ISSI/ISSI-BJ International Team Proposal: Population-Dynamical Archeology of Galaxies

Abstract: Galaxies show a huge diversity of structure and stellar populations, reflecting a complex and unknown mixture of star formation episodes and hierarchical merging events in their past that are impossible to observe directly. Promising new methods to recover the distribution of stellar orbits within a galaxy can reveal its dynamical 'skeleton', which in turn sets the spatial distribution of its baryons. However, to fully reconstruct the *assembly history* of the galaxy we must simultaneously infer ages for the recovered orbits of stars and star clusters. Age dating these stellar tracers provides a dynamical *memory* for the galaxy, as the orbits are imprinted by discrete events (galaxy mergers, starbursts) in the galaxy's history. We have begun the first steps towards this novel combination of stellar population and orbit-based dynamical modelling. With the support of the ISSI team framework, we will apply this revolutionary tool to existing data available from the astronomical community. The dynamical records this method identifies will pinpoint the epoch of major mergers which grew a galaxy's bulge and halo, or timescales over which its disk(s) formed. These focused meetings are necessary, as a particularly diverse set of expertise (spectroscopic data analysis, chemical evolution, dynamical modeling, algorithm optimization, model validation via comparison with simulations) are required to solve this problem. The timing of this funding proposal is crucial to fully exploit the wealth of space and ground based imaging and wide field spectroscopic data that are being released for thousands of galaxies – and for the first time, age-date the invisible past assembly history of galaxies.

Science Rationale:

Galaxies form over billions of years, through repeated episodes of star formation, accretion of molecular gas and mergers with other galaxies. When we observe the light from stars in a present-day galaxy, a given region contains a superposition of stars of many ages, and their orbits in the galaxy result from a multitude of star formation, or merger events. To disentangle this mixture of stars we need to consider their ages and orbits together. Current state-of-the-art imaging and spectroscopic analysis techniques cannot recover the ages (or metallicity, as a proxy for age) and orbits simultaneously. Therefore, despite the wealth of available space-based data, we are unable to determine via what mechanisms and over what timescales a galaxy's structures (disk, halo, bulge) formed. The work we propose here will change that. We have developed techniques to analyze the ages, metallicities and orbits of stars (and star clusters) *simultaneously*, and for the first time, recover the memory of how *individual* galaxies were assembled (Zhu, van de Ven, Leaman et al. 2020; *submitted*)

With the exception of our own Galaxy, the primary way to study galaxy evolution has been to look at more distant galaxies at high redshift, as an approximate window back in time. These high redshift observations are of low spatial resolution and do not provide a direct link between galaxies at different cosmic epochs. As such, this approach yields, at best, coarse statistical trends for populations of galaxies. Observations from integral field unit spectrographs (such as MUSE at the VLT) coupled with imaging from HST and upcoming telescopes

like the *James Webb Space Telescope* (JWST) and *Extremely Large Telescope* (ELT), now provide the opportunity to probe *distributions* of orbits and ages within *individual* galaxies. This will be done for thousands of nearby galaxies. However, we *need revolutionary tools capable of extracting and interpreting these evolutionary signposts, in order to recover the past assembly history of individual galaxies*.

Our group has recently developed and validated those unique tools. Using an innovative population-orbital decomposition approach, we leverage the dynamical and stellar population "memory" encoded in the light and orbital motions of stars, to re-construct the build-up of individual galaxies. Key to this is high resolution *Hubble Space Telescope* (HST) imaging which helps constrain the galaxy's mass distribution. Our dynamical models then tell us how stars orbit in the galaxy's gravitational potential; the addition of new stellar-population models tells us the chemical composition (metallicity) and ages of the stars on each orbit. The age and chemistry imprinted in a star at its birth and observable today, provide a calibration 'clock' to age date common types of orbits, and link their dynamical memory to discrete events in the galaxy's past assembly.

The new technique yields the first dynamical decomposition of a galaxy from integrated light spectroscopy, where the different orbital structures resulting from its formation can be age-dated. In **Figure 1** we show a schematic illustration of how the recovered orbit distribution results in different structural components of the galaxy. With our age and chemical tagging method, we can recover and understand how and over what timescale these dynamical components were assembled. Additionally, HST (and soon JWST) provide characterization of the star cluster populations in the outer halos of galaxies, which our team uses to estimate the number of mergers a galaxy has undergone in its past (Beasley, Trujillo, Leaman et al. 2018). These novel methods of galactic archaeology reveal the formation history of a galaxy in unprecedented detail by quantitatively recovering how mergers of smaller galaxies and star formation events created different structures that are responsible for the diversity we see today. This method extracts orders of magnitude more information from current ground and space-based integrated light spectroscopy of galaxies, and is necessary to fully exploit observations from upcoming facilities.

While existing methods are unable to disentangle the intrinsic dynamical structures of different stellar populations, our new approach will transform our understanding of galaxy evolution. We have already made significant progress in the development of this analysis code (with a method validation paper submitted to the journal), and initial application to several galaxies has begun. Thus, with thousands of galaxies observed with HST and spectroscopic IFU instruments publicly available (from e.g., MUSE, as well as the CALIFA, SAMI, MANGA surveys), we are positioned to fully exploit these community investments with our cutting-edge tools. Public JWST early release science and successful Cycle 1 GO proposals from our team would be an exciting bonus opportunity to apply our methods to these space-based observations in 2022. The culmination of these efforts and support from the ISSI will result in public analysis tools and results for the community which will revolutionize how we can 'look back' in cosmic history and understand, for the first time, the assembly and formation history of individual galaxies. We will demonstrate and disseminate the results of the collaborative

work in international journals, and make the analysis tools available to the community via public software repositories.

Team composition:
The members of this proposed team have a diverse set of expertise in cutting-edge dynamical modelling techniques (used to recover the underlying motions of stars in these galaxies from space-based observations), chemical evolution models (used to understand the metallicities and ages of different stars orbiting in a galaxy) photometric analysis (used to identify and characterize the star cluster populations of galaxies) and numerical simulations (used to test the performance and interpret the results of the method). To analyze the large and multi-dimensional datasets of modern space based photometric and integrated light spectroscopic observations efficiently, we also have started external collaborations with computer science experts to optimize our software. The named team of experts has a 6:6 (female:male) gender balance, and nearly all of us have worked together before on related projects in galaxy evolution. These aspects will aid the project by ensuring a diversity of strategies and efficient collaborative research efforts.

Our team members span multiple countries in Europe (Germany, Austria, Italy, U.K., Spain) as well as institutes in China and the USA, and represent postdoctoral research fellows, junior faculty members, and established faculty members in these astrophysics institutes. We would like to strengthen the core research team by adding diverse experts from additional institutes in Europe and China which are listed in this proposal. The triaxial Schwarzschild dynamical modelling code is developed by researchers in Europe, and significant expertise and application of it has been led by team members in China. We will strengthen this collaboration with the meeting at ISSI-Beijing. Similarly, the HST and JWST photometric studies, IFU spectroscopic observations and analysis expertise, which form the core observational data for this method, are led by teams in Europe and the USA. We have appended the list of proposed team members, their contact information and CVs to the end of this document.

Why the ISSI?:
The scope of our science goal (combining galaxy dynamics with chemical evolution) necessitates a diverse team of experts working on a common task over multiple years. The framework of the ISSI/ISSI-BJ international team meetings is essential to help this project and analysis method reach new heights, and provide a revolutionary set of tools for the scientific community to study galaxy evolution. We have leading experts in the method who are building groups in China, and the planned meetings in Bern and Beijing are extremely well suited to grow this collaboration with the galaxy evolution community in Europe.

Timeliness and synergy with observational facilities:
We are on the brink of a data revolution. Integral field spectroscopic surveys now provide clear views of the stellar kinematics and populations within hundreds of galaxies. Our team's involvement in these observations, and application of the new population-dynamical decomposition technique in the next two years, will reveal the formation history for these galaxies for the first time. Simultaneously, upcoming space-based and ground-based observatories will provide data for many more galaxies and at better resolution than is possible with current facilities. Of particular note are NASA/ESA's JWST (launch date Spring 2021; Cycle 1 proposal deadline Spring 2020) and the European Southern Observatory's ELT (first light 2025). Both observatories will operate in the Infrared (IR), which effectively allows us to study the oldest stars (earliest epochs of formation) with increased sensitivity. Being able to look out to larger distances also increases the number of galaxies we can study.

The IR integrated-light capabilities will allow us to measure both chemistry and kinematics for thousands of galaxies with unprecedented detail. We can only unlock the potential of such rich datasets with the tools we describe here, that can deconstruct a galaxy and its star clusters into its constituent parts from integrated-light images and infer how these components were dynamically assembled. With the tools necessary to exploit these important data in hand, these meetings will allow our team to maximize the science impact from existing ground based IFU and upcoming spaced-based observations during this exciting era for astronomy.

The HST and *Gaia* have both been fundamental for our understanding of nearby resolved galaxies (e.g., Watkins et al. 2019), and there are plenty of data available in their archives. We are actively applying our methods for merger history recovery to existing HST observations, in addition to leading proposals for more observations with HST and JWST. In so doing, we will also tease out new information from existing data, maximising the scientific return of these great observatories. Our proposal is particularly timely to capitalise on the fantastic synergy between HST, JWST and current ground-based spectroscopic facilities. The culmination of the proposed collaborative meetings will provide the astrophysics community revolutionary tools to transform our view of how galaxies evolve over time.

Requested resources and planned deliverables:
We anticipate that the team will meet in the early part of 2021 in Bern to discuss and complete tasks related to optimization and validation of the method. The subsequent meeting in mid-2022 in Beijing will focus on preparing key applications of the method to public (or proprietary Cycle 1) JWST data (anticipated early 2022), and extant wide field IFU spectroscopic data from our team's wealth of MUSE observations. The two meetings are crucial to combine the efforts of the experts from the member institutes towards this revolutionary goal. We anticipate that significant two-way knowledge transfer from the sub-groups in China and those in Europe will be necessary to maximize the impact of our method for the field. Hence, we request financial support (accommodation and per diems) for 24 person-meeting weeks, spanning two meetings (one each in Bern and Beijing).

We anticipate that in addition to successful completion and application of our population-dynamical decomposition method, these meetings will significantly aid, and result in:

- Publications in international journals
- Advertisement of the results from the meetings in international conferences
- Thesis research projects for PhD students
- Collaborative and expertise growth in the member countries and institutes
- Dissemination of analysis tools to the astronomical community

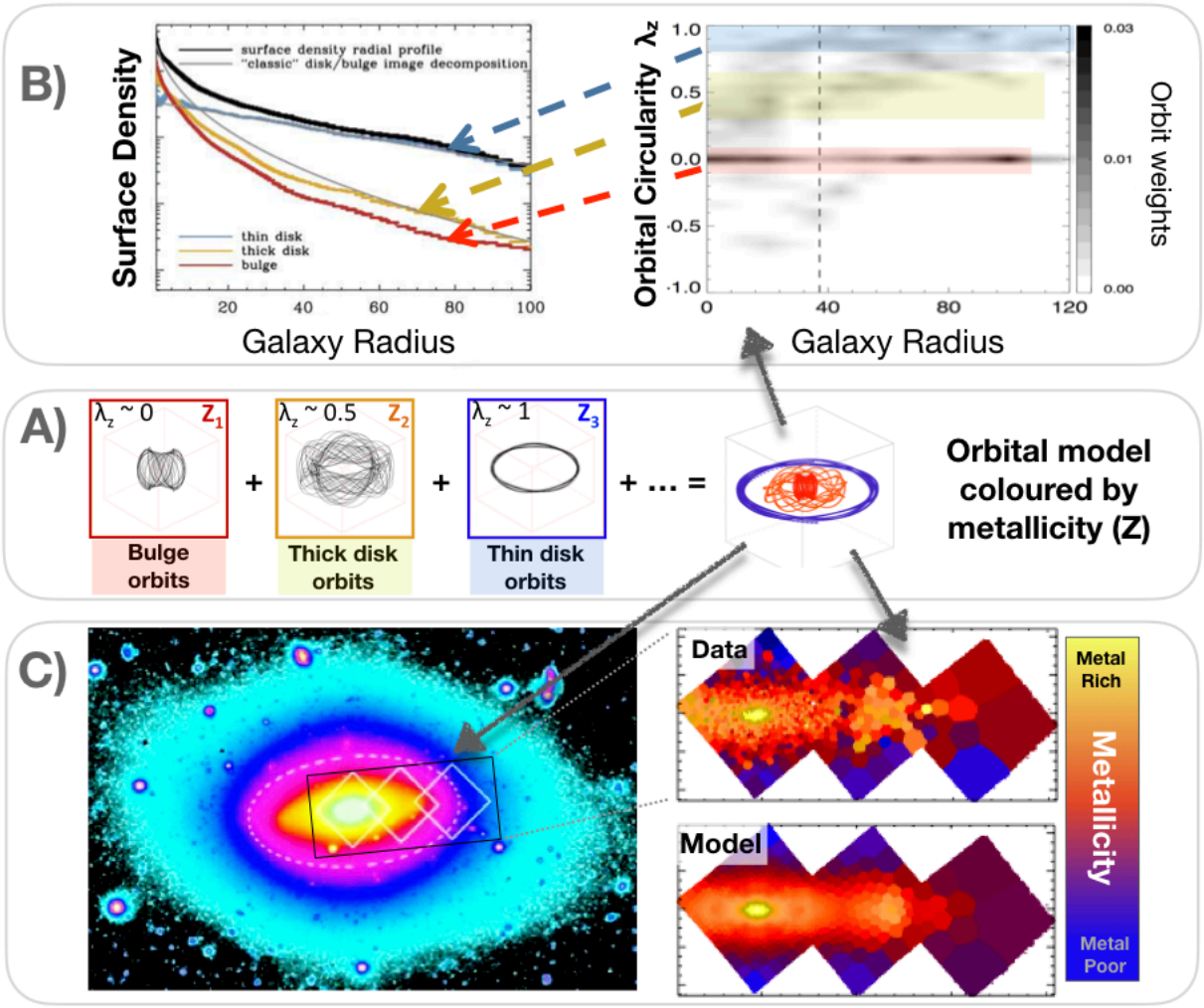

Figure 1: Schematic of population-orbital decomposition of a galaxy. *Middle Panel* (***A***)*:* Different stellar orbits are combined to reproduce a galaxy's observed internal kinematics, resulting in a dynamical model for the galaxy. Our new method now simultaneously tags ('colours') these orbits by age and metallicity. *Top panel* (***B***)*:* Orbits of different circularity result in different stellar surface density configurations in the galaxy. These give a more accurate decomposition of a galaxy's bulge and disk components than imaging data alone. *Bottom panel* (***C***)*:* The same orbit distributions coloured by age/metallicity, can now be projected on-sky and compared to the spatial distribution of ages/metallicities in the galaxy observed with MUSE. This new method provides the first way to clock the assembly of different dynamical structures which build up the galaxy (e.g., mergers, disk settling).

Team Contacts:

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5) **Dr. Mike Beasley**
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6) **Dr. Aura Obreja**
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10) **Dr. Marie Martig**
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11) **Dr. Stefano Zibetti**
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12) **Dr. Yunpeng Jin**

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NAME, First Name: LEAMAN, Ryan

Affiliation: Max-Planck Institute for Astronomy

Role in the project: co-Team Leader. Experience in chemical evolution and dynamical modelling, spectroscopic analysis techniques and analytic modelling of galaxy evolution processes.

Current position: Postdoctoral Research Fellow, MPIA

Former Position(s):

- 2019 – 2019 Visiting Professor, University of Vienna, Vienna, Austria
- 2015-2017 NSERC Postdoctoral Fellow, MPIA, Heidelberg, Germany
- 2012-2014 Postdoctoral Fellow, Marie Curie FP7 ITN Network 'DAGAL', based at the Insituto de Astrofisica de Canarias, Tenerife, Spain

Education:

- 2012 PhD in Astrophysics. "Constraints on Environmental and Secular Effects on the Chemodynamical Evolution of Dwarf Galaxies". Supervised by Prof. Kim Venn, University of Victoria, Victoria, Canada
- 2008 M.Sc. in Astronomy. Supervised by Profs. Kim Venn and Don VandenBerg, University of Victoria, Victoria, Canada
- 2005 B.Sc. in Physics, Astronomy (with distinction). Supervised by Prof. Paula Szkody, University of Washington, Seattle, Canada
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Services in National and/or International Committees (last ones):

- 2017. Reviewer for NWO Vidi Fellowship (Netherlands)
- 2015- present: Thesis committee member as main supervisor of 2 PhD students

Honors:

- 2015-2016, NSERC PDF Research Award (100000 CAD)
- 2017-2018, DAAD/DFG Personnel research exchange project grant (30000 EUR)
- 2005 John Baer Prize Award for undergraduate research, University of Washington

Selected Publications:

- Zhu**,** van de Ven**, Leaman** et al., 2020, MNRAS, submitted *Disentangling the formation history of galaxies via population-orbit superposition: method validation*
- Leung, **Leaman,** van de Ven, Battaglia, 2020, MNRAS, 493,320 *A dwarf-dwarf merger and dark matter core as a solution to the globular cluster problems in the Fornax dSph*
- **Leaman**, Ruiz-Lara, Cole, et al, 2020, MNRAS 492, 5102 *Globular cluster ejection, infall and the host dark matter halo of the Pegasus dwarf galaxy*
- Boecker, **Leaman**, van de Ven, Norris, Mackereth, Crain 2020, MNRAS, 291, 823, *A galaxy's accretion history unveiled from its integrated spectrum*
- **Leaman**, Fragkoudi, Querejeta et al., 2019, MNRAS 488, 3904 *Survival of molecular gas in a stellar feedback-driven outflow witnessed with the MUSE TIMER project and ALMA.*

- Zhuang, **Leaman**, van de Ven, Zibetti, Gallazzi, Zhu, Falcón-Barroso, Lyubenova, 2019, MNRAS 483,186, *A dynamical view on stellar metallicity gradient diversity across the Hubble sequence with CALIFA*
- Leung, **Leaman,** van de Ven, Lyubenova, Zhu, Bolatto, Falcón-Barroso, Blitz, Dannerbauer, ..., 2018, MNRAS 477, 254. *The EDGE-CALIFA survey: validating stellar dynamical mass models with CO kinematics*
- Beasley, Trujillo, **Leaman**, Montes, 2018, Nature 555, 483. *A single population of red globular clusters around the massive compact galaxy NGC1277*
- **Leaman,** Mendel, Wisnioski, Brooks, Beasley, Starkenburg, Martig, Battaglia, Christensen, Cole, de Boer, Wills, 2017, MNRAS 472, 1879. *A unified model for age-velocity dispersion relations in Local Group galaxies: disentangling ISM turbulence and latent dynamical heating*
- **Leaman,** Erroz-Ferrer, Cisternas, Knapen, 2015, MNRAS 450, 2473. *Triggered star formation in a merging gas-rich dwarf galaxy around NGC 7241*
- Romano, Bellazzini, Starkenburg, **Leaman**, 2015, MNRAS 446, 422. *Chemical enrichment in very low metallicity environments: Boötes I*
- **Leaman,** VandenBerg, Mendel, 2013, MNRAS 436, 122. *The bifurcated age-metallicity relation of Milky Way globular clusers and ist implications for the accretion history of the galaxy*
- VandenBerg, Brogaard, **Leaman**, Casagrande, 2013, ApJ 775, 134. *The ages of 55 Globular Clusters as determined using an improved Delta VHBTO method along with color-magnitude diagram constraints and their implications for broader issues*
- **Leaman,** Venn, Brooks, Battaglia, Cole, Ibata, Irwin, McConnachie, Mendel, Starkenburg, Tolstoy, 2013, ApJ 767, 131. *The comparative chemical evolution of an isolated dwarf galaxy: A VLT and Keck spectroscopic survey of WLM*
- **Leaman,** Venn, Brooks, Battaglia, Cole, Ibata, Irwin, McConnachie, Mendel, Tolstoy, 2012, ApJ 750, 33. *The resolved structure and dynamics of an isolated dwarf galaxy: A VLT and Keck spectroscopic survey of WLM*
- **Leaman,** 2012, AJ 144, 183. *Insights into pre-enrichment of star clusters and self-enrichment of dwarf galaxies from their intrinsic metallicity dispersions*

NAME, First Name: ZHU, Ling

Affiliation: Shanghai Astronomical observatory, Shanghai, China

Role in the project: co-Team Leader. One of the key members on developing a population-orbit model based on the orbit-superposition Schwarzschild model, which will be improved by other team members. My role is especially on the step of orbit chemical tagging, and implementing the empirical and theoretic age-metallicity relation—which will also be developed by other team members—in the population-orbit model. A new post-doc in my group (to be hired mid-2019) will focus on applying the new method to existing Integral Field Unit (IFU) observational data.

Current position: Researcher in Shanghai Astronomical observatory (2018.9-)

Former Position(s): Post-doc in Max-Planck institute for Astronomy (2013.9-2018.9)

Education: Tsinghua University, PhD, 2013; Tsinghua University, Bachelor's degree, 2008

Honors: Youth Qianren Fellow 2019

Selected Publications:

(1) **Ling Zhu, Glenn van de Ven, Ryan Leaman** et al., 2020, MNRAS, submitted *Disentangling the formation history of galaxies via population-orbit superposition: method validation*

(2) **Ling Zhu**, Remco van den Bosch, Glenn van de Ven, et al., *Orbital decomposition of CALIFA spiral galaxies*, MNRAS, 2018.1.1, 473: 3000~3018

(3**) Ling Zhu**, Glenn van de Ven, Remco van den Bosch, Hans-Walter Rix, et al., *The stellar orbit distribution in present-day galaxies inferred from the CALIFA survey*, Nature Astronomy, 2018.1.1, 2: 233

(4) **Ling Zhu**, Glenn van de Ven, et al., *Morphology and kinematics of orbital components in CALIFA galaxies across the Hubble sequence*, MNRAS, 2018.6.1, 479: 945~960

(5) **Ling Zhu**, Glenn van de Ven, Laura Watkins, Lorenzo Posti, *A discrete chemodynamical model of the dwarf spheroidal galaxy Sculptor: mass profile, velocity anisotropy and internal rotation*, MNRAS , 2016.7.1, 463: 1117~1135

(6) **Ling Zhu**, Richard Long, Shude Mao, et al., *The Next Generation Virgo Cluster Survey V: Modeling the dynamics of M87 with the Made-to-Measure* ApJ, 2014.6.1, 792: 59~77

NAME, First Name: VAN DE VEN, Glenn

Affiliation: Department of Astrophysics, University of Vienna, Türkenschanzstraße 17, 1180 Vienna, Austria

Role in the project: co-Team Leader. Key team member bringing the expertise on dynamical modelling of stellar systems, ranging from the Milky Way and its surrounding globular clusters and dwarf satellites, to nearby galaxies across the Hubble sequence. By combining the advanced dynamical models developed in my group with the unique stellar population and simulation expertise of other team members, we will be able to infer the luminous and dark matter distribution as well as uncover the 'fossil record' of the formation history of stellar systems.

Current position: Full Professor of Theoretical Extragalactic Astrophysics, University of Vienna

Former Position(s):

- 2017 – 2019 International Staff Member, ESO, Garching near Munich, Germany
- 2009 – 2017 Research Group Leader, MPIA, Heidelberg, Germany
- 2006 – 2009 Hubble Fellow, Institute for Advanced Study, Princeton, USA
- 2006 Astrophysics Postdoctoral Fellow, Princeton University, USA

Education:

- 2001 – 2005 Ph.D. in Astronomy at Leiden University (with honor)
- 1999 – 2001 M.Sc. in Astronomy + Mathematics at Leiden University (with honor)
- 1996 – 1999 B.Sc. in Astronomy + Mathematics at Leiden University
- 1996 – 1997 Computer Science propaedeuse (first year undergraduate) at Leiden University

Services in National and/or International Committees (last ones):

- 2012 – … Reviewer for funding agencies, incl. ERC/EU, URF/UK, NWO/Netherlands, FONDECYT/Chile, ANR/France, SNSF/Switzerland, AvH/Germany
- 2012 – … External PhD examiner in Austria(1), France (1), NL (4) and UK (2)
- 2010 – … Thesis committee member as main supervisor of 12 PhD students
- 2004 – … Referee astrophysical journals, incl. MNRAS, AJ, ApJ, Science
- 2014 – 2017 Member Works Council (Betriebsrat) at MPIA
- 2009 – 2016 Board member CALIFA survey with bi-annual ”Busy Week” meetings

Honors:

- ASTRO 3D Distinguished Visitor, Australia, June 2019
- ERC Consolidator Grant (2 million Euros), 2017 — 2022

- SAURON Group Achievement Award 2012 by UK Royal Astronomical Society
- Hubble Fellowship, 2006 — 2009
- Cum laude Ph.D. in Astronomy, Leiden University, 2005
- Cum laude M.Sc. in Astronomy & Mathematics, Leiden University, 2001

Selected Publications:

- Zhu L., **van de Ven G.**, Leaman R., . . . , MNRAS, 2020 (submitted, arXiv:2003.05561), *Disentangling the formation history of galaxies via population-orbit superposition: method validation*
- Boecker A., Leaman R., **van de Ven G.**, . . . , MNRAS, 2020, 491, 823, *A galaxy's accretion history unveiled from its integrated spectrum*
- Zhu L., **van de Ven G.**, van den Bosch R., . . . , Nature Astronomy, 2018, 2, 233, *The stellar orbit distribution in present-day galaxies inferred from the CALIFA survey*
- Falcón-Barroso J., Lyubenova M., **van de Ven G.**, ..., A&A, 2017, 597, 48, *Stellar kinematics across the Hubble sequence in the CALIFA survey: general properties and aperture corrections*
- Zhu L., **van de Ven G.**, Watkins L. L., Posti L., MNRAS, 2016, 463, 1117, *A discrete chemo- dynamical model of the dwarf spheroidal galaxy Sculptor: mass profile, velocity anisotropy and internal rotation*
- Amorisco N. C., Evans N. W., **van de Ven G.**, Nature, 2014, 507, 335, *The remnant of a merger between two dwarf galaxies in Andromeda II*
- Meidt S. E., Schinnerer E., **van de Ven G.**, . . . , ApJ, 2014, 788, 144, *Reconstructing the stellar mass distributions of galaxies using S4G IRAC 3.6 and 4.5 micron images: II. The conversion from light to mass*
- Singh R., **van de Ven G.**, Jahnke K., … , A&A, 2013, 558, 43: *The nature of LINER galaxies: Ubiquitous hot old stars and rare accreting black holes*
- Liu C., **van de Ven G.**, MNRAS, 2012, 425, 2144, *Chemo-orbital evidence from SDSS/SEGUE G-type dwarf stars for a mixed origin of the Milky Way's thick disc*
- Lee W. H., Ramirez-Ruiz E., **van de Ven G.**, 2010, ApJ, 720, 953: *Short Gamma-ray Bursts from Dynamically Assembled Compact Binaries in Globular Clusters: Pathways, Rates, Hydro- dynamics, and Cosmological Setting*
- van den Bosch R. C. E., **van de Ven G.**, 2009, MNRAS, 398, 1117–1128, *Recovering the intrinsic shape of early-type galaxies*
- Weijmans A.-M., Krajnovic´ D., **van de Ven G.**, … , 2008, MNRAS, 383, 1343–1358, *The shape of the dark matter halo in the early-type galaxy NGC 2974*
- van den Bosch R. C. E., **van de Ven G.**, Verolme E. K., … , 2008, MNRAS, 385, 647–666, *Triaxial orbit based galaxy models with an application to the (apparent) decoupled core galaxy NGC 4365*
- **van de Ven G.**, van den Bosch R. C. E., Verolme E. K., de Zeeuw P. T., 2006, A&A, 445, 513–543, *The dynamical distance and intrinsic structure of the globular cluster ω Centauri*

NAME, First Name: WATKINS, Laura L.
Affiliation: Space Telescope Science Institute – European Space Agency
Role in the project: Expert in analysis of internal and global kinematics of small stellar systems, discrete dynamical modelling of globular clusters and dwarf galaxies, using simulations to test models and inform future research directions.
Current position: ESA/AURA Astronomer Level II
Former Position(s): Fellow, University of Vienna & Visiting Fellow, European Southern Observatory – Fellow, European Southern Observatory – Postdoc, Space Telescope Science Institute – Postdoc, Max Planck Institute for Astronomy
Education: PhD, University of Cambridge (Cambridge UK)
Services in National and/or International Committees (last ones): Panelist: HST Cycle 27. Support for panels: HST Cycles 22, 23 & 24, JWST Early Release Science, ESO P104. AAS DDA Brouwer Award Selection Committee (2018, 2019, Chair 2020).
Honors: 2019 CoI HST GO-15911 (20 orbits) – 2019 CoI VLT/MUSE (18h) – 2018 CoI HST Archival Legacy ($394k) – 2018 CoI VLT/FLAMES 102.D-0164A (14.8h) – 2018 CoI VLT/NACO 101.D-0385A (9.5h) – 2017 PI HST Theory AR-15055 ($149k) – 2017 CoI VLT/MUSE 60.A-9181A (1.1h) – 2017 CoI HST GO-15173 (5 orbits) – 2015 PI HST Theory AR-14322 ($143k) – 2015 CoI HST GO-14235 (24 orbits) – 2015 CoI HST GO-14155 (5 orbits) – 2015 CoI VLT/MUSE 095.B-0585A (10h).
Selected Publications:

- Read et al. (incl. **Watkins**), 2020, submitted MNRAS, *"Breaking Beta: A Comparison of Mass Modelling Methods for Spherical Systems"*;
- Kamman et al. (incl. van de Ven, **Watkins**), 2020, MNRAS, 492, 966, *"The Peculiar Kinematics of the Multiple Populations in the Globular Cluster M80 (NGC 6093)*
- **Watkins** et al., 2019, ApJ, 873, 118, *"Evidence for an Intermediate Mass MW from Gaia DR2 Halo GC Proper Motions"*
- Hénault-Brunet et al. (incl. **Watkins**), 2019, MNRAS, 483, 1400, *"Mass Modelling Globular Clusters in the Gaia Era: A Method Comparison Using Mock Data from an N-body Simulation of M4"*
- **Watkins** et al; 2015, ApJ, 812, 149, "*HSTPROMO Catalogs of Galactic Globular Clusters. III. Dynamical Distances and M/L Ratios*"
- **Watkins** et al.; 2015, ApJ, 803, 29, "*HSTPROMO Catalogs of Galactic Globular Cluster. II. Kinematic Profiles and Maps*"
- **Watkins** et al. (incl. van de Ven); 2013, MNRAS, 436, 2598, "*Discrete dynamical models of omega Centauri*"

NAME, First Name: BEASLEY, Michael A.

Affiliation: Instituto de Astrofísica de Canarias (IAC)

Role in the project: Team Member. Expertise in globular clusters, stellar populations.

Current position:
• Dec. 2017 - now. Severo Ochoa Advanced Fellow

Former Position(s):
• Jan. 2001 - Dec 2004. Royal Society Postdoc, Swinburne, Melbourne, Australia
• Jan 2005 - Dec. 2006. SAGES fellow, UC Santa Cruz, U.S.A.
• Jan 2007 - Dec. 2009. Generic Postdoc, Instituto de Astrofísica, Spain
• May 2013 – Dec 2016. Severo Ochoa Postdoc

Education:
• BSc in Physics at Liverpool John Moores University (United Kingdom)
• Ph.D. in Astrophysics at the University of Durham (United Kingdom)
Services in National and/or International Committees (last ones):
• OPTICON H2020 proposal assessor

Honors:
• Royal Society young scientist grant (UK 2001)
• Monbusho scholarship award (Japan 2000)

Selected Publications:
• Beasley, M.A., 2020, review chapter in “Globular Clusters and Galaxy Formation” in book "Reviews in Frontiers of Modern Astrophysics: From Space Debris to Cosmology, Springer, doi:10.1007/978-3-030-38509-5
• Beasley, M.A. et al., 2018, Nature, 555, 483.
• Beasley M.A. et al., 2016, ApJL, 819, 20

NAME, **First Name**: OBREJA, Aura

Affiliation: University Observatory Munich

Role in the project:
Developer of the "galactic structure finder (gsf)" code, which finds dynamical components of simulated galaxies using clustering techniques in a parameter space derived from the integral of motions. My role in the project is to couple gsf with the output of the orbit superposition Schwarzschild model code with the aim of identifying galaxy substructures in observations, and cross match them with dynamical components in high resolution cosmological simulations.

Current position: Postdoc University Observatory Munich (from February 2017)

Former Position(s): Postdoc New York University Abu Dhabi (January 2016 – January 2017), Posdoc Max Planck Institute for Astronomy (February 2015 – December 2015)

Education:
- PhD in Astrophysics, Universidad Autonoma de Madrid (October 2010 – May 2015)
- MSc in Astrophysics, Universidad Autonoma de Madrid & Universidad Complutense (October 2008 – September 2010)

Selected Publications:
- **Obreja** et al. 2019, *Local photoionization feedback effects on galaxies*, 2019MNRAS.490.1518O
- **Obreja** et al. 2019, NIHAO XVI: *The properties and evolution of kinematically selected discs, bulges and stellar haloes*, 2019MNRAS.487.4424O
- Buck, Ness, **Obreja,** Macciò and Dutton 2019, *Stars behind bars II: A Cosmological Formation Scenario for the Milky Way's Central Stellar Structure*, 2019ApJ...874...67B
- **Obreja** et al. 2018, *Introducing galactic structure finder: the multiple stellar kinematic structures of a simulated Milky Way mass galaxy*, 2018MNRAS.477.4915O
- **Zhu, van de Ven,** Méndez-Abreu and **Obreja** 2018, *Morphology and kinematics of orbital components in CALIFA galaxies across the Hubble sequence*, 2018MNRAS.479..945Z

NAME, First Name: LYUBENOVA, Mariya

Affiliation: European Southern Observatories – Garching bei München, Germany

Role in the project: Core Team Member. Expert in galaxy nuclei stellar populations and dynamics, as well as in the interplay between baryons and dark matter in galaxies

Current position:
2017 – present: Faculty astronomer and Head of Media Relations at European Southern Observatory

Former Position(s):

- 2014 – 2017: Post-doctoral researcher in University of Groningen, the Netherlands
- 2010 – 2014: Post-doctoral fellow in Max Planck Institute for Astronomy, Heidelberg, Germany
- 2010: Visiting researcher in the Department of Astronomy, University of Sofia, Bulgaria
- 2009: Post-doctoral researcher, ESO, Garching bei München, Germany

Education:

- 2005 – 2008: Dr. rer. nat. in Astronomy (PhD), ESO, Degree awarded by Ludwig-Maximilians-Universität, Munich, Germany
- 2004 – 2005: MSc in Physics, Astronomy and Astrophysics, University of Sofia, Bulgaria
- 2000 – 2004: BSc in Physics, University of Sofia, Bulgaria

Services in National and/or International Committees (last ones):

- Reviewer for STFC (UK), National Science Fund (Bulgaria)
- 2017 – present: Serving on various selection boards for scientific fellowships, science support funding and advisory boards of PhD students at ESO
- 2015 - present: Jury member at the European Union Contest for Young Scientists

Selected Publications:

- **Lyubenova, M.** & Tsatsi, A. (2019), *Nuclear angular momentum of early-type galaxies hosting nuclear star clusters,* A&A, 629, A44
- Fahrion, K., **Lyubenova, M.** et al. (2019), *Constraining nuclear star cluster formation using MUSE-AO observations of the early-type galaxy FCC 47*, A&A, 628, A92
- Martín-Navarro, I., **Lyubenova, M.,** et al. (2019), *Fornax 3D project: a two-dimensional view of the stellar initial mass function in the massive lenticular galaxy FCC 167*, A&A, 626, A124

NAME, First Name: XU, Dandan

Affiliation: Department of Astronomy, Tsinghua University
Role in the project: Core Team Member. Expert on dynamical modelling and numerical galaxy simulations.
Current position: Associate Researcher
Former Position(s):
2013/06-2018/07: Postdoc at Heidelberg Institute for Theoretical Studies, Germany
2011/06-2013/05: Argelander Institute for Astronomy, Bonn University, Germany
Education:
2006/09-2010/02: Jodrell Bank Centre for Astrophysics, The University of Manchester, United Kingdom
2000/09-2004/07: Department of Astronomy and Astrophysics, Beijing University, China
Selected Publications:

1. **Xu, Dandan,** Zhu, Ling, Grand, Robert et al. 2019, MNRAS, 489, 1, 842. *A study of stellar orbit fractions: simulated IllustrisTNG galaxies compared to CALIFA observations*
2. ***Xu, Dandan***; Springel, Volker; Sluse, Dominique; Schneider, Peter; Sonnenfeld, Alessandro; Nelson, Dylan; Vogelsberger, Mark; Hernquist, Lars.
"*The inner structure of early-type galaxies in the Illustris simulation*",
2017, MNRAS, 469, 1824

3. Hilbert, Stefan; ***Xu, Dandan***; Schneider, Peter; Springel, Volker; Vogelsberger, Mark; Hernquist, Lars. "*Intrinsic Alignments in the Illustris simulation*",
2017, MNRAS, 468, 790

4. ***Xu, Dandan***; Sluse, Dominique; Schneider, Peter; Springel, Volker; Vogelsberger, Mark; Nelson, Dylan; Hernquist, Lars. "*Lens galaxies in the Illustris simulation: power-law models and the bias of the Hubble constant from time-delays*", 2016, MNRAS, 456, 739

5. ***Xu, Dandan***; Sluse, Dominique; Gao, Liang; Wang, Jie; Frenk, Carlos; Mao, Shude; Schneider, Peter; Springel, Volker. "*How well can cold dark matter substructures account for the observed radio flux-ratio anomalies*", 2015, MNRAS, 447, 3189

6. Vogelsberger, Mark; Genel, Shy; Springel, Volker; Torrey, Paul; Sijacki, Debora; ***Xu, Dandan***; Snyder, Greg; Nelson, Dylan; Hernquist, Lars. "*Introducing the Illustris Project: simulating the coevolution of dark and visible matter in the Universe*", 2014, MNRAS, 444, 1518

NAME, First Name: FALCÓN-BARROSO, Jesús

Affiliation: Instituto de Astrofísica de Canarias (IAC)

Role in the project: Core Team Member. Expertise in stellar populations

Current position:

- Dec. 2014 - now. Scientific Research Staff at IAC (Spain)

Former Position(s):

- Oct. 2002 - July 2003. Postdoc at University of Nottingham (United Kingdom)
- July 2003 - Feb. 2005. EURO3D postdoc at Leiden Observatory (The Netherlands)
- March 2005 - Feb. 2009. European Space Agency Research fellow (The Netherlands)
- March 2009 - Dec. 2014. Ramón y Cajal Advanced fellow at IAC (Spain)

Education:

- BSc in Physics at the Universidad de La Laguna (Spain)
- PhD in Astronomy at the University of Nottingham (United Kingdom)

Services in National and/or International Committees (last ones):

- External advisor for the Royal Astronomical Society (January 2019)
- ESO OPC B2 panel chair (2014-2015)

Honors:

- Group Achievement Award 2012 awarded by the Royal Astronomical Society (UK)

Selected Publications:

- **Falcón-Barroso** et al., 2019, A&A, 632, 59
- **Falcón-Barroso** et al., 2017, A&A, 597, 48.
- **Falcón-Barroso, J.**, 2016, in "*Galactic Bulges*", ASSL, 418, 161.
- **Falcón-Barroso** et al., 2011, A&A, 532, 8.
- Sarzi, M., **Falcón-Barroso, J.**, et al., 2006, MNRAS, 366, 1151.
- **Falcón-Barroso** et al., 2006, MNRAS, 369, 529.

NAME, First Name: MARTIG, Marie

Affiliation: Liverpool John Moores University, Liverpool, UK

Role in the project: Core Team Member. I work on the connection between the internal structure of galaxies and their cosmological formation history using a combination of galaxy formation simulations, data modeling, as well as direct data-model comparison. My recent research mostly focuses on the formation and evolution of Milky Way like disk galaxies, and in particular mechanisms for thick disk formation. For this project, I will provide simulated galaxies to test the new dynamical modelling code, but am also interested in using dynamical models to directly compare simulations and observations, and constrain formation histories of disk galaxies.

Current position: Senior Lecturer (since 2017), Liverpool John Moores University

Former Position(s):

- 2015-2017: Senior Postdoctoral Fellow, working with Hans-Walter Rix, MPIA, Heidelberg, Germany
- 2013-2015: Humboldt Fellow, hosted by Hans-Walter Rix, MPIA, Heidelberg
- 2010-2013: Postdoctoral Research Associate, working with Darren Croton, Swinburne University of Technology, Melbourne, Australia

Education:

- 2007-2010: PhD on "Galaxy formation in a cosmological context", supervised by Frederic Bournaud, CEA Saclay and Paris-Sud University, France
- 2006-2007: Master's degree in Astrophysics, Paris-Sud University and CEA Saclay, thesis on "Star formation in interacting galaxies" supervised by Frederic Bournaud

Services in National and/or International Committees (last ones):

2018-2019: Member of the committee awarding the Royal Astronomical Society Research Fellowship

Selected Publications:

Martig M., Minchev I., Ness, M., Fouesneau M., Rix H.-W., *A radial age gradient in the geometrically thick disk of the Milky Way*, 2016, ApJ, 831, 139

Martig M., Minchev I. & Flynn C., *Dissecting simulated disc galaxies I: the structure of mono-age populations*, 2014, MNRAS, 442, 2474

Martig M., Bournaud F., Croton D. J., Dekel A. & Teyssier R., *A diversity of progenitors and histories for isolated spiral galaxies*, 2012, ApJ, 756, 26

NAME, First Name: ZIBETTI, Stefano

Affiliation: INAF – Osservatorio Astrofisico di Arcetri (Firenze, Italy)

Role in the project: Core Team Member. Expert on stellar population modelling, spectral analysis of large data samples

Current position: Staff researcher (INAF) and Contract Professor (Università degli Studi di Firenze)

Former Position(s):
-2010-2011: postdoctoral fellow at DARK Cosmology Centre/Niels Bohr Institute, University of Copenhagen (DK)
-2007-2010: postdoctoral fellow at Max-Planck-Institut für Astronomie, Heidelberg (D)
-2004-2007: postdoctoral fellow at Max-Planck-Institut für extraterrestrische Physik, Garching bei München (D)

Education:
-2001-2004: PhD in Astronomy at the LMU München, thesis with Prof. S.D.M. White at Max-Planck-Institut für Astrophysik, Garching bei München (D)
-1995-2001: MSci at Univ. Milano, MSci thesis with Prof. Giuseppe Gavazzi

Services in National and/or International Committees (last ones):
-2015: Committee for the assignment of INAF doctoral fellowships
-2011-2012: Member of Observing Program Committee (OPC) Panel A – Cosmology for the evaluation of ESO proposals in Periods 88, 89, 90 and 91

Honors:
-Fellowship International Max Planck Research School 2001-2004 in Munich
-International Max Planck Research School distinction

Selected Publications:
-*Near-infrared spectroscopy of post-starburst galaxies: a limited impact of TP-AGB stars on galaxy spectral energy distributions*, **Zibetti, S.**, Gallazzi, A., Charlot, S., Pierini, D. & Pasquali, A. (2013), MNRAS, 428, 1479.
-*Resolved stellar mass maps of galaxies - I. Method and implications for global mass estimates*, **Zibetti, S.**, Charlot, S. & Rix, H.-W. (2009), MNRAS, 400, 1181.
-*Intergalactic stars in z~ 0.25 galaxy clusters: systematic properties from stacking of Sloan Digital Sky Survey imaging data*, **Zibetti, S.**, White, S. D. M., Schneider, D. P. & Brinkmann, J. (2005), MNRAS, 358, 949.

NAME, First Name: JIN, Yunpeng
Affiliation: Shanghai Astronomical Observatory, Chinese Academy of Sciences
Role in the project: expert on dynamical modelling
Current position: Postdoc
Education:
2010/09-2014/07: undergraduate student at the Department of Physics, Tsinghua University
2014/09-2019/11: PhD student at the National Astronomical Observatories, Chinese Academy of Sciences
Selected Publications:
Jin Y, Zhu L., Long R. J., Mao S., Xu D., Li H., van de Ven G., 2019, MNRAS, 486, 4753-4772. DOI: 10.1093/mnras/stz1170. "*Evaluating the ability of triaxial Schwarzschild modelling to estimate properties of galaxies from the Illustris simulation*."

Jin Y., Zhu L., Long R. J., Mao S., Wang L., van de Ven G., 2020, MNRAS, 491, 1690-1708. DOI: 10.1093/mnras/stz3072. "*SDSS-IV MaNGA: Internal mass distributions and orbital structures of early-type galaxies and their dependence on environment*."