addition, with an apparent magnitude  $r \sim 22.6$  mag at a distance of 85 au at the observation epochs, 2017 OF201 has the second brightest absolute magnitude among 411 known TNOs with wide orbits (a > 80 au) in the JPL Small-Body Database<sup>6</sup>.

With the ephemeris derived from DECam detections, we were able to quickly search for additional detections in the data archives of other telescopes to further improve the precision of the orbital fit and photometric measurements. We found nine additional *r*band images from the data archive of the 3.6 m Canada-France-Hawaii Telescope (CFHT), in which 2017 OF201 is found exactly at the predicted positions. These images were taken in 2011 and 2012, increasing the observation arc to seven years. We have also searched the data archive of the Subaru telescope and Gemini-North telescope, but unfortunately found no coverage.

#### 3. PROPERTIES OF 2017 OF201

We performed precise astrometric and photometric measurements (see Appendix A) on each of the 19 detection images to determine the orbit, color, and absolute magnitude of 2017 OF201. A summary of the derived properties is listed in Table 1.

Figure 1 illustrates the trajectory of 2017 OF201 on the sky, marked with detection dates and example detection images from DECam and CFHT. The combination of motion patterns from parallax (elliptic) and proper motion (straight) is recognizable. In fact, 2017 OF201 is quickly moving away from us and its parallax shrank

**Table 1.** Barycentric orbital elements and photo-metric information of 2017 OF201.

Parameters	Value
a (au)	$838.3\pm 6.8$
e	$0.94643 \pm 0.00045$
$i \; (deg)$	$16.20509 \pm 0.00009$
$\Omega \ (deg)$	$328.59148\pm0.0007$
$\omega ~({\rm deg})$	$337.73091 \pm 0.0016$
$\varpi$ (deg)	$306.32238 \pm 0.0023$
perihelion $q$ (au)	$44.9093 \pm 0.0086$
aphelion $Q$ (au)	$1632 \pm 14$
period (yrs)	24256
arc length (days)	2618
reference epoch $t_0$ (MJD)	56932.524451
	(2014-10-02)
distance at $t_0$ (au)	$83.83309 \pm 0.00049$
radial velocity at $t_0$ (au/yr)	$0.6355\pm0.0002$
$V \text{ mag at } t_0{}^a$	22.8
$H_V a$	3.5
g-r	$0.77\pm0.11$
r-z	$0.80\pm0.07$
$B-V^{b}$	$0.99\pm0.11$

<sup>a</sup>Computed using the Find\_Orb software.

<sup>a</sup>Converted from g-r using the SDSS transformation formula from Smith et al. (2002).

by 5% over the 7-year observation arc, enabling a precise determination of radial velocity and therefore the full set of orbital parameters.

The last time 2017 OF201 passed close to us was in November of 1930, and it will come back again in about 25,000 years. Interestingly, this last perihelion was in the same year of Pluto's discovery (Feb 1930), when 2017 OF201 reached its maximum brightness of V =20.1 mag, about 4 magnitudes fainter than Pluto<sup>7</sup>.

## $3.1. \quad Orbit$

The orbit of 2017 OF201 is determined using the online version of the Find\_Orb software<sup>8</sup>, which implements a least-squares fitting of the orbital elements to the astrometric measurements of the 19 detections. The best-fit values and uncertainty of orbital elements

<sup>&</sup>lt;sup>6</sup> https://ssd.jpl.nasa.gov/tools/sbdb\_query.html

<sup>&</sup>lt;sup>7</sup> Coincidentally, it was also in the same year of the establishment of the Institute for Advanced Study, where the first author of this paper is based.

<sup>&</sup>lt;sup>8</sup> https://www.projectpluto.com/fo.htm



Figure 1. Trajectory of 2017 OF201 on the sky from 2011 to 2018. Individual detections from 13 nights are shown on top of the predicted trajectory based on the best-fit orbit, which describes the detections very well with a scatter of 0.13 (DECam) and 0.03 (CFHT) arcsec in each component, consistent with the estimated astrometric error. The insets show example images from DECam (*r*-band on 2017-09-17) and CFHT (*r*-band on 2011-08-31).

are listed in Table 1. Thanks to the long observation arc from 2011 to 2018, the orbit of 2017 OF201 is precisely determined, with an undoubtedly wide semimajor axis ( $a = 838 \pm 7$  au), moderate perihelion distance (q = 44.9 au), and low inclination ( $i = 16.2^{\circ}$ ), located at the boundary between the scattering disk and inner Oort cloud.

The left panel of Figure 2 shows the plan view projection of the orbit of 2017 OF201 onto the ecliptic plane, together with some other TNOs with extremely wide and eccentric orbits (termed "extreme TNOs") for comparison. Its orbit is most similar to that of 2013 SY99 in terms of the semi-major axis and eccentricity (Bannister et al. 2017). With such a large aphelion distance (~ 1600 au), the Galactic tide will start to affect the orbital evolution. We will discuss its orbital dynamics in Section 4.

A notable characteristic of the orbit of 2017 OF201 is its longitude of perihelion of  $\varpi = 306^{\circ}$ , which significantly deviates from the apparent clustering observed among other extreme TNOs first noticed by Trujillo & Sheppard (2014). The right panel of Figure 2 illustrates the distribution of longitude of perihelia  $\varpi$  and semi-major axes *a* for known extreme TNOs. Objects with a > 200 au are predominantly clustered around  $\varpi \approx 60^{\circ}$ , which has been suggested as evidence for an undetected super-Earth beyond several hundred au (e.g., Trujillo & Sheppard 2014; Brown & Batygin 2016; Batygin & Brown 2016; Sheppard et al. 2019; Siraj et al. 2025). We shall explore later in Section 4.2 the implications of the fact that 2017 OF201 is an outlier to this clustering.

# 3.2. Color and variability

2017 OF201 has a color index of  $g - r = 0.77 \pm 0.11$  mag, similar to Sedna (g - r = 0.85) and much redder than the Sun (g - r = 0.44; Willmer 2018). Compared with the color distribution of the TNO population in Sheppard (2010), 2017 OF201 has a color consistent with other TNOs in the scattering disk and detached orbits, but is on the redder side. Given the depth and time sampling of the DECam and CFHT data, we do not detect any variability over 0.1 mag, which means the shape of 2017 OF201 is likely close to spherical. Deeper imaging with higher cadence is needed to probe the short-time variability due to rotation or satellite transit.

## 3.3. Size and mass estimate

The size of solar system bodies can be estimated from the observed brightness, distance, and an assumed albedo. We first obtain the V-band absolute magnitude  $H_V = 3.5$  using the Find\_Orb software based on our photometric measurements and the H, G phase curve<sup>9</sup>. Then, the diameter is estimated through the relation

<sup>&</sup>lt;sup>9</sup> In the H, G magnitude system (Bowell et al. 1989; Muinonen et al. 2010) adopted by the International Astronomical Union in 1985 for asteroids, the absolute magnitude H is derived from observations as  $H=H(\alpha)+2.5 \log[(1-G)\phi_1(\alpha)+G\phi_2(\alpha)]$ , where  $H(\alpha)=m-5 \log(r\Delta)$  is the reduced magnitude, m the apparent magnitude, r is the he-

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Figure 2. Left: Plan view of the orbits of TNOs with extremely wide orbits, including our newly discovered 2017 OF201, which has a distinct orbit is an outlier to the apsidal clustering of the others. For reference, the most probable orbit of Planet X from Siraj et al. (2025) is shown in black. Right: Distribution of longitude of perihelion  $\varpi$  of TNOs from Siraj et al. (2025). The purple shaded region indicates the clustering of  $\varpi$  around 60°. Objects with (meta)stable orbits are shown as solid (open) symbols. The newly discovered 2017 OF201, highlighted in red, does not belong to the apsidal clustering.

 $D = 2 \text{ au} \times 10^{0.2(m_{\odot}-H)}/\sqrt{\rho}$ , where  $m_{\odot}$  is the solar apparent magnitude (Willmer 2018) and  $\rho$  the geometric albedo. Given that the albedo of scattering disk objects correlates tightly with their size<sup>10</sup>, we find an estimate of  $\rho_V=0.15$  and D=700 km fits well the relation, indicating that 2017 OF201 is highly likely large enough to achieve hydrostatic equilibrium<sup>11</sup> and thus qualify as a dwarf planet. Future observations of thermal emission from ALMA will allow for simultaneous determination of size and albedo without the need to rely on the assumed correlation (e.g., Gerdes et al. 2017).

The discovery of such a large object with a high orbital eccentricity has interesting implications for the population of objects in the trans-Neptunian space. Throughout the orbit of 2017 OF201, it is detectable in DECaLS for only ~0.5% of the period around perihelion. This limited visibility window strongly suggests that a substantial population of similar objects – with large sizes, wide orbits, and high eccentricities – should exist but be difficult to detect due to their extremely large distance.

liocentric distance,  $\Delta$  is the geocentric distance,  $\alpha$  is the phase angle in degrees,  $\phi_1(\alpha) = \exp[-3.33 \tan^{0.63}(0.5\alpha)]$ ,  $\phi_2(\alpha) = \exp[-1.87 \tan^{1.22}(0.5\alpha)]$ , and G is set to 0.15, which is the average value for main-belt asteroids.

The mass of 2017 OF201 is estimated to be  $3 \times 10^{20}$  kg =  $1/20,000 \ M_{\oplus}$  when assuming a typical density of 1.7 g cm<sup>-3</sup> and a diameter of 700 km. Therefore, the whole population behind 2017 OF201 would add up 200 times to  $1\% \ M_{\oplus}$  (about the Moon's mass). For comparison, the total mass of the classic Kuiper belt is estimated to be  $1-2\% \ M_{\oplus}$  from object counting (Bernstein et al. 2004; Fraser et al. 2014) and dynamical estimates (Pitjeva & Pitjev 2018), and that of the scattering disk is  $1-10\% \ M_{\oplus}$  (Gladman et al. 2008; Volk & Malhotra 2008). Discovery of large TNOs with extremely elongated orbits such as 2017 OF201 and Sedna (Brown et al. 2004) thus reveals significant amount of mass in the outer solar system.

#### 4. ORBITAL DYNAMICS

We investigate the long-term dynamical evolution of 2017 OF201 using N-body simulations with the ias15 integrator (Rein & Spiegel 2015) in REBOUND<sup>12</sup> (Rein & Liu 2012). Only the outer two giant planets (Uranus, Neptune) are included explicitly, while the combined influence of the inner giants (Jupiter, Saturn) is modeled as a static solar oblateness  $(J_2)$ , following Batygin & Brown (2016) and Gerdes et al.  $(2017)^{13}$ . Due to 2017 OF201's large aphelion distance (~ 1600 au), its orbit may be perturbed by the Galactic tide. We imple-

<sup>&</sup>lt;sup>10</sup> See the first figure in https://www.johnstonsarchive.net/astro/ tnodiam.html

<sup>&</sup>lt;sup>11</sup> As argued by Mike Brown (https://web.gps.caltech.edu/ ~mbrown/dps.html), icy bodies larger than 600 km is "highly likely" a dwarf planet. For reference, the smallest icy body known to be nearly round and thus in hydrostatic equilibrium is Saturn's satellite Mimas, which has a diameter of about 400 km.

<sup>&</sup>lt;sup>12</sup> https://rebound.readthedocs.io/

<sup>&</sup>lt;sup>13</sup> For validation purposes, we also run computationally intensive simulations that directly integrated 2017 OF201 with Jupiter, Saturn, Uranus, Neptune, and Galactic tide. These simulations yielded results that are qualitatively consistent with our simplified model.

ment the Galactic tidal model from Levison et al. (2001) using the add\_force module in REBOUNDx<sup>14</sup> (Tamayo et al. 2020).

## 4.1. Possible origin of 2017 OF201

The semi-major axis of 2017 OF201 can evolve through chaotic diffusion driven by interactions with Neptune. However, the diffusion timescale T increases steeply with perihelion distance. Following Hadden & Tremaine (2024), it is approximately

$$T \approx 0.2 \text{ Myr} \times \exp\left[7.4\left(\frac{q}{a_{\rm N}}\right)\right] \approx 10^{10} \text{ yr}, \quad (1)$$

where  $a_N$  is the semi-major axis of Neptune and q is the perihelion distance of 2017 OF201. This implies that 2017 OF201 cannot reach its current large semi-major axis through perturbations from Neptune alone given the age of the solar system. Instead, its high-q, large-aorbit likely reflects the influence of external torques from stellar encounters or the Galactic tide, which act during or after an initial scattering event(Duncan et al. 1987; Bannister et al. 2017; Gladman & Volk 2021; Batygin et al. 2021).

2017 OF201 may have first been scattered outward by Neptune while retaining a low perihelion. Once at large a, the Galactic tide becomes dynamically important, gradually increasing q and detaching the orbit from Neptune. As the perihelion rises into a region where planetary perturbations are weak, the object undergoes slow angular momentum oscillation and reaches a configuration like that observed today (see Figure 6 for a schematic illustration).

To qualitatively test the plausibility of this migration scenario, we perform backward N-body integrations over a 3.5 Gyr timescale. We simulate 100 realizations of the system, each initializes 2017 OF201 with orbital parameters drawn from a multivariate normal distribution based on the best-fit values and uncertainties in Table 1.

Figure 3 shows a representative backward evolution of 2017 OF201's orbit, illustrating the final stage of the migration pathway discussed above. Once 2017 OF201 resides on a high-q, large-a orbit, the Galactic tide gradually reduces its angular momentum,  $J \propto \sqrt{a(1-e^2)}$ , leading to a slow decrease in q (Heisler & Tremaine 1986). Once the perihelion enters the planetary region, weak perturbations – primarily from Neptune – scatter 2017 OF201 into a more tightly bound orbit. While not definitive, this outcome supports the dynamical viability of a distant scattering-disk origin followed by perihelion lifting and subsequent inward migration.



Figure 3. A representative backward integration of 2017 OF201's orbit over 3.5 Gyr, showing the semi-major axis a (top) and perihelion distance q (bottom) as functions of time. The gradual decrease in the orbital angular momentum driven by the Galactic tide leads to a slow lowering of q. At later times, 2017 OF201's perihelion enters the planetary region, where weak interactions scatter it inward.

## 4.2. Implications for the hypothetical Planet X

As shown in Figure 2, the longitude of perihelion of 2017 OF201,  $\varpi = 306^{\circ}$ , lies outside the clustering region near  $\varpi \approx 60^{\circ}$  observed among other extreme TNOs. This distinction raises the question of whether 2017 OF201 is dynamically consistent with the Planet X hypothesis, which suggests that a distant massive planet shepherds TNOs into clustered orbital configurations.

Siraj et al. (2025) computed the most probable orbit for a hypothetical Planet X by requiring that it both reproduces the observed clustering in the orbits of extreme TNOs and preserves the long-term stability of those TNOs that are already stable in the absence of Planet X. To assess how such a planet would affect 2017 OF201, we perform forward N-body integrations including a planet with mass  $m_p = 4.1, M_{\oplus}$ , semi-major axis  $a_p = 296$  au, eccentricity  $e_p = 0.339$ , inclination  $i_p = 4.27^{\circ}$ , and longitude of perihelion  $\varpi_p = 242^{\circ}$  (Siraj et al. 2025). We compare this to a control simulation that excludes Planet X.

Figure 4 shows that, in the absence of Planet X, 2017 OF201 remains on a stable orbit for at least 1 Gyr under the influence of the known giant planets and the Galactic tide. In contrast, when Planet X is included, gravitational interactions lead to close encounters with Neptune that eject 2017 OF201 from the solar system in ~0.1 Gyr.

These results suggest that the existence of 2017 OF201 may be difficult to reconcile with this particular instantiation of the Planet X hypothesis. While not definitive, 2017 OF201 provides an additional constraint that complements other challenges to the Planet X scenario, such

<sup>&</sup>lt;sup>14</sup> https://reboundx.readthedocs.io/



Figure 4. Forward dynamical evolution of 2017 OF201 with (red) and without (blue) the influence of a hypothetical Planet X with orbital parameters from Siraj et al. (2025). Without Planet X, the orbit of 2017 OF201 remains stable for more than 1 Gyr under the influence of the known giant planets and the Galactic tide. In contrast, in the presence of Planet X, 2017 OF201 experiences close encounters with Neptune and is ejected from the solar system in ~0.1 Gyr.

as observational selection effects and the statistical robustness of the observed clustering.

### 5. CONCLUSION

We report the discovery of an exotic trans-Neptunian object 2017 OF201 from the archival data of DECaLS. Its orbit is extremely wide and eccentric (a = 838 au, q = 44.9 au,  $i = 16.2^{\circ}$ ). It is currently located at a distance of 90.5 au and is among the top ten most distant solar-system objects observed in the optical. Furthermore, it has the second brightest absolute magnitude  $H_V = 3.5$  among known TNOs with wide orbits (a >80 au). When assuming a typical albedo of 0.15, the diameter of 2017 OF201 is estimated to be 700 km, large enough to qualify as a dwarf planet. The discovery of 2017 OF201 suggests a population behind it with hundreds of objects possessing similar properties, because the probability for 2017 OF201 to be close enough and detectable is only 0.5% given its wide and eccentric orbit. Estimated from the large size of 2017 OF201, the total mass of that population is potentially 1% of Earth's mass, which is a significant fraction of the scattering disk.

We show that the orbit of 2017 OF201 is shaped by both Neptune's scattering and the Galactic tide at Gyr timescale (Figures 3 and 6), thus its orbit represents an overlap between the scattering disk and the inner Oort cloud.

The orbit of 2017 OF201 also presents an intriguing challenge to the Planet X / Planet 9 hypothesis. Previous discoveries of TNOs with extremely wide and elongated orbits suggest an apparent clustering in the longitude of perihelia  $\varpi \approx 60^{\circ}$ , motivating the idea that an undetected planet may be shepherding the extreme TNOs. However, with  $\varpi = 306^{\circ}$ , the orbit of 2017 OF201 is an outlier of that clustering (Figure 2) and likely unstable to gravitational influence from this hypothesized planet. Our *N*-body simulations suggest that the presence of the Planet X / Planet 9 that produces the clustering will cause ejection of 2017 OF201 in a short timescale around 0.1 Gyr (Figure 4). Nevertheless, more investigation is required to decisively rule out that hypothesis.

## Facilities: Blanco (DECam), CFHT (MegaCam)

Software: astropy (Astropy Collaboration et al. 2013), matplotlib (Hunter 2007), scipy (Jones et al. 2001), SExtractor (Bertin & Arnouts 1996), PSFEx (Bertin 2011), SCAMP (Bertin 2006), astrometry.net (Lang et al. 2010).

#### APPENDIX

#### A. ASTROMETRY AND PHOTOMETRY

We perform astrometric and photometric measurements of the object using both CFHT/MegaCam and DECam imaging data. Cutouts of those images with 2017 OF201 centered are shown in Figure 5.

For the detections in CFHT, we retrieve the single-epoch images from the Canada-France-Hawaii Telescope (CFHT)/MegaCam data archive<sup>15</sup>. These images are all in the *r*-band with 0.5–0.9 arcsec seeing. The instrument signatures (bias, dark, and flat) have been removed in these images, but they do not yet have astrometric solutions and photometric calibrations. We implement a two-step astrometric calibration process: first obtaining an initial solution using astrometry.net (Lang et al. 2010), followed by fine-tuning against Gaia DR3 reference stars (Gaia Collaboration



Figure 5. Cutout images of all 19 detections from both CFHT and DECam. Each image is 20 arcsec on a side. The detection time corresponds to the middle of each exposure. CFHT data are deeper and have a much better seeing than the DECam data. Our detection spans a long time baseline from Aug 2011 to Oct 2018, enabling precise determination of its orbit.

et al. 2021) using SCAMP (Bertin 2006). This procedure yields a final astrometric solution with an average positional uncertainty of 0.1". For photometric calibration, we first remove the sky background using SExtractor (Bertin & Arnouts 1996) with a mesh size of 60". We then construct a point spread function (PSF) model using PSFEx (Bertin 2011) from non-saturated point sources in each image, and perform PSF-fitting photometry using SExtractor. The photometric zeropoint is thus determined by comparing the instrumental magnitudes of non-saturated stars with their Pan-STARRS1 PSF magnitudes. Our object has an average r-band magnitude of r = 22.61 mag in the CFHT data from 2011 to 2012.

The DECam single-epoch images are downloaded from the Legacy Surveys<sup>16</sup>, which are reduced using the DECam Community Pipeline<sup>17</sup>. These images are photometrically calibrated using Pan-STARRS1 (Chambers et al. 2016) and have a preliminary astrometric solution. To ensure consistency with our CFHT analysis, we refine the astrometric calibration using SCAMP against the Gaia DR3 catalog. Similar to the CFHT data above, for each DECam image, we subtract the sky background with a mesh size of 60", generate the PSF model, and perform PSF-fitting photometry. The resulting photometric results have higher uncertainties since the DECam images are shallower and have poorer seeing conditions (0.8–2.0 arcsec) than the CFHT images.

<sup>&</sup>lt;sup>16</sup> https://www.legacysurvey.org/rawdata/

<sup>&</sup>lt;sup>17</sup> https://noirlab.edu/science/data-services/data-reduction-software/csdc-mso-pipelines/pl206



Figure 6. Left: TNOs with wide orbits (a > 150 au), 2017 OF201 has the second largest brightest among this population. Right: Schematic of a possible migration pathway for 2017 OF201. The object may have been scattered to large semi-major axis (a) while maintaining a low perihelion distance (q). Galactic tidal torques then slowly increase q, detaching the orbit from Neptune.

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