Curriculum Vitae

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Education

Max Planck Institute for Astronomy & Heidelberg University, Germany Ph.D. in Astronomy Thesis: Assessing the influence of astronomical phenomena on the Earth Supervisor: Dr. Coryn Bailer-Jones	2011 – 2015
Nanjing University, China M.S. in Astrophysics Thesis: Radio Jets and Galaxies as Cosmic String Probes Supervisors: Prof. Yongfeng Huang and Prof. Tan Lu	2008 – 2011
Wuhan University, China B.S. in Physics Thesis: Solutions of Higher Dimensional Cosmological Model with a Cosmological Constant Supervisor: Prof. Jueping Liu	2004 – 2008

Employment

Research fellow, Centre for Astrophysics Research, University of Hertfordshire, UK	2015 – present
Postdoctoral researcher, Max Planck Institute for Astronomy, Germany Advisor: Dr. Coryn Bailer-Jones	2015

Awards, Honors & Grants

Finalist of the Vice-Chancellor's Awards	2017
Funding from the Science and Technology Facilities Council (ST/M001008/1)	2017 – present
PANDORA project funded by the Leverhulme Trust (RPG-2014-281)	2015 – 2017
Grant from the Max Planck Society within the framework of the promotion of scientific cooperation with foreign countries	2015
Member of the GREAT-ITN network funded by the EU FP7 Marie Curie program under grant agreement 264895	2011 – 2014
Grant from the National Natural Science Foundation of China and the National Basic Research Program of China	2008 – 2011
Government grant for students with financial hardship	2006 – 2007
Government grant for outstanding students	2004

Research experience

Postdoctoral research: *Centre for Astrophysics Research, University of Hertfordshire (advisor: Hugh R. A. Jones)* 2015 - present

- create and compare algorithms for the detection of exoplanets with the radial velocity method
- investigate the utility of various algorithms in applications in other disciplines

Postdoctoral research: Max Planck Institute for Astronomy (advisor: Dr. Coryn Bailer-Jones) 2015
- numerical analysis of cometary orbits under the influence of stellar encounters

Doctoral research: Galaxies and Cosmology department, Max-Planck Institute for Astronomy (advisor: Dr. Coryn Bailer-Jones) 2011 – 2015
- built a dynamical model of the comet and asteroid impact history based on the solar motion around the Galactic center
- built a dynamical model of the non-isotropically distributed long period comets based on a model of the solar apex motion
- created a model of the terrestrial extinction rate based on the solar motion
- using time series models in a Bayesian framework

GREAT ITN exchange: Leiden Observatory (advisor: Dr. Anthony Brown) 2012
- simulated the Oort Cloud using the Kepler community code in the AMUSE framework
- used the bridge method in AMUSE to combine the perturbation of Oort Cloud from Galactic tide and stellar encounters

Masters research: Astronomy Department, Nanjing University (advisors: Prof. Yongfeng Huang and Prof. Tan Lu) 2008 – 2011
- calculated the weak lensing effect of cosmic string
- used the alignment-breaking parameter of radio jets to detect wiggly infinite cosmic strings
- used the distortion of background galaxies to detect wiggly infinite cosmic strings

Undergraduate research: School of Physics and Technology, Wuhan University (advisor: Prof. Jueping Liu) 2007 – 2008
- found solutions of Kaluza–Klein's space-time-matter theory with a cosmological constant

Talks

Contributed talk on “Agatha: disentangling periodic signals from correlated noise” in the Exoclipse conference in Boise, USA 2017

Invited talk on “Agatha: disentangling periodic signals from correlated noise” in the EPRVIII workshop at PennState, USA 2017

Invited talk on “The Oort Cloud” at the Letchworth & District Astronomical Society, UK 2016

“Comet impacts, glaciations and mass extinctions”, presented at NAOC, Beijing 2015

“Assessing the influence of astronomical phenomena on the Earth”, presented in the GREAT ITN Final Conference, Barcelona, Spain 2014

“Dynamical models for the impact rate and angular distribution of long period comets,” presented at the 223rd AAS meeting in the the Gaylord National Resort and Convention Center, Maryland, USA 2014

“The history of comet impacts modulated by the solar motion,” presented at the “European Week of Astronomy and Space Science” 2013

(EWASS2013), Turku, Finland

“Assessing the influence of astronomical phenomena on the Earth's biosphere” presented at the "European Planetary Science Congress 2012" (EPSC2012), Madrid, Spain — 2012

”Assessing of the influence of astronomical phenomena on the Earth's biosphere” presented at the “GREAT ITN WP3 Kick-off” meeting, Heidelberg, Germany — 2012

Service, Teaching, Tutoring & Outreach

Referee for AJ — 2017

Referee for MNRAS — 2016

Supervision of a Master student on a project titled “Finding close encounters: Toward a consensus on the influence of stellar flybys on the solar system over 10 million years” — 2016 - present

Supervision of undergraduate students in the lab course “Wavefront analysis with a Shack-Hartmann sensor”, MPIA, Heidelberg — 2012
- introduced the course and task
- helped students to finish the task and grade students' work

Volunteer for the “Hou Yi 2009” project in Anhui, China — 2009
- took photos of the Sun's corona during the solar eclipse
- introduced the solar eclipse on campus in Huazhong University of Science and Technology

Volunteer for the 2009 International Year of Astronomy at Pukou Observatory in Nanjing University, China — 2009
- helped undergraduate students to use small telescopes

Skills & Lauguages

- **Skills:** Time series analysis, MCMC, web app development, Bayesian inference, Celestial dynamics, AMUSE software
- **Computing experience:** R language (advanced proficiency), Python (intermediate)
- **Languages:** Chinese (native), English (advanced proficiency)

References

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Publications

- **Feng F.**, Jones H. R. A., Tanvir T. S., 2017d, *A catalogue of close encounter pairs,* submitted to MNRAS, arXiv:1707.05277
- **Feng F.**, Tuomi M., Jones H. R. A., Barnes J., Anglada-Escude G., Vogt S. & Butler R. P., 2017c, *Color difference makes a difference: four planet candidates around tau Ceti,* AJ, 154, 135 (media coverage: CNN, Daily Mail, BBC, Gizmodo, Sky News, Sky & Telescope)
- **Feng F.**, Tuomi M., Jones H. R. A., 2017b, *Evidence for at least three planet candidates orbiting HD20794, A&A, DOI:* https://doi.org/10.1051/0004-6361/201730406, arXiv:1705.05124
- **Feng F.**, Tuomi M., Jones H. R. A., 2017a, *Agatha: Disentangling periodic signal from correlated noise in a periodogram framework*, MNRAS, 470, 4794, the corresponding online application is available at http://www.agatha.herts.ac.uk
- Barnes J. R., Jeffers S. V., Anglada-Escude G., Haswell C. A., Jones H. R. A., Tuomi M., **Feng F.,** Jenkins J. S., Petit P., 2016, *Recovering planet radial velocity signals in the presence of starspot activity in fully convective stars,* MNRAS, 466, 1733
- **Feng F.**, Tuomi, M., Jones, H. R. A., Butler, R. P., & Vogt, S., 2016, *A Goldilocks principle for modeling radial velocity noise,* MNRAS, *461, 2440*
- **Feng F.**, & Bailer-Jones C.A.L., 2015, *Finding the imprints of stellar encounters in long-period comets,* MNRAS, 454, 3267
- **Feng F.**, & Bailer-Jones C.A.L., 2015, *Pleistocene deglaciations paced by variations of the Earth's orbit*, Quaternary Science Review, 122, 166
- **Feng F.**, & Bailer-Jones C.A.L., 2014, *Exploring the role of the Sun's motion in terrestrial comet impacts*, MNRAS, 442, 3653
- **Feng F.,** & Bailer-Jones C.A.L., 2013, *Assessment of the influence of the astronomical phenomena on the Earth's biosphere*, ApJ, 768, 152
- Domainko W., Bailer-Jones C.A.L., **Feng F.,** 2013, *A history of the gamma-ray burst flux at the Earth from Galactic globular clusters*, MNRAS, 432, 258
- **Feng F.,** 2012, *Radio jets and galaxies as cosmic string probes*, Frontiers of Physics, 7, 461

During my PhD, I have investigated the influence of various astronomical phenomena on the Earth's climate and biosphere. I have applied Bayesian inference to the analysis of geological time series such as fossil, ice core, and cratering records (e.g. Feng & Bailer-Jones 2013, 2015a). I have also simulated the solar motion in the Galaxy to investigate the connection between the Sun's motion and the mass extinction rate and impact rate recorded by craters on the Earth. Unlike previous studies, I did not find any strong connections (Feng & Bailer-Jones 2014). Without invoking a companion in the outer solar system, I have explained the anisotropic perihelia of long periodic comets using the solar apex motion (Feng & Bailer-Jones 2014). As a postdoc at Max Planck Institute for Astronomy, I have continued my PhD project by simulating the evolution of Oort cloud under the perturbations from known stellar encounters. This is the first attempt to quantify the influence of stellar encounters on the Oort cloud (Feng & Bailer-Jones 2015).

During the postdoc research performed at the University of Hertfordshire, I have applied the Bayesian reference in the analysis of radial velocity data to detect exoplanets. I have introduced the so-called "Goldilocks principle" in the noise modeling of radial velocity data to avoid false positives and false negatives (Feng et al. 2016). According to my research, the moving average model is optimal in modeling correlated noise.

I have developed the red noise periodograms called Bayes factor periodogram (BFP) and marginalized likelihood periodogram (MLP) based on likelihood optimization and marginalization. These periodograms are combined to form a framework, which is implemented in the Agatha web application (`http://www.agatha.herts.ac.uk`). Agatha has been found to outperform previous periodograms in terms of removing correlated noise, selecting noise models, and testing consistency of signals (Feng et al. 2017a).

I have also introduced a new noise proxy called "differential radial velocities" to model the wavelength-dependent noise in the radial velocity data. This proxy is able to weight *a posteriori* the radial velocity data measured within different wavelength ranges. The application of this proxy as well as the other statistical methods I have developed in the data of HD 20794 and tau Ceti leads to detections of a few Earth-size planets corresponding to radial velocity variation as low as 0.3 m/s, the weakest signal ever detected using the radial velocity method (Feng et al. 2017b,c).

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Feng, F., Tuomi, M., Jones, H. R. A., et al. 2017c, submitted (linked in CV)

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Interstellar travel in a network of habitable worlds

Interstellar travel is challenged by the significant distance between stars and the techniques available for long-period manned travel with relativistic speed. Projects like Breakthrough starshot aim at sending a unmanned gram-scale “StarChip” to alpha Centauri using beamed laser propulsion (Bae 2012; Lubin 2016). Although the technology required for manned interstellar travel may take decades to develop, if successful, this would bring us to a new era of interstellar travel.

Assuming a full knowledge of the habitability of nearby Earth analogs, we need to know the optimal time and routes of approaching them. Since interstellar travel may take thousands of years to prepare and complete, the distance between stars could change significantly. For example, a star with a relative speed of 50 km/s would travel about 10 kAU per kyr. Such a change is significant for manned interstellar travel especially when the speed of the spaceship is far less than the speed of light. Therefore an exploration of the best routes and targets for interstellar travel is crucial for the spread of human’s civilization around the Galaxy. As a DTM fellow, I plan to explore optimal routes for interstellar travel in a network of habitable worlds (HWs) by finding habitable planets around close encounters of the Solar System and of close encounter pairs in the Galaxy. I will achieve this goal with the following steps.

- **Encounters of the Solar System and encounter pairs:** Scholz’s star and GJ 710 passed and will pass the Sun at respective distances of 52 kAU and 13 kAU, 70,000 yr ago and 1.35 Myr from the present (Mamajek et al. 2015; Berski & Dybczyński 2016). Although it will take more than 1 Myr for GJ 710 to move to its perihelion, it may only take 22 kyr for an M-dwarf like Scholtz’s star which is six times faster than GJ 710. These fast encounters may pass the Sun by less than 0.1 pc within a few thousand years and thus are perfect targets for human’s initial interstellar travel.

  I have already identified 0.2 million close encounter pairs with periapses less than 1 pc (Feng et al. 2017a). I will make a new catalog of more encounters of the Solar System and more encounter pairs with more precise periapsis using the upcoming Gaia data releases, which will provide accurate astrometric data and reasonable radial velocity precision. Close encounters of a star would also influence the habitability of the circumstellar planets through dynamical effects (Bailer-Jones 2011; Feng & Bailer-Jones 2013, 2015a). Therefore the new encounter catalog would shape a network of close encounters not only for interstellar travel but also for assessing the interstellar climate of potentially habitable and thus colonizable worlds.

- **Finding planets around encounters:** The radial velocity variations caused by Earth analogs is comparable with or even lower than the noise level induced by stellar activity and instrumental bias (Fischer et al. 2016; Feng et al. 2017d). Thus the main challenge of the radial velocity method is how to disentangle planetary signals from noise. In my previous studies (Feng et al. 2016, 2017b,c,d), I have developed various data analysis techniques (e.g. Agatha, Fig.1) and used them to detect radial velocity signals with semi-amplitudes as low as 0.3 m/s. I plan to apply these methods in the analysis of the radial velocity data of close encounters to identify Earth-like planets.

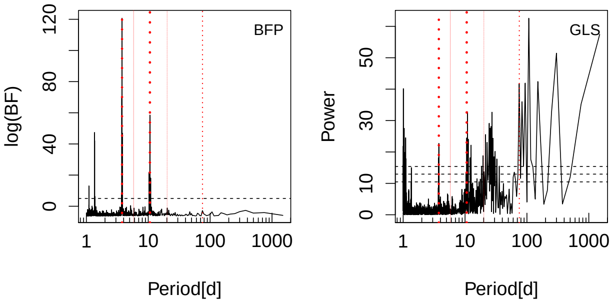

Fig. 1: The BFP (left panel) and the widely used generalized Lomb-Scargle periodogram (GLS; right panel) for the second synthetic system of the radial velocity challenge (Dumusque et al. 2017). The signals are denoted by red dotted lines, and the size of the red dots is proportional to the signal amplitudes. The false alarm probability of 0.1%, 1% and 10% are denoted by horizontal dashed lines in the right panel. The dashed line in the left panel denotes the Bayes factor threshold of 150.

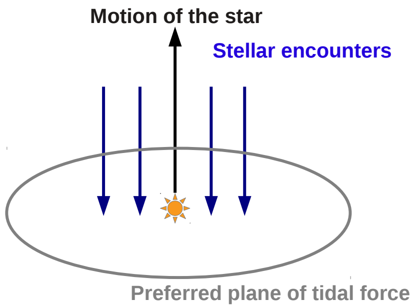

Fig. 2: Diagram of the preferred tidal plane. Stellar encounters tend to approach a planetary system in the opposite direction of the motion of the host star, producing a preferred plane where the tidal forces imposed on the planets are the strongest.

- **Studying the formation/evolution and habitability of Sun-like systems:** During my PhD, I have discovered a tidal plane around a planetary system caused by anisotropic stellar encounters induced by the stellar peculiar motion with respect to the local standard of rest (Feng & Bailer-Jones 2014). This mechanism is called "kinematic tide" in my recently submitted paper (Feng et al. 2017a). Unlike Kozai mechanism, the tidal plane would impose stochastic force on the disc and planets, and change the inclination or angular momentum of planet/disc, leading to spin-orbit misalignment. Since the tidal force is anti-propportional to the semi-major axis, the planetary system or protoplanetary disc would be warped by the kinematic tide. This warp structure is visible from the inclinations of the solar system, that is, outer planets are more inclined than the inner planets with respect to the solar equator despite slight randomization probably due to planet scattering. I also find similar phenomena in a limited exoplanet sample. It is even possible to infer the birth environment from the warp structure of a planetary system. This kinematic tide may also be able to explain the Galactic warp. As a Carnegie DTM fellow, I plan to apply this mechanism to explain the formation of extra-solar planetary systems.

  I will also study the influence of encounters on the habitability of planetary systems. The mass extinctions on the Earth are probably partly caused by asteroid/comet impact events (Alvarez et al. 1980; Bailer-Jones 2009). The impact rate depends on the dynamics of giant planets and the population of objects in the debris disk and/or Oort cloud (e.g. Feng & Bailer-Jones 2015a). Thus the architecture/structure of a planetary system would strongly influence the habitability of an exoplanet.

  To quantify this influence, I plan to simulate the formation and dynamical evolution of extra-solar systems. First, since the architecture of a system is typically unknown, I will sample the orbital elements of particles in the stable regions derived from analytical analysis of the Lagrange stability of known exoplanets (Barnes & Greenberg 2006), and integrate the orbits of these particles together with known exoplanets to determine the optimal orbital solution of unknown planets. Second, I will build models of debris disks based on the disc samples observed by telescopes such as HST and Spitzer. Third, I will simulate the whole system in the AMUSE software environment (Portegies

Zwart et al. 2013), following the numerical approach used for Oort cloud simulations (Feng & Bailer-Jones 2014, 2015b).

- **Exploring an optimal route for interstellar travel in a network of habitable worlds:** Based on the results of the above steps, I will make a network of HWs for interstellar travel. First, I will identify the HWs around encounters to form a time-varying network. Then I will explore the optimal time and routes for interstellar travel by optimizing the distance between HWs over time. Third, I will simulate HW networks in a Monte Carlo fashion to account for the incompleteness of HW sample and to study the time scale and various parameters in the model of interstellar travel. This work will be the first attempt to quantify the influence of different factors in the time scale of Galactic colonization and to deal with the Fermi paradox in a robust way.

With many experts on exoplanet research, the DTM in Washington is a perfect place for me to pursue the proposed research. In particular, I will work with Prof. Paul Butler to fully analyze the archived RV data from KECK/PFS/APF/LICK, Rainer Spurzem and upcoming data from instruments like G-CLEF and GMTNIRS on GMT. I will also work with John Chambers, Alycia Weinberger, and Alan Boss in order to study the formation and habitability of these planetary systems and to find an optimal route for interstellar travel in the network of habitable worlds. I will also continue my collaboration with the international exoplanet team including Coryn Bailer-Jones, Simon Portegies Zwart, Mikko Tuomi, Hugh Jones, Guillem Anglada-Escude, John Barnes, Steve Vogt, Paul Butler, James Jenkins, etc. I expect this research project to provide a considerable sample of Earth analog candidates and to advance our understanding of planetary habitability and to provide feasible routes and HW network for interstellar travel.

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Bailer-Jones, C. A. L. 2009, International Journal of Astrobiology, 8, 213

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Barnes, R., & Greenberg, R. 2006, The Astrophysical Journal Letters, 647, L163

Berski, F., & Dybczyński, P. A. 2016, A&A, 595, L10

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Fischer, D., Anglada-Escude, G., Arriagada, P., et al. 2016, ArXiv e-prints, arXiv:1602.07939

Lubin, P. 2016, arXiv preprint arXiv:1604.01356

Mamajek, E. E., Barenfeld, S. A., Ivanov, V. D., et al. 2015, ApJL, 800, L17

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