CORNELL UNIVERSITY
Department of Astronomy
Cornell Center for Astrophysics and Planetary Science

Prof. Dong Lai
618 Space Sciences Building
Cornell University
Ithaca, NY 14853

Tel: (607) 255-4936
Fax: (607) 255-6918
DL57@cornell.edu
https://donglai6.github.io/

November 6, 2025

Search Committee
Faculty Position in Astrophysics

Dear Committee,

It is a great pleasure to recommend **Yubo Su**, currently a research assoc던ate at CITA, for a faculty position (Assistant Professor) at UC Berkeley. I have known Yubo since he joined the Cornell graduate program in the fall of 2017, and I have been his Ph.D. adviser since 2018. He graduated from Cornell in the summer of 2022.

During his Ph.D. period, Yubo's research covered several areas of astrophysical dynamics (both fluid dynamics and few-body dynamics), with applications to white dwarf (WD) and massive star binaries, merging black boles, and (exo)planets. He carried out the first hydrodynamical simulations of nonlinear gravity wave breaking in stellar envelopes, an important "microphysics" for understanding tidal evolution in close white-dwarf and massive-star binaries. He studied the observational signatures (spin-orbit misalignments and mass ratio distribution) of different formation channels of merging black-hole binaries detected by LIGO/VIRGO. He derived new semi-analytical formulae to calculate tidal evolution of eccentric, massive stellar binaries, the progenitors of compact neutron star binaries. Most importantly, in a series of three papers, he made fundamental contributions (including real analytic advances since early 1980s) to the classical problem of "Colombo's top" (a rotating planet that precesses around a varying orbital axis) and he has used his new analytical result to explore the origin of (exo)planetary spin/obliquity and related dynamical evolution (e.g. the origin of ultra-short period planets). His work showed that super-Earths in multi-planet systems can settle down into various non-trivial high-obliquity states — this will likely have a large impact on future observations of these planets (including habitable planets around M stars).

Yubo is certainly one of most talented and accomplished students that I have seen in the last 27 years (from Cornell and those from other institutions that I happen to have met). In terms of problem-solving skills, he has few matches. He is particularly strong and efficient in using theoretical analysis (including advanced applied math) combined with various numerical tools in attacking theoretical problems. He is independent in his research and has come up with many ideas of solving problems during our many collaborations. He is curious and could get obsessed when encountering intriguing puzzles – Indeed, the reason that he has worked very different subjects (often simultaneously) was because of his curiosity and his problem-solving efficiency. He has thrived as a postdoc at Princeton, working simultaneously on different areas. He has successfully worked with students. Overall, his superb technical skills, creativity, hardwork and strong motivation and drive to solve difficult problems (while enjoying the process), plus his engaging personality, indicate that he will have a bright future in academic research.

I provide more details on some of Yubo's research, focusing on the works that I am familiar with, before making some final remarks at the end.

Yubo's first research project at Cornell involved hydrodynamical simulations of nonlinear breaking of internal gravity waves in stellar envelope. This process has long been recognized as the key to understanding tidal dissipation in massive stellar binaries and white-dwarf binaries, the latter being quite relevant to many areas of astrophysics, from Type Ia supernovae to gravitational wave sources for LISA. The wave breaking process is also important for some aspects of planetary atmosphere dynamics. But how this process works is unclear and the details (e.g., how and where the wave breaking occurs, what is the width of dissipation region?) can have very important observational consequences. With Daniel Lecoanet (Northwestern), Yubo carried out the first ever hydrodynamical simulations of gravity wave breaking in astrophysical setups (stratified stellar envelopes). He adapted a complex multi-dimensional spectral code (Dedalus) to this problem and designed several clever numerical tests; he played the key role in the interpretation of the results, showing his in-depth understanding of various fluid phenomena. His published paper (**Su, Lecoanet & Lai 2020**) revealed several new features not anticipated in previous theoretical works (e.g. the formation of critical layer where wave absorption occurs, with the width controled by KH instability, partial reflection of waves by the critical layer). Because gravity wave breaking is such a fundamental process in astrophysical/planetary contexts, I believe Yubo's results will have a lasting value. Following up on this work, Yubo finished a study on tidal evolution in massive star binaries on highly eccentric orbits. Thanks to his superb analytical skills, he was able to derive new, easy-to-use, analytical expressions for the orbital evolution rates for such systems (**Su & Lai 2021c**) – this is very useful for understanding the evolution of massive star binaries leading to the formation of double neutron star systems.

While working on the gravity wave breaking project, Yubo developed an interest in planetary spin dynamics (out of discussions initiated in my group meeting). This led to his three significant papers on "Comlomb's top" (a rotating planet whose spin axis precesses around a varying orbital axis) and planetary spin obliquity. In the first paper (**Su & Lai 2020**), Yubo studied evolution of planetary spin in a system that contains a slightly misaligned, dissipating protoplanetray disk. Most students/researchers would just do some numerical calculations and get the result and that would be it. But Yubo made new contribution this classic subject by deriving the "transition probabilities" as the system undergoes various "separatrix crossings" under very general conditions (including "partial adiabatic resonance advection"), a non-trivial technical achievement that goes well beyond the famous work by J.Henrard in 1980s. Thanks to Yubo's superb theoretical skills, he was able to characterize the planet's spin evolution analytically under various conditions (different initial spin orientations, non-adiabatic effect, etc). I believe that the method and results that Yubo developed will have permenant value, going beyond the specific application studied in this paper.

In the second paper of the "Colombo's top" series, Yubo examined planet spin evolution including tidal dissipation (**Su & Lai 2021a**). While aspects of this problem has been considered before (e.g. the earlier work by Ward), Yubo's work provides, for the first time, the complete characterization of the long-term evolution of the planetary spin for an arbitrary initial spin orientation, and develops a new theoretical method to analytically obtain the probability of resonance capture into high-obliquity "tidal Cassini equilibria" driven by tidal dissipation – this technical inovation was entirely due to Yubo (and I would say it is an analytical breakthrough). Applying his general theoretical results to exoplanetary systems, Yubo showed that a super-Earth with a companion can have a substantial probability of being trapped in the high-obliquity state (despite efficient tidal alignment torque). He also critically examined the recently proposed "obliquity tide" scenarios for the formation of ultra-short-period Earth-mass planets and for the orbital decay of hot Jupiter WASP-12b – he found that in both cases, the probability of resonant capture into high-obliquity state is low and that such a high-obliquity state can be easily broken by the required orbital decay.

In the 3rd paper of the "Colombo's top" series, Yubo studied spin evolution of a planet when it is surrounded by at least two other planetary companions (**Su & Lai 2022**). The celebrated works by J.Laskar and by J.Wisdom in 1990s showed that in this case, the planet's obliquity may evolve chaotically due to resonance overlaps – such evolution occured for Mars and had a strong influence in Mars' climate evolution. However, when Yubo included tidal torques in the spin evolution (which is important for super-Earths), he discovered that under some conditions, the planetary spin can evolve into some nontrival "mixed-mode resonances", in which the the spin axis precesses at some fractional mixture of the inclination mode frequencies of the multi-planet system! Moreover, he was able to analytically calculate the obliquities of these resonances. We believe this work is of interest not only to (exo)planetary science, but also to the general nonlinear dynamics community.

While working on the "planet spin trilogy", Yubo became very interested in the formation channels of merging black-hole binaries detected by LIGO/VIRGO, and he carried out two theoretical studies on the observational signatures of tertiary-induced BH binary mergers. The first study concerns BH spin obliquities. With a former postdoc Bin Liu, we (Liu & Lai 2017,2018) have previously discovered through numerical integrations ("population synthesis") that the BH spin (initially aligned with the orbital axis) tends to evolve toward a "perpendicular" state (spin-orbit misalignment angle of 90 degrees) when the BH binary undergoes Lidov-Kozai (LK) eccentricity oscillations induced by an inclined external companion and merges via gravitational radiation. We were very intrigued by this numerical finding, but were not able to provide a satisfactory anylyical understanding of this result. Yubo took up this theoretical challenge, and developed a new analytical formalism for understanding this problem (**Su, Lai & Liu 2021, PRD**). He showed that, under certain conditions, the eccentricity oscillations of the binary can be averaged over to determine the long-term behavior of the BH spin in a smooth way. He demonstrated that the final spin-orbit misalignment angle is often related to the binary's primordial spin orientation through an approximate adiabatic invariant, and thus explaining the "90-degree attractor". In another theoretical work (**Su, Liu & Lai 2021 PRD**), Yubo studied the mass ratio distribution of tertiary induced binary BH mergers. An attractive feature of such mergers is the enhanced merger probability when the octupole-order effects, also known as the eccentric Kozai mechanism, are important. Since the octupole strength increases with decreasing binary mass ratio q , such LK-induced mergers favor binaries with smaller mass ratios. Using a combination of numerical and analytical approaches to characterize the octupole-enhanced binary BH mergers, Yubo showed that for typical hierarchical triples, the binary merger fraction can increase by a large factor (up to 20) as q decreases from unity to 0.2 . The resulting mass ratio distribution for merging binary BHs produced in this scenario is in tension with the observed distribution obtained by the LIGO/VIRGO, although significant uncertainties remain about the initial distribution of binary BH masses and mass ratios.

More recently, Yubo studied the production of stellar obliquities in "stellar spin + disk

+ binary" system, a problem previously studied by various authors, including myself and a previous student (J.J. Zanazzi). Unlikely these previous works, Yubo was able to obtain several new anaytical results, which allow him to survey the parameter space efficiently and uncover some new dynamical behavior in the system (Su & Lai 2025). Importantly, such "primordial" stellar obliquities can significantly modify the prediction of the final stellar obliquities of hot Jupiters produced by tertiary-induced high-eccentricity migration (Vick, Su & Lai 2023).

I could go on discussing other works Yubo has carried out, such as his work with postdoc Laetitia Rodet on high-eccentricity migration of giant planet induced by stellar flybys (Rodet, Su & Lai 2021). But I will stop here as the letter is already quite long. Suffice it to say that I have been most impressed by his ingenuity and skills, and I have enjoyed and learned a lot from working with him in the last few years.

But Yubo is also an all-around outstanding student while at Cornell: He wrote a successful proposal and won a three-year NASA graduate fellowship. He is strongly motivated, hard working, and always has a cheerful, positive attitude (he is a successful long-distance runner, and has the "grit"). He is interactive, the most helpful person to others (e.g. he is the go-to person for other students seeking technical helps). I know he has been an excellent TA, and has also been active in various activities in the department.

Yubo has been productive as a postdoc at Princeton. I am impressed by his recent work with a Princeton student and Jeremy Goodman on the surprising new dynamical behavior of the obliquities of planets with finite rigidity. His work on tertiary-induced mergers in triple systems is also very interesting. Working with Josh Winn and a student, Yubo discovered a new mechanism of forming hot Jupiters. His recent work (to be submitted) on stellar oscillation and interior rotation is most interesting ! I'll let others to comment on these works.

Over the last 27 years, I have had chance to work closely with about 20 Ph.D. students, many of whom have landed in top postdoc positions after their Ph.Ds, and a few have become faculty members (e.g. at Caltech). While every student is different and has different strengths, in terms of overall technical ability and creativity, I would rank Yubo as the top two or three. Yubo will be able to successfully work on any theoretical/computational astrophysics/planetary problems that he finds interesting. He has already demonstrated his ability to mentor students (including undergraduate students). I know that he truely enjoys interacting with students and teaching. I believe that he will have a successful academic career at a top-tier research university. I recommend him enthusiastically for the faculty position at your university.

Sincerely Yours,

Dong Lai
Benson Jay & Mary Ellen Simon Professor
Cornell University
and
T.D.Lee Chair Professor
Tsung-Dao Lee Institute, Shanghai