Dear Dr. Michael Endl,

We first express our gratitude to anonymous referee for significantly enhancing the scientific value of this manuscript; the referee led our interpretation of statistical results to a correct direction. As shown below, we revised the manuscript based on the referee's comments and suggestions.

We attached our responses to the major and minor referee's comments in the end of this letter. All of the revised points are marked in red in the revised draft.

We hope that these modifications satisfy the criterion of the publication in the Astrophysical Journal.

Thank you very much for your careful consideration on this manuscript,

Shohei Goda

Major Problems

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1) Why are the results with regard to the G-type stars fundamentally different from that of previously published papers? The authors argue that for G-type stars, Doppler masses imply that planets up to 25 Jupiter mass form by CA, while several studies of exoplanets transiting G-type stars imply that gas giants form by CA only up to 4 Jupiter mass (Narang et al. 2018, AJ, 156, 221) or up to 4 to 10 Jupiter mass (Schlaufman 2018), while higher-mass planets form by DI, based on the host star metallicities. The latter result (Schlaufman 2018) is mentioned only briefly in the final paragraph of section 4.3. The reasons for reaching different conclusions from these previous studies need to be examined in greater detail than is presently the case.

- Schlaufman (2018) treated only 7 samples with masses from 4 to 25 M_J and the mean host-star metallicitiy of the 7 samples is 0.12 dex, which is almost consistent with that taken by our statistical analysis. Thus, we concluded that there is no transition for the two planetary formation mechanisms in the mass regime between 4 and 10 M_J. On the other hand, Santos et al. (2017) and Narang et al. (2018) collected the planet samples orbiting wide spectral types of stars. However, the disk lifetime varies with the host-star mass (Ribas et al. 2015) and the core-accretion model may depend on the spectral type of star, given that the disk mass correlates with the host-star mass. Based on these considerations, we collected a large-number of samples and performed statistical analysis for each spectral type of star. We revised the relevant sentences as below.

"A hybrid scenario for planetary formation was first discussed by Ribas & Miralda-Escude (2007) and Matsuo et al. (2007); they focused on the distribution of host-star metallicities and planet masses. Subsequently, Santos et al. (2017) and Narang et al. (2018) investigated the relation between the host-star metallicities and planet masses for the samples hosted by various spectral types of stars, and showed that the gas giants are divided into two regions separated by a boundary mass of 4 M_J. They have interpreted the two populations as outcomes originating from the two planetary formation mechanisms; gas giants lighter than 4 M_J are core-accreted planets, while those more massive than 4 M_J are formed through the disk instability. However, gas giants are expected to have formed differently and evolved around the various spectral types of stars in the core-accretion mechanism, given that the proto-planetary disk mass varies with the host-star masses (Ida & Lin 2005). The disk lifetime, which largely impacts the core-accretion scenario, also depends on the host-star masses (Ribas et al. 2015). In addition, outer gas giants, which are much larger than 4 M_J

and detected by direct imaging, preferentially orbit early-type stars. Thus, it is preferable to perform statistical analysis for each spectral type of host star. Conversely, Schlaufman (2018) restricted the samples to the gaseous objects orbiting G-type stars, and showed that there is a transition between 4 and 10 M_J instead of a clear boundary at 4 M_J. However, only seven samples had masses ranging from 4 to 25 M_J, and it was difficult to explain why the planetary formation changed in that mass regime. In addition, although all the previous studies have concluded that the two planetary formation mechanisms are separated by a boundary mass (with or without a transition), the two mechanisms may coexist in the same mass regime." [at the fourth paragraph of Section 1]

- We also added the following sentences in Section 3.2 to explain in detail how our result is different from the acquired by Schlaufman (2018).

"These results are not in agreement with the conclusion reached by Schlaufman (2018); there is a transition of the host-star metallicity in the mass range between 4 and 10 M_J. However, in the study by Schlaufman (2018), only seven samples had masses ranging from 4 to 25 M_J. In addition, we found that the mean metallicity of the seven samples is 0.12 dex, which is almost equal to that obtained from our analysis. Thus, the mean host-star metallicity for the samples with masses ranging from 4 to 25 M_J around G-type stars is as high as the metallicity for the samples lighter than 4 M_J." [at the second paragraph of Section 3.2]

- Finally, we summarized in Section 4.3 the difference between the results acquired by the previous studies and this study, and discussed the reason why we reached new results in Section 4.3.

"Previous observational studies on dual planetary formation scenarios (Ribas & Miralda-Escude 2007; Santos et al. 2017; Schlaufman 2018) have shown that a boundary mass of 4 to 10 M_J exists in the diagram of host-star metallicities and masses for gaseous objects and have pointed out that this boundary reflects the transition between the two planetary formations; *i.e.*, the upper limit for the core-accreted planets is around 4 M_J. However, we found that the boundary at 4 M_J reflects the difference between planetary formations around G-type and early-type stars; the disk instability has a more important role in formation of massive planets around early-type stars. These results have been obtained by a statistical analysis of large-scale samples comprising planets and brown dwarfs that orbit host stars having masses more massive than 0.8 $M_\odot$ for each spectral type of stars. The bottom-up and top-down formation mechanisms act in the same planetary mass regimes without these formation mechanisms being divided by a mass boundary." [at the fourth paragraph of Section 4.3]

2) The discussion of the theoretical formation mechanisms is superficial, with a selective choice of citations used to argue for the authors' preferred interpretation (third paragraph in the Introduction). These papers should also be cited and their results described:

2A) Lin et al. (2018, MNRAS, 480, 4338) found their pebble accretion models to be extremely inefficient, losing 90% of the pebbles to inward drift, with the result that Jupiter-mass planets were rarely formed by this variant of CA, and even fewer super-Earths, contrary to Kepler demographics.

2B) Chambers (2016, ApJ, 825, 63) found that pebble accretion even in 100 AU radius disks could not lead to gas giants orbiting stably beyond 13 AU.

2C) Chambers (2018, ApJ, 865, 30) found that pebble accretion in 30 AU radius disks could produce a range of warm and cold gas giants, but no hot Jupiters, contrary to observations.

2D) Suzuki et al. (2018, ApJL, 869, L34) showed CA is unable to reproduce the observed population of intermediate-mass giant planets inferred from microlensing detections.

2E) Similarly to 2D), the Kepler data set (e.g., Thompson et al. 2018, ApJS, 235, 38) shows that most common type of exoplanet is a relatively short-period super-Earth that resides in an area of discovery space that was predicted to be a planetary desert by the CA population synthesis models of various authors, starting with Ida & Lin 2004b. Dittkrist et al. (2014, A&A, 567, A121) attempted to eliminate that theoretical CA desert, but only at the price of depleting most of the cold gas giants from discovery space beyond a few AU.

2F) Coleman & Nelson (2014, MNRAS, 445, 479) noted that when overly optimistic inward migration rates assumed in CA population synthesis models were corrected, few gas giants were able to form and survive inward orbital migration.

- Thanks to referee's suggestion, we could notice that there are several discrepancies between the planetary distribution predicted by the core-accretion models and the observation results. We introduced the discrepancies, citing these studies commented above. We added the following paragraph in Section 1 to allow the readers to understand the reason why this study focuses on a hybrid scenario for planetary formation.

"Several discrepancies existed between the planetary distributions predicted by the core-accretion model and the observation results. The paucity of planets due to the rapid gas accretion of the core-accretion model (Ida & Lin 2004a; Dittkrist et al. 2014) is not consistent with the existence of abundant gas dwarfs close to the host stars, as revealed by the Kepler data (e.g., Thompson et al. 2018). In addition, Suzuki et al. (2018) proved that the Saturn-mass planets beyond the snow line around late-type stars, which were detected by the microlensing method, are much more plentiful than the mass distributions predicted by the core-accretion models (Ida & Lin 2004a; Mordasini et al. 2009). Furthermore, the pebble accretion model that plays an important role in formation of proto-planetary core (Ormel & Klahr 2010; Lambrechts & Johansen 2012) has certain drawbacks. For example, Lin et al. (2018) showed that the pebble accretion rate is largely limited by the fast radial drift speed of mm--cm-sized pebbles because of the gas drag; this rate is insufficient for the formation of cores, which leads to runaway gas accretion. Note that pebble accretion might form planetary systems similar to the solar system, including gas giants, when the pebble accretion rate is enhanced by icy pebbles beyond the snow line (Chambers 2016). Chambers (2018) tuned the parameters of the pebble accretion model to the frequencies of planets with masses ranging from 0.01 to 100 M_J and to the semi-major axes of 0.01 to 10 au derived by several observational surveys. The tuned model successfully generated short-period gas dwarfs, but it failed to reproduce hot Jupiters. Regarding the inner migration, Coleman & Nelson (2014) showed that no gas giants survived in their N-body simulations because of rapid inner type-I migration induced by the saturated co-rotation torque of the proto-planet core. Previous studies on population synthesis have applied optimistic migration for the survival of gas giants. Thus, the current core-accretion models need to be improved to bridge the gap between the observation results and theories. Another formation scenario such as disk instability may be also required." [at the third paragraph of Section 1]

- We cited Chambers (2016, ApJ, 825, 63) in the second paragraph of Section 1 to explain that the pebble accretion cannot form the outer gas giants discovered by the direct imaging.

"Additionally, Chambers (2016) showed that it is difficult to form gaseous objects beyond 10 au via pebble accretion. In fact, the dynamical masses of the four planets orbiting HR 8799, which were constrained using high-precision astrometric measurements (Wang et al. 2018), were consistent with those predicted from their infrared fluxes; assuming that the four planets follows the hot-start evolutionary track (Baraffe et al. 2003)." [at the second paragraph of Section 1]

3) All of the above theoretical results imply that CA has significant problems and should not be accepted uncritically as the only gas giant formation mechanism for G-type stars. In particular, the frequent use of the phrase "... can be explained naturally by the core accretion model" seems to be unwarranted in the light of this theoretical work.

- We tried to look for a simple picture about the planetary formation around G-type and early-type stars in the previous manuscript. According to the referee's suggestions, we removed the sentences implying that planets around G-type stars are naturally explained by the core accretion, and discussed the possibility of the disk instability around G-type stars in Section 4.1 as follows:

"However, a few planets exist around very metal-poor stars located beyond the core-accretion model (Mordasini et al. 2012). As discussed in Section 1, several discrepancies exist between the planetary distributions revealed by various observations and those predicted by the core-accretion models. Considering that disk instability has an important role in the formation of gas giants around early-type stars (see Section 4.2), some of the massive planets are the disk-instability-induced-planets." [at the third paragraph of Section 4.1]

4) The conclusions are worded simplistically to an extent that seems to be unjustified by the results presented. In Figure 6 (left), there are a number of G-type star exoplanets with masses above 25 Jupiter mass that have high metallicities, just as there are a number of G-type star exoplanets with masses below 4 Jupiter mass that have low metallicities, yet the first group is inferred to have all formed by DI, and the latter all by CA. The same concern applies to the early-type star mass bins in Figure 6 (right). The authors seem to seek a simpler explanation for their analysis than is warranted, given their interesting results. Why not propose the need for hybrid gas giant formation theories, allowing both processes (CA and DI) to operate in a complementary manner, rather insisting that only the end-member processes need to be invoked for a certain mass host star? E.g., does the data really require that stars with masses of 1.5 solar masses form gas giants above 4 Jupiter mass only by DI, while stars with masses of 1.3 solar mass form gas giants only by CA?

- Thanks to referee's suggestion, we could interpret the discrepancies between the core-accretion model and our results acquired by the statistical analysis as a support of a hybrid scenario for planetary formation, and concluded that the boundary of 4 M_J reflects the difference between planetary formation processes around early-type and G-type stars; the disk instability has a more important role in the planetary formation more around more early-type of stars than that around G-type stars. As noted in the response to the referee comment (3), our claim was modified as follows: if is essential to have a hybrid scenario for planetary formation for the formation of diverse planetary systems. Based on the above considerations, we revised the sentences as below.

“In contrast, the lower mass limit appears to reflect the difference between planetary formation processes around early-type and G-type stars; disk instability plays a greater role in the planetary formation process around early-type stars than that around G-type stars. Population with masses between 4 and 25 Jupiter masses that orbit early-type stars comprise planets formed not only via the core-accretion process but also via gravitational disk instability because the population preferentially orbits metal-poor stars or is independent of the host-star metallicity. Therefore, it is essential to have a hybrid scenario for the planetary formation of the diverse systems.” [at line 8 on abstract]

“However, the lower boundary mass represents a difference between the planetary formation processes around G-type and early-type stars; disk instability has a more important role in planetary formation around more early-type stars as compared with the planetary formation around G-type stars.” [at the fifth paragraph of Section 1]

“Therefore, the intermediate-mass planets around early-type stars are mainly formed by the core accretion, whereas disk instability plays an important role in the massive-planet formation. However, the upper mass limit for the planetary objects orbiting G-type stars is approximately 25 M_J; therefore, some of the massive planets would naturally be core-accreted planets. Both the bottom-up and top-down formation mechanisms occur around early-type stars.” [at the third paragraph of Section 4.2]

“However, we found that the boundary at 4 M_J reflects the difference between planetary formations around G-type and early-type stars; the disk instability has a more important role in formation of massive planets around early-type stars. These results have been obtained by a statistical analysis of large-scale samples comprising planets and brown dwarfs that orbit host stars having masses more massive than 0.8 $M_\odot$ for each spectral type of stars. The bottom-up and top-down formation mechanisms act in the same planetary mass regimes without these formation mechanisms being divided by a mass boundary.” [at the fourth paragraph of Section 4.3]

- We also strengthened in Section 4.3 our claim that the hybrid planetary formation occurs around G-type and early-type stars, adding Figure 10 that shows the distributions of eccentricities as functions of the host-star metallicities for the intermediate-mass and massive planets orbiting G-type and early-type stars.

“In addition, when we focused on the distributions of the eccentricities and the host-star metallicities for the samples orbiting early-type stars, we found that the eccentricities of the massive-mass planets orbiting the metal-poor stars are low, whereas the eccentricities of the samples around the metal-rich stars ranged widely from 0 to 0.9; the eccentricity distribution for the massive planets varied largely with the metallicity (see Figure 10). When the eccentricity of the disk-instability-induced planet is not enhanced (Mayer et al. 2004; Mayer 2010; Boss 2011), the disk instability is thought to mainly occur around the metal-poor stars. In contrast, both the core-accretion and disk-instability mechanisms formulate the wide eccentricity distribution for the samples that orbit the metal-rich stars. The theoretical expectations shown in Figure 9 are supported by plotting the eccentricities of the companion masses against the host-star metallicities. Thus, we accepted a hybrid scenario for the planetary formation around G-type and early-type stars.” [at the second paragraph of Section 4.3]

5) In the context of the issues raised in 4) above, note that the mean metallicity variations inferred for the host stars in Figure 6 are only about 0.25 dex (left) or 0.13 dex (right), i.e., mean metallicities that vary by factors of about 1.8 or 1.3, respectively. These small variations are interpreted as being diagnostic of formation by CA or DI. Theoretical CA population synthesis models typically vary the initial parameters by much larger factors, such as initial disk masses ranging from 0.004 to 0.09 solar masses (Mordasini et al. 2009; A&A, 501, 1139), and dust to gas ratios of 0.04, twice as high as solar (Mordasini et al. 2012). These two assumptions can be played off against each other, as noted by Mordasini et al. (2012), and with multiple free parameters to vary, it cannot be said that there is a unique prediction of the theoretical models.

- According to the referee's suggestion, we discussed the problem of the core-accretion population synthesis in terms of reproduction of the planetary distribution (planet masses versus host-star metallicities), and inserted the following paragraph inn Section 4.3.

"We found that the variations in the mean host-star metallicities around G-type and early-type stars are approximately 0.25 and 0.13, respectively, corresponding to the factors of 1.8 and 1.3 (see Figure 6). The findings led to the conclusion that the hybrid planetary formation around G-type and early-type stars occurs. On the other hand, core-accretion population synthesis (e.g., Ida & Lin 2004a; Mordasini et al. 2009) strongly depends on the initial parameters, such as the initial disk gas masses and dust--gas ratios of a disk. The disk masses and dust--gas ratios of the core-accretion population synthesis that we adopted ranges from 0.009 to 0.09 $M_\odot$ and from 0.04 to 2 times the solar metallicity (Mordasini et al. 2009), respectively; the two parameters cancel each other in the reproduction of planetary distribution (Mordasini et al. 2012). It is still not possible to make a uniform prediction of the planetary distribution. The current population synthesis models have difficulty finding slight host-star metallicity variations that could lead to the hybrid planetary formation." [at the third paragraph of Section 4.3]

6) Again, in the context of 4) and 5) above, note that in Figure 8 (right), the lowest metallicity bin for G-type stars has more exoplanets than any of the higher metallicity bins, yet the CA models of Mordasini et al. (2012) predict zero gas giants in lowest metallicity bin. This major finding should be highlighted as a significant failing of those CA predictions.

- According to the referee's suggestion, we emphasized in Section 4.1 that there are a few planets that locate beyond the core-accretion model as follows:

"In fact, as shown in the right panel of Figure 8, the mean masses for the observations of planets around G-type stars agree well with the simulation samples over the entire range of metallicities except for the lowest metallicity bin where the population synthesis does not generate any planets." [at the first paragraph of Section 4.1]

"However, a few planets exist around very metal-poor stars located beyond the core-accretion model (Mordasini et al. 2012). As discussed in Section 1, several discrepancies exist between the planetary distributions revealed by various observations and those predicted by the core-accretion models. Considering that disk instability has an important role in the formation of gas giants around early-type stars (see Section 4.2), some of the massive planets are the disk-instability-induced-planets." [at the third paragraph of Section 4.1]

Minor problems

1) Introduction - fourth P - 2nd sentence - Please give citations for the claim that the upper mass limit for planetary objects is 25 Jupiter mass, and the theoretical assumptions involved in this claim, compared to the new theory papers to be cited, as in 2) above.

- According to the referee's suggestion, we revised the sentences in Section 1 as below.

"We determined that the host-star metallicities of the samples with masses ranging from 0.3 to 4 M_J and from 4 to 25 M_J around G-type stars are continuously the same, and these host-star metallicities are higher than those for the samples more massive than 25 M_J. Given that a massive core-inducing runaway gas accretion onto the core prior to the disk lifetime tends to be formed in the disk with high metallicity (Ida & Lin 2004b; Mordasini et al. 2012), the upper mass limit for the core-accreted planets is approximately 25 M_J. The fact that the samples more massive than 25 M_J around early-type stars is deficit has also been confirmed. Thus, the upper boundary mass is thought to represent the upper mass limits for the planetary objects that can be formed around G-type and early-type stars." [at the fifth paragraph of Section 1]

2) Section 3.2 - second P - The claim is made that the star formation process cannot form objects with masses less than 25 Jupiter mass. Boss (2001, ApJ, 551, L167) showed that collapsing molecular cloud cores could fragment into clumps with masses as small a Jupiter mass, bluring the line between star and planet formation processes.

- According to the referee's suggestion, we added the following sentences in Section 3.2. However, we maintained our claim that a boundary between the planetary and star formation is around 25 M_J, considering the result that the mean metallicity for the samples more massive than 25 M_J is smaller than for those with masses less than 25 M_J.

"On the other hand, a star-formation process, such as a gravitational core collapse and the fragmentation of a molecular cloud (Padoan & Nordlund 2004; Hennebelle & Chabrier 2008), could possibly form gaseous objects with masses ranging from 5 to 15 M_J (Boss 2001); an obvious mass boundary may not exist between the planetary-formation and star-formation processes. However, the mean metallicity for the samples much larger than 25 M_J is significantly lower than that for the samples lighter than 4 M_J. The star-formation process does not depend on the metallicity of a molecular cloud; therefore, the mass boundary between the star- and planetary-formation mechanisms is thought to be approximately 25 M_J." [at the second paragraph of Section 3.2]

Others

- We mentioned the deficit of the samples more massive than 25 M_J around early-type stars and discussed the upper mass limit for planetary objects in Section 3.2.

"We also emphasize that the number of samples more massive than 25 M_J around early-type stars is much smaller than those around G-type stars. The lack of any samples around early-type stars probably reflects the upper mass limit for objects that evolve from the planetary formation mechanisms. The lack may also show the different formations for sub-stellar components around G-type and early-type stars." [at the third paragraph of Section 3.2]

- We also introduced an observational result, which indicate that planets may be formed via the disk instability, to strengthen the claim that a hybrid planetary formation occurs around G-type and early-type stars. We added the following sentence to the second paragraph of Section 1.

"In fact, the dynamical masses of the four planets orbiting HR 8799, which were constrained using high-precision astrometric measurements (Wang et al. 2018), were consistent with those predicted from their infrared fluxes; assuming that the four planets follows the hot-start evolutionary track (Baraffe et al. 2003)." [at the second paragraph of Section 1]