Galactic Rings
Signposts of Secular Evolution in Disk Galaxies

27th May, 2018 – 1st June, 2018

The University of Alabama
Bryant Conference Center
240 Paul W. Bryant Drive
Tuscaloosa, AL 35401

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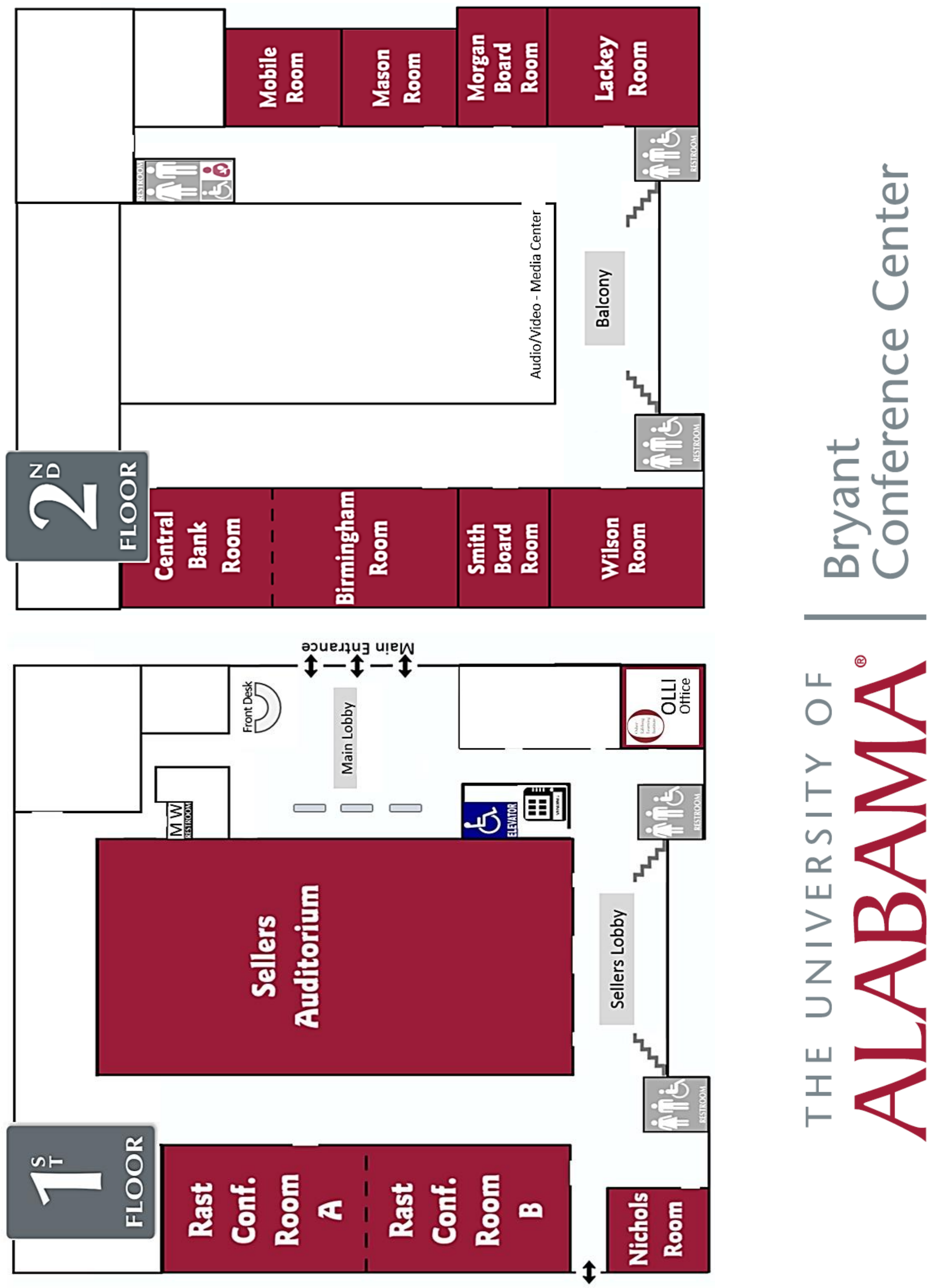
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Central Bank Room
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Mason Room
Morgan Board Room
Lackey Room
Audio/Video - Media Center
Balcony
RESTROOM
1ST FLOOR
Rast Conf. Room A
Rast Conf. Room B
Nichols Room
Sellers Auditorium
Sellers Lobby
Main Lobby
Front Desk
Main Entrance
ELEVATOR
OLLI Office
M W RESTROOM
THE UNIVERSITY OF ALABAMA
Bryant Conference Center

Logistics

Venue

Registration and check-in will take place in 'Sellers Lobby' at the Bryant Conference Center. All conference sessions will take place in 'Sellers Auditorium'. Lunches will take place in Rast A & B. Opening reception will be in Rast B.

Internet connection

Wi-Fi Network : UA-BryantConfCtr-BryantMuseum
Wi-Fi Password: *Bryant#1913
Eduroam is also available

Conference Mobile App

Search and download "UA Conference Services" in your Apple or Google Play Store.
Enter the Event ID: galactic
Username: your email (entered during abstract submission/registration)
Password: galactic

Daily Shuttle Service

Hotel Indigo
Shuttle will leave from the hotel at 8:20 a.m. each day.
Shuttle will leave from the BCC at 5:45 p.m. each day.

Hampton Inn
Shuttle will leave from the hotel at 8:35 a.m. each day.
Shuttle will leave from the BCC at 5:45 p.m. each day.

Airport Return Shuttle Service

Friday, June 1st
Shuttle leaves BCC at 12:00 p.m.; Arrives at airport at 1:15 p.m.
Shuttle leaves BCC at 2:00 p.m.; Arrives at airport at 3:15 p.m.

Saturday, June 2nd
Shuttle leaves Hotel Capstone at 8:00 a.m.; Arrives at airport at 9:15 a.m.
Shuttle leaves Hotel Capstone at 2:00 p.m.; Arrives at airport at 4:15 p.m.

Program

Sunday, May 27, 2018

5:00 - 7:00 p.m.: Opening Reception at Bryant Conference Center

Monday, May 28, 2018

8:00 a.m. - 9:00 a.m.	Registration & Refreshments
9:00 a.m. - 10:25 a.m.	Session I: Observational and Theoretical Overviews of Rings
R. Buta & F. Combes	Conference Introductions and Logistics
Ken Freeman	Galactic Rings: Historical Overview
J. Alfonso L. Aguerri	Rings and Disk Resonances
10:25 a.m. - 10:55 a.m.	Coffee Break
10:55 a.m. - 12:30 p.m.	Session II: Structural Properties of Rings
Ron Buta	Galaxy Evolution and the Morphology of Galactic Disk Rings
Heikki Salo	Multicomponent Structural Decompositions of Barred and Ringed Galaxies
Peter Erwin	Inner and (Mostly) Outer Rings and the Structure of Galactic Disks
Jairo Mendez-Abreu	The Intrinsic shape of galactic structures in ringed galaxies
12:30 p.m. - 2:00 p.m.	Lunch Break
2:00 p.m. - 3:30 p.m.	Session III: Dynamics of Ringed Galaxies
Lia Athanassoula	A multi-aspect view of bars and of the structures they drive
Merce Romero-Gomez	Rings and manifolds in barred galaxies
Daniel Pfenniger	Time-dependent resonances in barred galaxies: Implications for ring structures and secular evolution
3:30 p.m. - 4:00 p.m.	Coffee Break
4:00 p.m. - 5:30 p.m.	Session IV: Poster Session
	5-minute lightning talks
John Forbes	Rings as the shutdown of radial transport
Ron Buta	Comparison of Corotation Resonance Determinations
Marja Seidel	Ring galaxies as gravitational probes of pure dark matter halos
Bill Keel	Forging Dark Rings - Radial Clearing of Dust near Resonance Rings
Isaura Fuentes-Carrera	Kinematics of the ionized gas of the active ring galaxy NGC 5728
Shahram Talei	Making models of stellar halos to identify merger histories
4:30 p.m. - 5:30 p.m.	Poster Viewing
6:00 p.m.	Early Career Scientists Dinner – Surin Thai

Tuesday, May 29, 2018

8:00 a.m. - 9:00 a.m.	Registration & Refreshments
9:00 a.m. - 10:30 a.m.	Session V: Multi-Wavelength Tracers of Star Formation I
Johan Knapen	Star Formation and Stellar Populations in Disk Rings
Francoise Combes	Multi-wavelength Observations of Galactic Rings
Donovan Domingue	Rings in the KPAIR Herschel Survey of Galaxy Pairs
Irina Kostiuk	Current Star-Formation Rates in Early-Type Disk Galaxies with Outer Rings
10:30 a.m. - 11:00 a.m.	Coffee Break
11:00 a.m. - 12:30 p.m.	Session VI: Multi-Wavelength Tracers of Star Formation II
Olga Sil'chenko	Ultraviolet Rings in S0 Galaxies
Dimitri Gadotti	The TIMER Project: Time Inference with MUSE in Extragalactic Rings
Walter Maksym	Rings and Rays: a Chandra View of NGC 3081
Simón Díaz-García	Bars, rings, and signatures of secular evolution as seen in the S4G survey
12:30 p.m. - 2:00 p.m.	Lunch Break
2:00 p.m. - 3:55 p.m.	Session VII: Ringed and Barred Galaxies
Marja Seidel	Inner Rings in Barred Galaxies as probes to unravel disk galaxy evolution
Francesca Fragkoudi	Feedback from nuclear rings: Caught in the act with ALMA and MUSE-TIMER data
Mattia Sormani	On the origin of nuclear rings in barred galaxies
Woo-Young Seo	Effects of Disk Mass and Gas Fraction on the Formation of Nuclear Rings.
Ivan Katkov	Ansae in barred ringed galaxies
Isabel Perez	Unveiling the nature of barlens structures with TIMER
3:55 p.m. - 4:25 p.m.	Coffee Break
4:25 p.m. - 5:30 p.m.	Session VIII: Poster Session
	5-minute lightning talks
Eija Laurikainen	Barlenses in the CALIFA survey
Justus Neumann	The Nature of Star Formation within Bars
Francesca Fragkoudi	The secular origin of the Milky Way bulge
Amy Jones	2D metallicity gradients and how they depend on substructures in MaNGA galaxies
Gene Byrd	NGC 4622: A clear example of spiral density wave star formation in a ring galaxy
Colin Hancock	Arm structure, bars and rings in 3-armed spiral galaxies
Adrian Bittner	How do spiral arm contrasts relate to bars, disc breaks and other fundamental galaxy properties?
5:00 p.m. - 5:30 p.m.	Poster Viewing

Wednesday, May 30, 2018

8:00 a.m. - 9:00 a.m.	Registration & Refreshments
9:00 a.m. - 10:30 a.m.	Session IX: Barred Galaxy Dynamics
Xiaolei Zhang	Collective Effects and Secular Dynamical Evolution of Galaxies
Kathryne Daniel	Constraints on angular momentum changes for corotating stars
Joan Font	Annular kinematic segregation of galaxy disks
Luis Garma	Bar pattern speed estimates using the Tremaine-Weinberg method in MaNGA galaxies
10:30 a.m. - 11:00 a.m.	Coffee Break
10:55 a.m. - 12:30 p.m.	Session X: Barred Galaxy Properties
Shardha Jogee	Spatially Resolved Metallicity Distributions in Barred and Unbarred Galaxies: Implications for Galaxy Evolution since z∼2
Amelia Fraser-McKelvie	The Origin of Bars in Quenched Disk Galaxies: A MaNGA View
Charlotte Donohoe-Keyes	Determining the epoch of bar formation
Adriana de Lorenzo-Cáceres	Secular evolution driven by double-barred systems in the TIMER survey
Wesley Peters	Photometric Properties of Bars in Low Surface Brightness Galaxies
12:45 p.m. - 6:00 p.m.	Excursion with boxed lunches
	End of Day 3
	Dinner on own

12:45 p.m. - 2:00 p.m.	Shuttle to Moundville ∼ 40 minute drive
2:00 p.m. - 3:00 p.m.	Picnic lunch – Indoor or outdoor at Moundville. Boxed lunches need to be ordered on Monday at registration desk. Lunch cost is not included in registration.
3:00 p.m. - 5:00 p.m.	Moundville grounds and museum tour with tour guides. Please wear comfortable shoes.
5:00 p.m. - 6:00 p.m.	Shuttle returns participants to hotels.

For those not attending the Moundville excursion, a guided tour of the fossil collection at the Alabama Museum of Natural History (AMNH) can be arranged between 2:00 - 4:00 p.m.

Thursday, May 31, 2018

8:00 a.m. - 9:00 a.m.	Registration & Refreshments
9:00 a.m. - 10:35 a.m.	Session XI: Spiral Structures in Disk Galaxies
Elena D'Onghia	Formation and Evolution of Spiral Structure in Disk Galaxies
Bill Keel, Steven Bamford	The properties and origins of spiral structure across the galaxy population
Carmen Sánchez Gil	Study of stellar formation and evolution in spiral galactic disks
Tom Peterken	A new technique to measure pattern speeds of spirals in MaNGA
10:35 a.m. - 11:05 a.m.	Coffee Break
11:05 a.m. - 12:30 p.m.	Session XII: Collisional Ring Galaxies
Alexei Moiseev	Accretion-generated rings: coplanar and non-coplanar structures
James Higdon	The Star-forming ISM in Collisional Ring Galaxies
Florent Renaud	This Cartwheels on fire: gas flows and star formation in collisional ring galaxies
12:30 p.m. - 2:00 p.m.	Lunch Break
2:00 p.m. - 3:30 p.m.	Session XIII: Rings in Milky Way and Local Group Galaxies
Juntai Shen	Understanding the nuclear ring and other gaseous features of the Milky Way
Robert Benjamin	Are the Near and Far 3 Kiloparsec Arms of the Milky Way Actually A Galactic Ring?
Yumi Choi	A Ring-like Stellar Overdensity Structure in the Large Magellanic Cloud
Thomas Bensby	Unravelling the Origin of the Monoceros Ring - Detailed abundances in the Southern Structure
3:30 p.m. - 4:00 p.m.	Coffee Break
4:00 a.m. - 5:30 p.m.	Session XIV: Secular Processes in Disk Galaxies
Marcin Semczuk	Spiral arms, the warp and the stream in M33 as a result of an interaction with M31
Benjamin Davis	Black Hole Mass Scaling Relations for Spiral Galaxies Determined from Pitch Angles and Multicomponent Structural Decompositions
Min Du	Black Hole Growth in Disk Galaxies Mediated by the Secular Evolution of Short Bars
Justus Neumann	A combined photometric & kinematic recipe for evaluating the nature of bulges using CALIFA.
Benne Holwerda	The Dust Forecast; Predicting the Dust Attenuation in Spiral Disk Galaxies.

6:30 p.m. - 7:00 p.m.	Refreshments at Alabama Museum of Natural History
7:00 p.m. - 9:00 p.m.	Conference Dinner at Alabama Museum of Natural History

Friday, June 1, 2018

8:00 a.m. - 9:00 a.m.	Registration & Refreshments
9:00 a.m. - 10:50 a.m.	Session XV: Rings and other Galaxy Structure in Simulations
Frederic Bournaud	Ring galaxies in the nearby and distant Universe
Facundo Gomez	Warps, waves and rings in the stellar discs of the Auriga cosmological simulations
Nicolas Peschken	Galactic bars and galaxy interactions in the Illustris simulation
Grzegorz Gajda	Tidally induced bars in gas-rich dwarf galaxies orbiting the Milky
Tomasso Zana	Bar formation in cosmological simulations
10:50 a.m. - 11:15 a.m.	Coffee Break
11:15 a.m. - 12:20 p.m.	Session XVI: Cosmological Context
Karen Masters	Galaxy Morphology from Galaxy Zoo
Preethi Nair	Redshift evolution of bars, rings and spiral arms
12:20 p.m. - 12:45 p.m.	Session XVII: Wrap-up
	Discussion & Conference Summary
	End of Conference

Scientific Organizing Committee

Ronald Buta, The University of Alabama, US (co-chair)
Francoise Combes, Observatoire de Paris, France (co-chair)
Lia Athanassoula, Laboratoire d'Astrophysique de Marseille, France
Victor Debattista, University of Central Lancashire, United Kingdom
Peter Erwin, Max-Planck-Institute for Extraterrestrial Physics, Germany
Kenneth Freeman, The Australian National University, Australia
Dimitri Gadotti, European Southern Observatory, Germany
Enrica Iodice, INAF-Astronomical Observatory of Capodimonte, Italy
Woong-Tae Kim, Seoul National University, Korea
Johan Knapen, Instituto de Astrofsica de Canarias, Spain
Eija Laurikainen, University of Oulu, Finland
Preethi Nair, The University of Alabama, US
Juntai Shen, Shanghai Astronomical Observatory, China
Olga Sil'chenko, Sternberg Astronomical Institute, Lomonosov MSU, Russia

Local Organizing Committee

Preethi Nair, The University of Alabama, US (co-chair)
Ronald Buta, The University of Alabama, US (co-chair)
Jeremy Bailin, The University of Alabama, US
Amy Jones, The University of Alabama, US
Bill Keel, The University of Alabama, US
Lauren Lewis, Bryant Conference Center, US
Sea Talantis, Bryant Conference Center, US

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Abstracts

Monday, May 28, 2018

Session I - Overview of Galactic Rings

Galactic Rings: Historical Overview

28 May 09:05 40 min

Kenneth Charles Freeman
Research School of Astronomy & Astrophysics, The Australian National University

The various families of galactic rings provide insights into a wide range of processes that contribute to the evolution of galaxies. I will give a historical overview of the different kinds of Galactic Rings, from observational and theoretical perspectives.

Rings and Disk Resonances

28 May 09:45 40 min

J. Alfonso L. Aguerri
Instituto de Astrofisica de Canarias, Spain

Resonances are places in the disks where stars and gas strongly interact with other galaxy components. In particular, a large amount of angular momentum can be exchanged at resonances between the dark matter halo. This can produce important secular evolution in disk galaxies. Rings of star formation are common in disk galaxies at all Hubble types. They can be produced by internal or external galaxy processes and are easily observed in galaxies up to redshift about 1. Rings are related with disk resonances. This implies that they can be used as resonance tracers in the disks during a long period of the galaxy lifetime. In this talk I will review the main results obtained in the literature about the relation between rings and resonances in disk galaxies.

Session II - Structural Properties of Rings

Galaxy Evolution and the Morphology of Galactic Disk Rings

28 May 10:55 25 min

Ron James Buta
The University of Alabama

Galactic disk rings (i.e., features generally known as nuclear, inner, and outer rings) have well-defined properties that suggest that most such rings are molded by internal dynamical processes as opposed to external interactions. In my presentation, I will describe the insights into galaxy evolution provided by specific and general aspects of ring morphology, such as: their typical elongated shapes and preferred alignments with respect to bars, the way barred galaxy rings often resemble dominant families of orbits (e.g., as in cuspy inner rings and dimpled outer rings), the existence of doubled inner, outer, and nuclear rings, the apparent morphological continuity of rings and pseudorings, the preference for relatively weak bars in ringed galaxies, the wide range in intrinsic shapes of inner rings as compared to outer rings, differences between early- and late-type galaxy rings and between barred and nonbarred galaxy rings, the small to large misalignments between bars and inner rings occasionally seen, the relation between rings and lenses, cases where bars significantly underfill an inner ring, the presence of multiple rings having significantly different linear scales and time scales in the same galaxy, the strong correlation between intrinsic inner ring shape and the distribution of HII regions, and variation of ring properties along the Hubble sequence. Also likely relevant to ring evolution are the 3D structure of bars, the distinction between primary and secondary bars, and the dark spaces seen in many galaxies showing orbit-related rings.

Multi-component structural decompositions of barred and ringed galaxies

28 May 11:20 25 min

Heikki Salo, Eija Laurikainen
University of Oulu

Multi-component GALFIT decompositions using 3.6 micron S4G and optical SDSS data are described. Besides standard bulge+disk+bar components used in the S4G decomposition pipeline, we also include models for barlenses (a roundish inner component embedded in a narrow bar) and for various types of rings. The goal is to compare how the presence/properties of rings relate to the properties of other structural components. Tests with synthetic images from N-body simulations, treated in a similar fashion as observations, are also reported, comparing decomposition parameters to model-components derived directly from N-body data.

Inner and (Mostly) Outer Rings and the Structure of Galactic Disks

28 May 11:45 25 min

Peter Erwin
Max-Planck-Institute for Extraterrestrial Physics

I will discuss what is currently known about connections between rings, particularly outer rings, and the underlying radial profiles of galactic disks. Correlations between rings and truncations (Type II profiles, with downbending breaks in the surface-brightness profile) allow us to distinguish between two general models of profile formation. In many early-type disk galaxies, outer rings coincide with downbending breaks, suggesting that ring formation is directly linked to break formation, most likely due to an outer Lindblad resonance. But outer rings also coexist with Type I profiles (where no break is present), and in some cases with Type II profiles where the break is well outside the ring, the latter are indications that many truncations, especially in late-type spirals, are due to a different mechanism, such as a star-formation threshold. I will also discuss how rings can potentially produce false breaks in Type I profiles, especially in edge-on galaxies, as well as potential connections between outer rings and anti-truncated (Type III) profiles.

The intrinsic shape of galactic structures in ringed galaxies

28 May 12:10 20 min

Jairo Mendez-Abreu
Instituto de Astrofisica de Canarias

In this talk I will review our recent results on the intrinsic three-dimensional (3D) shape of bulges and bars, and its relation with inner and outer ring properties, in a statistically significant sample of galaxies from the CALIFA survey. Our work, based on the outcome of accurate multi-component structural decompositions of the galaxies, allows to deriving a probabilistic estimation of the 3D shape of individual structures, and it provides a new look at the secular evolution processes taking place in nearby galaxies. Besides leading to the detection of a merger-induced polar bulge in NGC4698, our analysis revealed that low Sersic indices (or low B/T) bulges have no preference in being oblate, prolate, or triaxial. On the contrary, bulges with high Sersic index in early-type galaxies, or in more massive galaxies, are mostly oblate systems. Bars are predominantly prolate spheroids, with a small fraction of triaxial and oblate bars. The typical flattening (intrinsic C/A semiaxis ratio) of the bars in our sample is 0.26, which matches well the typical intrinsic flattening of stellar discs at these galaxy masses. Combining the probability distributions of the intrinsic shape of bulges and bars we propose a new diagnostic to separate classical and disk-like bulges based on their relative intrinsic flattening. The connection between the 3D properties of bulges and bars with the presence of inner and outer rings, as well as their implications on the secular evolution of disk galaxies, will be presented in this talk.

Session III - Dynamics of Ringed Galaxies

A multi-aspect view of bars and of the structures they drive

28 May 14:00 40 min

Lia Athanassoula
Laboratoire d'Astrophysique de Marseille (LAM)

Bars are complex objects. In order to understand them and the structures they drive or are associated with (spirals, rings, lenses etc.) it is necessary to adopt a multi-aspect approach. The dynamical view starts from simple test particle studies – which are the roots of the corresponding orbital structure theory – to reach fully self consistent state-of-the-art dynamical simulations. This view has been essential to our understanding of bar formation and evolution and of the properties of the related structures. However, for a more global and yet more realistic view, one needs to add to the picture gas and the star formation, feedback and cooling which are associated to it. Further progress is possible by including the effects of environment and of accretion. Last but not least, by coupling a hydro + N-body code with a chemical evolution code it is possible to obtain information on the metallicity and the distribution of the various elements in the bar and in the components related to it. This is particularly crucial at the present time, as Gaia and the associated ground-based surveys have started giving results of unprecedented quality. I will very briefly describe the new understanding achieved as each of these views is brought in the picture and argue for the necessity of such a multi-aspect view.

Rings and manifolds in barred galaxies.

28 May 14:40 25 min

Merce Romero-Gomez[1], Lia Athanassoula[2], J.J.Masdemont[3]
[1]ICCUB-IEEC; [2]LAM; [3]UPC-IEEC

Rings appear in galaxies as prominent features having different morphologies and sizes. In this talk, we review the characteristics of outer and inner rings given by Ron Buta and we link them with the manifolds. Manifolds are a set of orbits which are present in the galactic potential when the axisymmetry of the galaxy is broken by the presence of, for example, a bar. There are two sets of manifolds at each end of the bar, namely two outer and two inner forming the outer and inner rings, respectively. We review that the characteristics of the manifold rings correlate well with the characteristics of the bar, providing a prediction tool to astronomers. Finally, we will show up-to-date applications of the manifolds in warped-barred galaxies and interacting galaxies.

Time-dependent resonances in barred galaxies: Implications for ring structures and secular evolution

28 May 15:05 25 min

Daniel Pfenniger[1], Kanak Saha[2], Yu-Ting Wu[3], Ron Taam[3]
[1]University of Geneva, Geneva Observatory; [2]IUCAA; Pune; India; [3]ASIAA; Taipei; Taiwan

The classical concept of resonance in disk galaxies has been developed with the assumption that a single pattern rotating with a constant speed perturbs the galactic potential, allowing to analyze the galaxy dynamics in a time-independent rotating frame. With these assumptions resonances, like the corotation and Lindblad resonances, are conceptually well defined, and at least one global integral of motion, the Jacobi constant, exists, confining star motion. Barred galaxies, however, have been shown since a long time (Sellwood & Sparke 1988) to possess at least two patterns rotating at distinct speeds, the bar and the spiral arms. Each pattern by its gravitational influence torques the other and modulates in time at the strongest the bar corotation region and its surrounding resonances. So the usual corotation and Lindblad resonances lose their usual meaning, and become "time-dependent resonances". We have reconsidered this situation using detailed analyses of fully self-consistent N-body models (Wu, Pfenniger & Taam 2016, 2018, Kanak, Pfenniger & Wu 2018) in order to quantify the dynamical incidence of these multiple patterns. To achieve this we needed to develop new methods to determine the instantaneous and local pattern speeds (Pfenniger, Kanak & Wu 2018). In this paper we will describe the consequences of these works about secular evolution, in particular the action non-conservation limiting the lifetime of rings, and helping stellar migration and, in combination with the bar vertical resonances, the formation of a thick disk.

Session IV - Poster Session I Lightning Talks and Viewing

Rings as the shutdown of radial transport

28 May 5 min

John C. Forbes[1], Mark Krumholz[2], Andreas Burkert[3], Avishai Dekel[4]
[1]Harvard University; [2]Mt. Stromlo Observatory; [3]University Observatory Munich; [4]Hebrew University Jerusalem

The local depletion timescale (the ratio of gas surface density to star formation surface density) is a few Gyr throughout galactic disks. This implies that galaxies must be constantly refueled. If galaxies accrete their gas predominantly at large radii, the centers of galaxies must be resupplied by inward radial transport of gas. A promising candidate mechanism for this transport is gravitational instability. We show here that galaxies undergoing this process will generically face the low-redshift shutdown of gravitational instability, followed by the rapid depletion of gas at their centers, leading to a ring of star formation at the interface between the stable and unstable part of the disk.

Kinematics of the ionized gas of the active ring galaxy NGC 5728

28 May 5 min

Isaura L. Fuentes-Carrera
Escuela Superior de Fisica y Matematicas, Instituto Politicnico Nacional

Extended kinematical studies of ionized gas in spiral galaxies have proven to be a powerful tool to identify motions related to the presence of structure such as bars, rings and spiral arms. In the case of active galaxies, this studies can also shed information on the inflow of gas from outer regions of a galaxy to its inner/nuclear parts. In this work, we present scanning Fabry-Perot observations of the active spiral ringed galaxy NGC 5728. We derive the velocity field of the ionized gas, the dispersion velocity and residual velocities maps. These fields are compared to morphological features in the galaxy at different wavelengths The pattern speeds of different density perturbations are derived and included in our morpho-kinematical analysis of this galaxy.

Ring galaxies as gravitational probes of pure dark matter halos

28 May 5 min

Marja K Seidel[1], Barry Madore[2], Melissa Jacquart[1], Michael Weisberg[1]
[1]Carnegie Observatories; [2]University of Pennsylvania

What is the Universe made of and how did it evolve? To date, we only know that baryons make up barely 5% of the total energy density of the Universe. In the context of our standard, LCDM, cosmological model, a quarter of the remaining 95% is dark matter. While our current understanding is that all luminous galaxies are embedded in large dark matter halos, CDM predicts a wealth of small scale structure which is in tension with current observations of low mass galaxies. This raises the possibility that not every dark matter halo hosts a luminous component, as also suggested by the missing satellites or the too-big-to-fail problems. The challenge is to detect those empty dark matter halos via gravitational signatures only. One of the clearest indicators of pure interactions are *ring galaxies*, single objects that are unambiguously the result from head-on collisions of two components. Instead of identifying two luminous components, we look for isolated ring galaxies without any visible companion. We will present a suite of hydrodynamic idealized collision simulations between a baryonic disk and a pure dark matter collider (including physical models for star formation and stellar feedback) to show that these galaxies are consistent with forming from a dark collider. In addition, we aim at detecting these pure dark matter halos through spectroscopic observations of isolated ring galaxies taken at the 6.5m Magellan telescopes. This is a cross-disciplinary program between astrophysicists and philosophers of science to study the unique blend of observation, simulation, theory, and reasoning that allows us to observe what we cannot see dark matter only visible through gravitational interaction, here by using ring galaxies.

Forging Dark Rings - Radial Clearing of Dust near Resonance Rings

28 May 5 min

William C. Keel[1], Benne Holwerda[2], Sarah Bradford[3], Anna M. Davis[4], Chris Lintott[5]
[1]The University of Alabama; [2]University of Louisville; [3]MTSI; [4]Stennis Space Center; [5]Oxford University

We use ringed and pseudoringed galaxies from the Galaxy Zoo sample of backlit galaxy systems, and in strongly lensing galaxy clusters, to determine the distribution of dust attenuation across resonance-ring structures and associated bars. Use of large background galaxies (and in a few favorable cases, long gravitational-lensing arcs) avoids the intercloud favoritism of small background galaxies, although these systems have given serendipitous anecdotal data that clear regions exist within resonance rings and adjacent to strong bars. We analyze HST, WIYN, or CTIO imaging for 9 backlit resonance rings. Some stellar rings are notably poor in dust, with V-band attenuations

< 0.02. Others are associated with thick dust lanes (V-band transmission < 0.5), but have nearly transparent surroundings on both sides. This pattern is independent of whether there is a strong bar inside the ring.

Comparison of Corotation Resonance Determinations

28 May 5 min

Ronald James Buta[1], Xiaolei Zhang[2]
[1]University of Alabama; [2]George Mason Universit

Multiple methods have been proposed in recent years to locate the corotation resonance (CR) in specific galaxies. In this poster, we compare the results from three methods: (1) the streaming phase-reversal (FB) method (Font et al., 2014, MNRAS, 444, L85), where sign changes in the residual velocity field are used to locate CR, (2) the potential-density phaseshift (PDPS) method (Zhang and Buta, 2007, AJ, 133, 2584), where a mass surface density map inferred from an image is used to locate CR as sign changes in phase shift versus radius plots, and (3) the gap method (Buta, 2017, MNRAS, 470, 3819), where dark gaps between inner and outer rings are assumed to trace the location of the CR.

Making models of stellar halos to identify merger histories

28 May 5 min

Shahram Talei, Jeremy Bailin
The University of Alabama

Abstract: Mergers are thought to be an important mechanism for forming rings, but we do not have good tools for identifying the merger histories of ringed galaxies. Stellar halos, while containing just a small fraction of stars in every galaxy, in principle encode those merger histories via their mass, metallicity, and structure. However, good theoretical models of stellar halos, which are necessary to decode that history, are lacking. We are developing a new semi-analytic/N-body simulation code called CoSANG to generate stellar halos in self-consistent cosmological simulations at low computational cost, which will be used to interpret stellar halo observations.

Tuesday, May 29, 2018

Session V - Multi-Wavelength Tracers of Star Formation I

Star Formation and Stellar Populations in Disk Rings

29 May 09:00 40 min

Johan Knapen
IAC Tenerife

Most rings form stars, and some rings form stars at very high rates indeed. I will review star formation in outer, inner, and nuclear rings, as well as the stellar population in these classes of rings. Implications for the secular evolution of galaxies will be discussed, as will the use of rings as 'star formation laboratories'.

Multi-wavelength observations of galactic rings

29 May 09:40 40 min

Francoise Combes
Observatoire de Paris

Rings are the location of resonances, where gas accumulates, and new stars form. These processes can be followed through different tracers, from the radio at low frequency to the very high X-rays, passing through Halpha, UV or far-infrared as main indicators of star formation. The physics of the atomic and molecular gas will be presented, and their dynamics, through gravitational torques investigation

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Rings in the KPAIR Herschel Survey of Galaxy Pairs

29 May 10:20 5 min

Donovan Louis Domingue
Georgia College & State University

The Herschel KPAIR survey provided far-infrared imaging and star formation measures for a sample of K-band selected "major-merger" candidate galaxy pairs in the local universe. The survey results suggest that spirals paired with other spirals are more likely to exhibit enhanced star formation than their counterpart spirals paired with early-type galaxies. Among the spirals in the KPAIR sample, 16 (12%) may be described as displaying galactic ring structures. The rings are not resolved in the Herschel imaging. They are distributed among both types of pairs, spiral+spiral (7 rings) and spiral+early type (9 rings). The specific star formation rates (sSFR, SFR/Mass) of the individual ringed spirals and a comparison to the population of paired galaxies are presented. The ringed spirals have moderate sSFR comparable to that of a non-paired control sample of galaxies and spirals paired with early-types in all mass bins included in the survey.

Current Star Formation Rates in Early-Type Disk Galaxies with Outer Rings

29 May 10:25 5 min

Irina Petrovna Kostiuk[1], Olga Sil'chenko[2]
[1]Special Astrophysical Observatory of the Russian Academy of Sciences, Russia; [2]Sternberg Astronomical Institute, Lomonosov Moscow State University, Russia

By using the atlas of stellar rings ARRAKIS (Comeron et al. 2014) we have compiled the list of early-type, S0-Sb, disk galaxies with outer stellar ring-like features (56 rings and 61 pseudorings). Current star formation, with the mean age of the young stellar population less than 200 Myr, is present in about a half of the rings. We have determined dust-corrected star formation rates, SFR, as well as SFR surface densities and absolute AB magnitudes in the ultraviolet (NUV and FUV bands of the GALEX cosmic mission) and (FUV-NUV) colors for the outer rings and for the galaxies as a whole. For further analysis we have took the SFR values averaged over FUV and NUV estimates. We demonstrate the relations between the dust-corrected SFR characteristics, UV colors, the galaxy morphological types, and integrated absolute magnitudes for the galaxies and their ring structures.

Session VI - Multi-Wavelength Tracers of Star Formation II

Ultraviolet Rings in S0 galaxies

29 May 11:00 25 min

Olga K. Sil'chenko[1], Irina Proshina[1], Alexei Kniazev[1,3], Oleg Egorov[3]
[1]Sternberg Astronomical Institute of the Lomonosov Moscow State University; [3]SAAO

Despite the general view that lenticular galaxies are 'red and dead', they often possess a large amount of cold gas, and roughly the half of gas-rich S0 galaxies reveal some level of current star formation organized in ring-like structures. We have undertaken a spectral study of a sample of starforming (UV-bright) rings in nearby S0 galaxies to clarify the origin of the gas and the regimes of star formation in the rings. We have found frequent decoupling between the gas and star kinematics implying the gas external origin. Also we have measured emission-line fluxes in the rings for all strong emission lines in the optical spectral range, trying to check the mechanism of gas ionization by plotting the emission-line flux ratios onto the diagnostic BPT-diagrams. Most emission-line rings confirm the gas excitation by young stars, and we have succeeded to estimate the gas oxygen abundance in these rings through the 'strong-line method'. To our surprise, the gas oxygen abundance in the rings is always close to solar one, despite the subsolar metallicity of the underlying old stellar populations and independently on the ring radius.

The TIMER Project: Time Inference with MUSE in Extragalactic Rings

29 May 11:25 25 min

Dimitri Gadotti and the TIMER team
European Southern Observatory

The TIMER project is a survey with the integral-field spectrograph MUSE (at the VLT) of nearby barred galaxies with prominent central structures, such as nuclear rings or inner discs. The powerful instrumental setup provides an unprecedented view of the central regions of these galaxies. The main goals of the project include: estimating the cosmic epoch when discs of galaxies settle, leading to the formation of bars and the onset of internal secular evolution, testing the downsizing hypothesis for galaxy formation, whereby more massive galaxies are formed first, and estimating the history of external gas accretion in disc galaxies. I will briefly describe how the survey is built and the derivation of high-level data products. The latter include maps of the spatial distribution of parameters describing the stellar line-of-sight velocity distribution, and of mean stellar ages and metallicities. We also derived the spatial distribution of star formation histories and physical properties of the warm/hot phases of the ISM across our MUSE fields. In addition, we also obtained the spatial distribution of the kinematic parameters of the warm/hot ISM. I will summarize some of our first results and illustrate how this dataset can be used for a plethora of other scientific applications, e.g., studying stellar feedback into the ISM, AGN outflows, properties of nuclear and primary bars, stellar migration and chemical enrichment, and the gaseous and stellar dynamics of the rich variety of central components in disc galaxies (such as nuclear rings and spiral arms, barlenses, box/peanuts and bulges).

Rings and Rays: a Chandra View of NGC 3081

29 May 11:50 20 min

Walter Peter Maksym[1], Martin Elvis[1], Pepi Fabbiano[1], M. Karovska[1], Alessandro Paggi[1], John Raymond[1], Guido Risaliti[2],Thaisa Storchi-Bergmann[3], Junfeng Wang[4]
[1]Harvard-Smithsonian Center for Astrophysics/Smithsonian Astrophysical Observatory; [2]INAF Arcetri; [3]UFRGS; [4]Xiamen University

We present new X-ray observations of the nearby ($\sim$ 34 Mpc) ringed Seyfert 2 galaxy NGC 3081 using the Chandra X-ray observatory. We will discuss reprocessing by the extended circumnuclear gas, some of which is likely associated with the Seyfert bicone, as well as likely reprocessing of the X-rays by the primary star-forming ring.

Bars, rings, and signatures of secular evolution as seen in the S4G survey

29 May 12:10 20 min

Simón Díaz-García[1], Johan Knapen[1], Heikki Salo[2], Eija Laurikainen[2], Martn Herrera-Endoqui[2]

[1]Instituto de Astrofisica de Canarias (IAC); [2]University of Oulu

Using the Spitzer Survey of Stellar Structure in Galaxies (S4G), we obtain average de-projected stellar density radial profiles (1D) and mean stellar bars (2D) by stacking hundreds of re-scaled 3.6 micron images of disk galaxies, binned by various fundamental properties including the total stellar mass and the prominence of rings/bars. We show, with unprecedented statistical significance, how stellar bars cause the radial spread of the disk and enhance the central stellar concentration. We then apply these stacking techniques to obtain average bars, rings, and disks in Halpha and at UV wavelengths, and to obtain mean colours in optical and near-IR passbands. This allows us to trace the ongoing star formation (SF) across galactic disks and in the circumnuclear regions with high S/N, detecting low level SF, and thus testing its dependence on local dynamical conditions (e.g. shear or torques by stellar non-axisymmetries). We find that bars contribute to the redistribution of cold gas and the regulation of SF within galactic disks. In addition, we shed light on the formation mechanisms of rings and spirals. For a sample of face-on and moderately inclined disk galaxies (i>65) we study the dimensions of resonance rings, ringlenses, and the spiral pitch angles as a function of the bar size and strength, using human-supervised measurements, and we compare our results to state-of-the-art simulation models. Bar strengths are calculated via Fourier decomposition of galaxy images, ellipse fitting, and from the gravitational tangential-to-radial forces. We conclude that stellar bars play a role in the formation of spiral arms and rings, although other factors come into play as well.

Session VII - Ringed and Barred Galaxies

Inner Rings in Barred Galaxies as probes to unravel disk galaxy evolution

29 May 14:00 20 min

Marja Kristin Seidel[1], Dimitri A. Gadotti[2], Paula Coelho[3], Charlotte Donohoe-Keyes[4], Jesus Falcon-Barroso[5], Francesca Fragkoudi[6], Bernd Husemann[7], Taehyun Kim[8], Ryan Leaman[7], Gigi Leung[7], Adriana de Lorenzo-Caceres[5], Marie Martig[4], Inma Martinez-Valpuesta[5], Justus Neumann[9], Isabel Pérez[10], Miguel Querejeta[9], Patricia Sanchez-Blázquez[11], Glenn van de Ven[7]

[1]Carnegie Observatories; [2]European Southern Observatory, Munich, Germany; [3]Universidade de Sao Paulo, Brasil; [4]Liverpool John Moores University, United Kingdom; [5]Instituto de Astrofisica de Canarias, España; [6]Max-Planck-Institut fur Astrophysik, Deutschland; [7]Max-Planck-Institut fur Astronomie, Deutschland; [8]Korea Astronomy and Space Science Institute; [9]European Southern Observatory; [10]Universidad de Granada, Espana; [11]Universidad Autonoma de Madrid, Espana

The plurality of existing galaxies in today's Universe remains in many facets an enigma in terms of their individual formation and evolutionary histories. Direct observations of high redshift galaxies and their low surface brightness disks are challenging. Therefore we use bars as chronometers and their built central structures as tracers to better understand the settling of massive galaxy disks. When disks become massive and cold enough, bars form quickly. Especially during the early formation, bars go through a buckling phase that provokes significant gas inflow to the inner regions. Inner structures such as nuclear rings and inner disks are hence formed by this inflow through the bar. By determining the star formation history of such bar-built inner structures in nearby galaxies we establish when the major galaxy disk settled into a cold state. We use observations of different integral field spectrographs such as WiFeS on the ANU 2.3m telescope in Siding Spring Observatory and MUSE at the VLT at ESO, as part of the TIMER team effort. The outstanding spectral resolution (R=7000, R=3000 respectively) and spectral coverage combined with the spatial resolution and a high signal-to-noise-ratio allow us to derive star formation histories while sampling at 10-100pc resolution. From both studies, we obtain a lower limit of when the disks settled of around redshift 2, coinciding with the peak of cosmic star formation. In addition, we find that about 50% of the stellar mass must have formed at that point, regardless of environment. So when the stars start dominating the potential of the galaxy, it allows the disk to settle, to form a bar that funnels gas to the center triggering the formation of central substructures, while quenching star formation in the bar region.

Feedback from nuclear rings: Caught in the act with ALMA & MUSE-TIMER data

29 May 14:20 20 min

Francesca Fragkoudi[1], Ryan Leaman[1], Miguel Querejeta[2], Gigi Leung[1], Dimitri Gadotti[2]

[1]Max Planck Institute for Astrophysics; [1]ESO and the TIMER collaboration

Stellar feedback plays a significant role in modulating star formation, redistributing metals and shaping the baryonic structure of galaxies. However, the efficiency of its energy deposition to the interstellar medium has been difficult to constrain observationally. As part of the MUSE-TIMER project, we have identified a molecular gas and dust shell, in ALMA and HST data, at the leading edge of an energetic outflow from the starbursting nuclear ring of the barred galaxy NGC 3351. The total energy budget of this stellar feedback event is comparable to low-luminosity AGN, and we show, via analytic and hydrodynamical modeling of the feedback processes, that stellar radiation pressure can drive the ionized and molecular gas out of the nuclear ring, in accordance with our observed MUSE kinematics. The morphology of the CO shell and emission-line diagnostics suggest a scenario where magnetic field lines in the dusty ISM aided its survival as it was launched from the ring by stellar feedback. This system's unique properties can serve as a useful litmus test for subgrid prescriptions in hydrodynamical galaxy simulations, as well as shed light on the feedback processes occurring in the central regions of disk galaxies.

On the origin of nuclear rings in barred galaxies

29 May 14:40 20 min

Mattia Carlo Sormani[1], Francesca Fragkoudi[2], Emanuele Sobacchi[3], Matthew Ridley[4]

[1]University of Heidelberg, Germany; [2]MPA Garching, Germany; [3]Ben-Gurion University of Israel; [4]University of Oxford

We present a novel and simple dynamical theory for the origin of nuclear rings in barred galaxies. In analogy with the usual theory of accretion discs, the theory is based on shear viscous forces among nested annuli of gas. However, in contrast with the usual case, the gas follows non circular orbits in a barred potential. This qualitatively changes the usual picture: instead of transporting angular momentum outwards while mass is accreted inwards, a trapping region is created where a stable and infinitely-long lived ring can survive. Our theory allows to predict the size of the nuclear ring given the underlying gravitational potential. The predicted radius in general significantly differs from the radius of the inner Lindblad resonance. The theory could provide a powerful tool to constrain the gravitational potential of barred galaxies, in particular their pattern speed.

Effects of Disk Mass and Gas Fraction on the Formation of Nuclear rings

29 May 15:00 15 min

Woo-Young Seo[1], Woong-Tae Kim[1], Phil Hopkins[2]
[1]Seoul National University; [2]Caltech

To study the formation and evolution of stellar bars and gaseous nuclear rings in realistic environments, we use GIZMO, a mesh-free hydrodynamic code, to run fully self-consistent three-dimensional simulations of Milky-Way sized isolated disk galaxies consisting of a stellar disk, gaseous disk, and live dark halo. Our simulations incorporate a prescription for star formation and feedback via supernovae and stellar winds. We find that the ring size varies with time as it is affected by the bar strength and the central mass concentration (CMC). A ring is very small when it first forms due to a small CMC and initial bar growth. Subsequent bar weakening as well as enhanced CMC make the ring grow in size afterwards. The rings form faster in more massive disks, and are larger in disks with a larger gas fraction. The bars and nuclear rings formed in our models have properties similar to those in the Milky Way.

Ansae in barred ringed galaxies

29 May 15:15 20 min

Ivan Katkov[1], Alexei Kniazev[2], Olga Sil'chenko[1]
[1]Sternberg Astronomical Institute, Lomonosov Moscow State University; [2]South African Astronomical Observatory

The general view of galaxy formation and evolution includes bars as the major drivers of the internal secular evolution of galaxies. The bars are very frequent phenomena: about one-third of all disk galaxies are strongly barred and an additional one-third are moderately barred. Often bars in galaxies are accompanied by rings and ansae phenomena at the end of bars. The ansae are bright enhancements at the ends of bar which are thought to be formed in the secular evolution phase ($>$ 5Gyr) of disk galaxies. The ansae are frequent phenomena since 40% of early-type disk galaxies reveal this feature but their properties and dynamical significance are still poorly understood. Based on the optical spectroscopic observations at SALT (South Africa) telescope we studied the stellar populations of ansae regions in 7 barred disk galaxies. All considered galaxies possess rings at the end of bars except one where the ring is less prominent. We found that ansae regions are significantly distinguished in the stellar metallicities in all galaxies. At the same time these regions do not reveal peculiarities in the stellar age profile. We discussed how these findings provide additional important information that should be taken into account for detailed gaseous-stellar dynamical models to restrict the bar evolution.

Unveiling the nature of barlens structures with TIMER

29 May 15:35 20 min

Isabel Perez and the TIMER collaboration
University of Granada

Boxy/peanut bulges are considered to be part of the same stellar structure as bars and both could be linked through the buckling instability. The Milky Way is our closest example. These B/P bulges are ubiquitous, 40% of galaxies would present this type of central structures that have been linked to the bar. Some recent works have associated bar lenses to B/P bulges as seen face-on. Whether barlens are characterized by bar or disc kinematics and stellar populations closer to those of a bar or whether they are similar to the disc still remains unknown. Both the kinematics and the stellar population information would help to discern the nature of these structures and determine whether they are the product of buckled bars or not. We will present the kinematics, stellar age distributions on the barlens region of 13 galaxies with MUSE/VLT data from the TIMER project.

Session VIII - Poster Session II Lightning Talks and Viewing

Barlenses in the CALIFA survey

29 May 5 min

Eija Irene Laurikainen[1], Heikki Salo[1], Jarkko Laine[2], Joachim Janz[1]
[1]University of Oulu, Finland; [2]University of Hamburg, Germany

Barlenses are studied in the Calar Alto Legacy Integral Field Survey (CALIFA: Sanchez et al. 2012) of 1064 galaxies. They are recognized as lens-like structures embedded in bars, and are suggested to be the face-on counterparts of the Boxy/Peanut/X-shaped bars. Barlenses and/or X-shapes appear in 25% of the CALIFA galaxies, which galaxies have often inner rings or inner lenses. Detailed multi-component decompositions are carried out, fitting besides the bulges, disks and bars, also the barlenses with a separate function. Similar decompositions are performed for simulation snapshots, taken from models in which barlenses formed during the galaxy evolution. For a half of the decomposed galaxies stellar populations and metallicities were studied using the CALIFA V500 grating data-cubes. We find that most of the flux of the photometric bulge (i.e. flux above the disk extrapolated to the galaxy center) in the studied galaxies is dominated by a barlens.

The Nature of Star Formation within Bars

29 May 5 min

Justus Neumann[1], Dimitri Gadotti[2], Lutz Wisotzki[1], Bernd Husemann[3], and CARS collaboration
[1]Leibniz-Institut for Astrophysik Potsdam; [2]ESO; [3]MPIA Heidelberg

The presence and nature of galaxy bars is in close connection to all secularily built structures. Understanding the formation and evolution of bars furthers our knowledge about their impact on and interplay with co-existing secular galaxy components such as galactic rings. Various authors have observed a lack of star formation within the bar region of some barred disc galaxies, while other galaxies show significant star formation in their bars. The absence of star formation can theoretically be explained by shear. Gas clouds that are traveling along the bar are subject to a velocity gradient perpendicular to the bar mayor axis. The resulting shear can disrupt the clouds and prevent them to collapse and form stars. With this poster, I would like to show how 3D spectroscopy can be used to connect spectroscopic parameters with photometric properties in order to study how star formation can be inhibited in some galaxy bars. We use spatially resolved H_{alpha} flux from VLT/MUSE observations of 16 nearby barred galaxies together with a detailed two-dimensional photometric image decomposition to explore how the absence and presence of star formation within the bar is connected to structural properties of the bar and the host galaxy.

The Secular Origin of the Milky Way bulge

28 May 5 min

Francesca Fragkoudi[1], Paola Di Matteo[2], Misha Haywood[3], Mathias Schultheis[3], Sergey Khoperskov[3], Ana Gomez[2], Francoise Combes[2]
[1]MPIA; [2]Observatoire de Paris; [3]Laboratoire Lagrange - OCA

Examining the chemo-morphological relations of stellar populations in the Milky Way (MW) bulge can provide clues to the formation history of our Galaxy, and of disc galaxies in general. To explore the possible disc origin of the MW bulge populations I used an N-body simulation where the bulge is formed secularly through the vertical heating of a bar, which is formed from a composite thin+thick disc. In this model the thick disc is metal-poor, alpha-enhanced, massive and centrally concentrated, as has been shown to be the case for the chemically defined thick disc of the Milky Way. The model is compared to data of the bulge obtained with the near infrared spectroscopic survey APOGEE. As I will show, all the chemo-morphological relations examined are well reproduced by the model, as is the metallicity distribution function (MDF) of the MW bulge as a function of longitude and latitude. These findings show that the chemical composition of the MW bulge is consistent with it being made up of thin+thick disc stellar populations. I will discuss these results in light of the mounting evidence – from morphology, kinematics and chemistry – of the MW bulge's pure disc (i.e. secular) origin.

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2D metallicity gradients and how they depend on substructures in MaNGA galaxies

29 May 5 min

Amy Michelle Jones, Preethi Nair, and the MaNGA team
The University of Alabama

Many galaxies have a metallicity gradient, however there is a large scatter about the slope of this gradient. Typically the galaxy is azimuthally averaged to look only at the 1D metallicity profile as a function of radius. With IFU observations, we no longer need to azimuthal average, but instead can use the 2D metallicity map to describe metallicities in galaxies. With SDSS IV MaNGA observations, we can disentangle the scatter in the 1D profile by measuring metallicity gradients along certain substructures within the galaxies, e.g. spiral arms and bars. By looking at the gradients along the structures, we hope to minimize the scatter and compare these different gradients. We will use the full 2D information to find quantitative parameters, such as asymmetry, M20, and MID diagnostics, to describe the metallicity distribution within galaxies and see how these correlate with other galactic properties and structure.

NGC 4622: A clear example of spiral density wave star formation in a ring galaxy

29 May 5 min

Gene Gilbert Byrd
Dept. of Physics and Astronomy, The University of Alabama

Our HST NGC 4622 images are discussed; heritage.stsci.edu/2002/03/index.html. Normal to the line of nodes, the SE edge is turned toward. The SW away ∼19 deg...The NE node line recedes and the SW approaches so orbits are clockwise on the sky. The Beads on a string NE arm (1) winds inward CCW. Gas clouds enter the more slowly turning arm on the CONVEX side outside an outer co-rotation circle. (OCR=36, 5.16, 1kpc). These become short-lived associations on the CONCAVE side Side switching happens going inward along (1). A bright association occurs in the MIDDLE of the arm at the OCR where the CW orbital angular rates of gas clouds and the arm angular rate match. Within the OCR, associations of arm (1) are on the CONVEX side as the arm catches up on slower gas clouds which light on the other side. Closer in, the NE portion of arm (2). is also inside the OCR. Associations on the convex side are clearer for this less obscured portion. Yet to be ignited absorbing clouds are visible inside arm (2) at NE. An unusual rising rotation curve is observed crossing the arm pair OCR. A leading arm pair would be amplified there. If there is an extended massive dark matter halo to create the rising curve.. A puzzling single trailing arm winds outward CCW from center, opposite through another, inner ICR=22. There the rotation curve is flat which would amplify a trailing arm. Color observations show density wave phase and side switching at ICR. A merger-induced oscillating nucleus would have a one-fold perturbation strong near the center with a two-fold perturbation still strong farther

out, triggering the two arm kinds. Alar Toomre christened us (ref) The backward astronomers who found the backward galaxy. One of us, Tarsh Freeman, passed away at age 66 on Jan. 19, 2018. Perhaps he is now getting to see up-close what is happening in NGC 4622.. Ref for above discussion. G. Byrd, T. Freeman, S. Howard, R. Buta 2008. AJ., 135, 408. See http://www.researchgate.net/profile/Gene_Byrd2 for this poster.

Arm structure, bars and rings in 3-armed spiral galaxies

29 May 5 min

Colin Hancock, Bill Keel
The University of Alabama

We examine the structure of 180 candidate 3-armed spiral galaxies from the Galaxy Zoo 2 results. We use the SpArcFiRe web interface to quantify the pitch angle, separation, and radial extent of distinct arms. As suggested by visual inspection, the patterns range from 3-fold symmetric arms to 2-armed patterns with an additional or branched arm of comparable length and brightness. The visual impression that these are two distinct groups is difficult to test quantitatively, because it is common for the arms to have quite different pitch angles (and thus radius-dependent separations). An unexpected outcome is that bars (and resonance rings around the arms) are no less common in 3-armed spirals than in the overall lisper population, the 3-armed dominant patterns manage to coexist with very strong twofold driving patterns in the inner parts of these disks. Likewise, some clear 3-armed spirals have large close companions and tidal disturbances, at odds with the idea that m=3 structures grow in the absence of external perturbations.

How do spiral arm contrasts relate to bars, disc breaks and other fundamental galaxy properties?

29 May 5 min

Adrian Bittner[1], Dimitri A. Gadotti[2], Bruce G. Elmegreen[3], Lia Athanassoula[4], Debra M. Elmegreen[5], Albert Bosma[4], Juan-Carlos Muñoz-Mateos[6]
[1]University Observatory Munich; [2]European Southern Observatory, Garching, Germany; [3]IBM Research Division, T.J. Watson Research Center, USA; [4]Aix Marseille Université, CNRS, LAM, Laboratoire d'Astrophysique de Marseille, France; [5]Vassar College, USA; [6]European Southern Observatory, Santiago, Chile

To better understand the role that spiral arms and bars play in the secular evolution of disc galaxies, we investigate how the properties of spiral arms relate to other fundamental galaxy properties, including bars and disc breaks. We use previously published measurements of those properties, and our own measurements of arm and bar contrasts for a large sample of galaxies, using 3.6 micron images from the Spitzer Survey of Stellar Structure in Galaxies. Galaxies with flocculent arms are clearly distinguished from other spirals, especially by their lower stellar mass and surface density. Multi-armed and grand-design galaxies are similar in most of their fundamental parameters, excluding some bar properties and the bulge-to-total ratio. Based on these results, we revisit the sequence of spiral arm classes, and discuss classical bulges as a necessary condition for standing spiral wave modes in grand-design galaxies. We find a strong correlation between bulge-to-total ratio and bar contrast, and a weaker correlation between arm and bar contrasts. Barred and unbarred galaxies exhibit similar arm contrasts, but the highest arm contrasts are found exclusively in barred galaxies. Interestingly, the bar contrast, and its increase from flocculent to grand-design galaxies, is systematically more significant than that of the arm contrast. We corroborate previous findings concerning a connection between bars and disc breaks. In particular, in grand-design galaxies, the bar contrast correlates with the normalized disc break radius. This does not hold for other spiral arm classes or the arm contrast. Our measurements of arm and bar contrast and radial contrast profiles are publicly available.

Wednesday, May 30, 2018

Session IX
Barred Galaxies Dynamics

Collective Effects and Secular Dynamical Evolution of Galaxies

30 May 09:05 30 min

Xiaolei Zhang[1], Ron Buta[2]
[1]George Mason University; [2]University of Alabama

Growing observational evidence points to the likelihood of a general trend of galaxy morphological evolution along the (inverse) Hubble sequence. The chief dynamical mechanism responsible for this evolution, however, had been a highly debated subject. We show that when galaxies are analyzed as globally self-consistent dynamical systems, which admit unstable density wave modes, emergent new meta-laws appear which invalidate the differential treatment of classical approaches based on Boltzmann's kinetic equation and its descendants (i.e., the stellar dynamical equation and the Eulerian fluid equations). The collective interactions of N-particles in a galaxy disk lead to the formation of collisionless shocks at the density wave crest, which interact with the basic state disk matter, leading to the secular redistribution of disk mass (manifested as the morphological evolution of galaxies along the Hubble sequence), as well as the damping and stabilization of the growing wave amplitude to achieve quasi-steady state of the wave mode. Analyses of near- and mid-infrared images of galaxies confirm the predictions of the dynamical theory, and lead to practical applications of the so-called potential-density phase shift (PDPS) approach as an accurate and efficient method for locating corotation resonances in spiral and barred galaxies, as well as for calculating the secular mass flow rates in galaxies for building up the Hubble sequence within cosmologically relevant timescales. Applied to the ringed barred spiral NGC 3351, the PDPS method interprets the bar as being "superfast", and the ring as due to the snow-plough effect from the interaction of the inner bar and the outer spiral modal patterns, each having distinct pattern speed. This result differs from that of the usual passive orbit analysis, which interprets SB inner rings in terms of inner 4:1 resonance with a normal (relatively slow) bar.

Constraints on angular momentum changes for corotating stars

30 May 09:35 20 min

Kathryne J. Daniel
Bryn Mawr College

Stars that corotate with a non-axisymmetric structure, like a spiral pattern or bar, can be trapped in an orbital family called horseshoe orbits. In the last decade, these orbits have been of particular interest when they are induced by time-dependent amplitude spiral arms in the disk, thus leading to radial migration of stars. Should radial migration be an efficient process, it could play an significant role in the chemical and structural evolution of disk galaxies. I will present results from my recent analytic explorations aimed at constraining the efficiency of this process. In these investigations we applied an analytic criterion to define the phase-space volume for horseshoe orbits to a variety of disk galaxy models with various energy and angular momentum distributions. We find that kinematically colder populations and higher amplitude perturbations have a higher fraction of stars in horseshoe orbits, while higher amplitude perturbations also induce larger maximum changes in individual angular momenta. I will also present preliminary results suggesting that these maximum distances are likely limited by overlap with other dynamical resonances in the disk, even in the case of a single perturbation. I will discuss implications and compare them with observational and simulated data.

Annular kinematic segregation of galaxy disks

30 May 09:55 20 min

Joan Font, John E. Beckman
Instituto de Astrofisica de Canarias, Spain

Our technique (FB) for the precise measurement of corotation radius, based on using the phase change by of the radial component of stellar or gas motion expected at this radius, has recently been compared with the classical Tremaine-Weinberg method showing complete agreement where both could be applied. However FB is more generally applicable and can be used over complete galaxies, from the innermost zones with nuclear bars to the outermost spiral arms. When this is done, the result is to uncover more than one corotation radius per galaxy. We have found corotations at roughly 2.5 times the radius of the ends of nuclear bars and (in the same objects) at between 1 and 2 times the radius of the ends of the major bars. But beyond this there are corotations associated with radially separated annuli containing segments of spiral arms. The number of corotations per galaxy ranges from 1 to 7 in a sample of some 150 objects. We have also found a virtually universal coupling pattern between the annuli such that, given two corotations, CR1 and CR2, the Outer Lindblad Resonance of CR1 falls at CR2 and the inner 4:1 ultraharmonic resonance of CR2 falls on CR1. These coupling patterns occur at least once in over 70% of observed disks, with a maximum occurrence of 4 such patterns in a single galaxy. This work marks only the beginning of applicable studies of angular momentum distribution and evolution in disk galaxies.

Bar pattern speed estimates using the Tremaine-Weinberg method in MaNGA galaxies

30 May 10:15 15 min

Luis A Garma, Erik Aquino-Ortiz, Hector Hernandez-Toledo, Mariana Cano-Diaz, Octavio Valenzuela, Sebastian F. Sanchez
Instituto de Astronomía - UNAM

Understanding the role stellar bars play in the dynamical evolution of galaxies has been a challenging problem, in part because of the difficulty in estimating fundamental parameters like the bar pattern speed. Based on the continuity equation, the Tremaine & Weinberg (1984) method is the only direct method to measure the bar pattern speed, however it has only been applied to a limited number of galaxies. In this talk, I will discuss how we have applied this method to MaNGA galaxies emphasizing the treatment of the associated errors in different steps of the methodology.

Session X
Properties of Barred Galaxies

Spatially Resolved Metallicity Distributions in Barred and Unbarred Galaxies: Implications for Galaxy Evolution since z∼2

30 May 11:00 20 min

Shardha Jogee[1], Kyle Kaplan[2], Lisa Kewley[3], Guillermo A. Blanc[4], and the VENGA collaboration
[1]University of Texas at Austin; [2]University of Arizona; [3]Australian National University; [4]Universidad de Chile

We present a study of the spatially resolved ionized gas metallicity in nearby barred and unbarred spirals using integral field spectroscopic (IFS) data from the VIRUS-P Exploration of Nearby Galaxies (VENGA) survey, which has excellent high spatial resolution (median 380 pc) and wide coverage from the bulge to the outer disc. Contrary to some earlier studies, which claimed a difference in metallicity gradient between barred and unbarred galaxies, we find that isolated barred and unbarred spirals exhibit similarly shallow gas metallicity profiles from the inner kpc out to large radii. These results imply that present-day stellar bars are not the primary agent responsible for flattening metallicity gradients, and have associated implications for cosmological models of gas inflows and stellar feedback at $z>2$. We also find that the metallicity gradients in our $z \sim 0$ massive spirals are markedly shallower than published gradients for lensed lower mass galaxies at $z \sim 1.5$ - 2.0. This type of evolution in metallicity gradients since $z\sim2$ is better reproduced in cosmologically motivated hydrodynamical simulations with conventional stellar feedback (e.g. in MUGS simulations) than those with enhanced stellar feedback (e.g., MaGICC simulations).

The Origin of Bars in Quenched Disk Galaxies: A MaNGA View

30 May 11:20 20 min

Amelia K. Fraser-McKelvie, Alfonso Aragón-Salamanca, Michael Merrifield
University of Nottingham

Rings, bars, and spiral arms are transient phenomena that occur in a large proportion of quiescent disk galaxies. Whether these enhanced stellar densities are hangovers from a galaxy's days as a spiral, or have formed since transformation to early-type is unknown however. To investigate this, we examine a population of strongly-barred quiescent galaxies within the Mapping Nearby Galaxies at APO (MaNGA) galaxy survey, many of which also possess what appear to be loose spiral arms and ansae. We propose two possible origins for these galaxies: 1) They are passive spiral galaxies that have been quenched with the help of bar structure. 2) They were lenticular galaxies that have formed a bar instability and in doing so, produced tidal features that look similar to spiral arms. We utilize spatially-resolved spectroscopy from the MaNGA survey to determine the stellar populations of the bar, arm and interarm regions of these galaxies. Preliminary results suggest that for most galaxies, the entirety of the disk quenched similarly recently, advocating for a common ancestor for all galaxy structure. These results will aid in the understanding of bar and ansae formation and their role in galaxy quenching.

Determining the epoch of bar formation

30 May 11:40 15 min

Charlotte Donohoe-Keyes, Phil James, Marie Martig and the TIMER Collaboration
Astrophysics Research Institute, Liverpool John Moores University

Bars in early-type spiral galaxies are surrounded by a region of suppressed star formation, which we term the star formation desert. That region itself is usually embedded within a younger ring. With a sample of zoomed in cosmological simulations we analyze the connection between bars, rings and star formation deserts. In particular, using simulated galaxies with bars forming at different times, we find that the cessation of star formation within the star formation desert coincides with the epoch of bar formation. This supplies a novel method to determine when bars formed, which we apply to MUSE data of nearby barred galaxies from the TIMER collaboration. This gives new insights into the timescales of bar formation and the interplay between bars, star formation deserts, rings and their host galaxies.

Secular evolution driven by double-barred systems in the TIMER survey

30 May 11:55 20 min

Adriana de Lorenzo-Cáceres, and the TIMER team
Instituto de Astrofísica de Canarias (IAC)

The TIMER project (Time Inference with MUSE in Extragalactic Rings) is a well-designed survey of barred and ringed galaxies with noticeable central structures, such as inner bars and nuclear rings, which are considered as footprints of secular evolution. The current TIMER sample is composed by 19 galaxies, three of them being confirmed double-barred systems. In this talk I will present unprecedented results on double-barred galaxies provided by the superb integral-field spectroscopic TIMER data. We confirm the ubiquitous appearance of sigma-hollows in double bars, in agreement with the recent scenario of an intrinsic vertical velocity dispersion feature for their origin. A detailed study of the star formation histories, in combination with two-dimensional multi-component photometric decompositions, allows us to dissect double-barred galaxies and to discern the nature of inner bars. We find that they have been secularly assembled after the outer bars, but still are relatively old systems. A slight rejuvenation of the very central regions due to a non-efficient gas inflow through the inner bars is also observed. I will discuss all these results in the context of the secular evolution nature of central structures in ringed galaxies.

Photometric Properties of Bars in Low Surface Brightness Galaxies

30 May 12:15 15 min

Wesley Peters, Rachel Kuzio de Naray
Georgia State University

We present results on photometric properties of bars in low surface brightness galaxies (LSBs). Given the expected structure of their dark matter halos, these galaxies are thought to be quite stable against bar formation. However, because barred LSBs are typically avoided in kinematic studies and because LSBs (of all types) are usually missing from large scale surveys of galaxies, the bars in these systems are not well understood or measured. Using optical B and I-band images, we have characterized the length, strength, and corotation radius of bars in nearly twenty LSBs. We find that the bars in our sample are weaker than those in "normal" high surface brightness galaxies (HSBs), but comparable in length and relative bar pattern speed. We place these bars into context with those found in HSBs, as well as with expectations from numerical simulations.

Thursday, May 31, 2018

Session XI - Spiral Structures in Disk Galaxies

Formation and Evolution of Spiral Structure in Disk Galaxies

31 May 09:00 40 min

Elena D'Onghia
University of Wisconsin-Madison

I will review the various mechanisms of formation of spiral structure in disk galaxies, with emphasis on the longevity of the arms. This has interesting consequences for many aspects of disk evolution, including the currently popular claim that stars such as our Sun can radically migrate from their birthplaces due to the action of time-variable spiral arms, a process termed stellar radial migration. I will also review the relevance of the continuing bombardment of galaxy disks by dark-matter clumps and larger satellites in producing vertical oscillations of stellar disks, rings in the disk plane, and wobbles and discuss the implications for our Milky Way.

The properties and origins of spiral structure across the galaxy population

31 May 9:40 20 min

William Clifford Keel[1], Steven Bamford[2], Ross Hart[2], and the Galaxy Zoo team
[1]The University of Alabama; [2]University of Nottingham

This talk presents the key results of an extended study combining Galaxy Zoo visual morphological information with automated spiral arm pitch-angle measurements, bulge-disc decompositions and multi-wavelength photometry, for a sample of several thousand galaxies. We find that galaxies with different numbers of spiral arms are distributed similarly in terms of stellar mass, environment and specific star-formation rate. On the other hand, those with two-spiral arms are significantly redder and contain less gas than their multi-armed counterparts. We reconcile this disparity by observing that two-arm spirals are more efficient at converting gas into stars, but that a larger proportion of this star-formation occurs in highly obscured regions. This points to distinct differences in the mechanisms responsible for two- and many-armed spiral structure. In the absence of bars and tidal interactions, a popular mechanism for spiral arm formation is via swing-amplification. This model makes predictions for spiral arm properties, which depend on the relative masses and sizes of a galaxy's stellar and dark matter components. We combine structural measurements and scaling relations in order to predict arm properties for the unbarred galaxies in our sample, which we then confront with observations. For one half of these galaxies, primarily those with two-arms, the observed arm numbers are inconsistent with expectations from swing-amplification. For the other half, the predicted distribution of arm properties is reasonable. Furthermore, providing we adopt inner halo profiles which depend on galaxy mass and size, in a

manner predicted by recent hydrodynamical simulations, we obtain a good correlation between observed arm properties and those predicted by the model. We conclude that an identifiable half of unbarred spiral galaxies contain arm patterns dominated by secular swing-amplification, while the remainder are driven by tidal interaction or density wave mechanisms.

Study of stellar formation and evolution in spiral galactic disks

31 May 10:00 20 min

Carmen Sánchez Gil[1], Emilio J. Alfaro Navarro[2], Enrique Perez[2], Miguel Cerviño[3], Joss Bland-Hawthorn[4], Heath Jones[5]

[1]University of Cadiz, Spain; [2]Instituto de Astrofisica de Andalucía-CSIC, Granada, Spain; [3]Instituto de Astrofísica de Canarias, Tenerife, Spain; [4]Sydney Institute for Astronomy, University of Sydney, Australia; [5]Australian Astronomical Observatory, Australia

Spiral arms formation is still an open problem. Even in our Galaxy, the number of spiral arms and its origin is not well-known. It could even coexist different or several modes of formation in the same galaxy. On the one hand, we present hierarchical bayesian inference models to determine the age in disks of nearby and nearly face-on, spiral galaxies. For a sample of 9 galaxies Halpha data are taken with Taurus Tunable Filter, (TTF), ultraviolet band far UV or FUV from GALEX, and infrared bands at 24, 70 and 160 microns from Spitzer surveys. This is, we present the burst ages for young stellar populations in a sample of nearby and nearly face-on galaxies, proving enough spatial resolution of the galactic disks. And Halpha to FUV flux ratio is a good relative indicator of the very recent star formation history (SFH). Through synthetic stellar populations model, we obtain theoretical Halpha/FUV ratios to compare with our observed flux ratios, and thus to estimate the ages of the observed regions. Due to the nature of the problem, it is necessary to take into account the mean uncertainties, and the interrelationships between parameters when the Halpha/FUV flux is obtained. We propose a Bayesian hierarchical model, where a joint probability distribution is defined to determine the parameters (age, metallicity), from the observed data. The joint distribution of the parameters is described through an i.i.d. (independent and identically distributed random variables), generated through MCMC (Markov Chain Monte Carlo) techniques. The sample associated shows a variety of morphologies, as spiral arms and rings among others. The age patterns obtained for these galaxies indicate the great diversity of physical mechanisms that seem to act in the modeling of the star-to-large formation process scale. We analyze with more detail the possible origin of such structures as a function of spatial patterns from their age maps. The comparison of the age patterns obtained with those predicted by Dobbs & Pringle (2010) for the distribution of young clusters allows us to conjecture about the different physical mechanisms that excite and maintain the spiral arms. The casuistry is varied: training stellar spiral arms mainly induced by density waves (M100, M74 and M51), circumnuclear rings (M94), age gradients affecting the entire galaxy (from West to East, M63), or radial age gradient (M74), or dominated by HII regions. N1068 seems to be a

good and clear example, as outcome of our results, that AGN interaction with gas can reach larger scales (up to 7-8 kpc from the nucleus). Finally, we address the study of the detection in Halpha of a radial corrugation in the vertical velocity field in disks of nearly face-on, spiral galaxies. With the aim of studying the corrugated velocity patterns in terms of the star formation processes, we describe the geometry of the problem and establish its fundamental relationships. In particular, the relationship between density of the ionized gas and the amplitude of the corrugation in speed. Two large groups have been found. In one of them the velocity and gas density show a out of phase correlation by a distance of a few hundred pc. The another class does not seem to show a well-defined pattern. These two classes show different physical properties of the ionized gas defined from different diagnostic diagrams (Sanchez-Gil et. al 2015). The origin of the corrugations is still matter of debate. Corrugations are closely link, as cause/effect, to the large scale star formation processes: density waves, tidal interactions, collisions of high velocity clouds with the disk, or a galactic bore generated by the interaction of a spiral density wave with a thick gaseous disk, as modeled by [Martos & Cox 1998, Martos et al. 1999], etc. Which mechanism is the origin of disk corrugations is still an open problem.

A new technique to measure pattern speeds of spirals in MaNGA

31 May 10:20 15 min

Tom Peterken, Michael Merrifield, Alfonso Aragon-Salamanca
University of Nottingham

The pattern speed is one of the defining properties of morphological structure such as spiral arms, which in turn dictates the locations of ring features. Unfortunately, it is notoriously difficult to measure, as it only has an indirect connection to measurable parameters such as the stellar rotation speed. Here, we present an entirely new method to determine this fundamental quantity by directly measuring the offset between the location of the arm and young stellar component emerging from it. A pilot application to SDSS-IV MaNGA data shows that this approach has real promise, and, as a bonus, also gives an independent direct measure of the timescale for star formation.

Session XII - Collisional Ring Galaxies

Accretion-generated rings: coplanar and non-coplanar structures

31 May 11:05 40 min

Alexei Moiseev
Special Astrophysical Observatory, Russian Academy of Sciences

The majority of known rings in galaxy disks are formed under the action of "classical" dynamical mechanisms like bar resonance or head-on collision with a satellite. However, a small fraction of galactic rings can be explained by a capture of the external matter like dwarf companions, external gaseous clouds or even cosmic web filaments. In this review, we consider observational properties of the accretion-generated rings and related objects in order to constrain different scenarios of their origin. In particular, we present new results of the study of gas kinematics and chemical abundance in polar ring galaxies based on the long-slit and 3D spectroscopy with the scanning Fabry-Perot interferometer at the Russian 6-m telescope. It's important to emphasize that the external accretion can produce not only non-coplanar multi-spin structures (external and inner polar rings and disks) but also rings of star formation that are coplanar with the main galaxy disk. Perspectives and first results of modern 3D-spectroscopic surveys of galaxies in studying accretion rings are discussed.

The Star-forming ISM in Collisional Ring Galaxies

31 May 11:45 25 min

James Lloyd Higdon[1], Sarah J. U. Higdon[1], Richard J. Rand[2], Sergio Martin Ruiz[3]
[1]Georgia Southern University; [2]University of New Mexico; [3]ESO

Collisional ring galaxies provide interesting perspectives on the triggering/quenching of large scale star formation and the destructive effects of massive stars on molecular cloud complexes. I will present new results utilizing high resolution radio, sub/millimeter, infrared, and optical data that illustrate the role of gravitational stability and divergent gas flows in star formation regulation, factors influencing the ISM's molecular fraction, and evidence of peculiar star formation laws and efficiencies in two highly evolved ring galaxies: Cartwheel and the Lindsay-Shapley ring.

This Cartwheel's on Fire: Gas Flows and Star Formation in Collisional Ring Galaxies

31 May 12:10 20 min

Florent Renaud
Lund Observatory

Collisional rings represent a unique laboratory to study galaxy evolution. Despite an orbital configuration making them rare, such systems yield much simpler morphology and kinematics than classical mergers, and can thus be used to better understand the physical processes acting during interactions. In this view, and to help the interpretation of increasingly richer observational dataset, in particular from IFUs, we need new generation, predictive simulations of rings. In this talk, I will use a recently published parsec-resolution hydrodynamical simulation of the Cartwheel galaxy to illustrate the main physical processes at stake. I will present results on the processes of ring formation, in particular the prediction of the presence of a cylindrical structure above the ring, and also galactic-wide gas flows and collision-driven starburst activities. The results from this simulation and its forthcoming siblings could help bring observers and theoreticians together to analyze data and to prepare the next observation campaigns.

Session XIII - Rings in Milky Way and Local Group Galaxies

Understanding the nuclear ring and other gaseous features of the Milky Way

31 May 14:05 25 min

Juntai Shen[1], Zhi Li[1], Ortwin Gerhard[2]
[1]Shanghai Astronomical Observatory; [2]MPE

The gas inflow pattern in the Milky Way is mainly dictated by its bar and spiral arms. We study the nuclear ring/disk and other gaseous structures in the Milky Way with high-resolution hydro-dynamical simulations. Our model can reproduce the morphology and kinematics of many key observational features such as the nuclear ring, Bania's Clump, the Connecting arm, the Near and Far 3-kpc arms, the Molecular Ring, and the spiral arm tangent points. We also test the dynamical effects of the nuclear bulge, the main spiral arms, and the long bar component on key gaseous structures. Our results may have important implications for understanding the dynamical structures of the Milky Way and other nearby barred galaxies.

Are the Near and Far 3 Kiloparsec Arms of the Milky Way Actually A Galactic Ring?

31 May 14:30 20 min

Robert Benjamin
University of Wisconsin-Whitewater

Whether the Galaxy contains a stellar ring, i.e. an overdensity of stars surrounding the central bar, is uncertain. There is no compelling evidence for a stellar ring in the mass distribution. But there are two structures that could arguably be identified as an interstellar, star-forming ring. The first is the Molecular Ring (Scoville & Solomon 1975, Jackson et al. 2006). However, in the Galaxy, it is very difficult to distinguish between a spiral and ring, most recent investigations seem to favor the idea that this structure is a spiral arm, c.f Jackson et al. (2008) or Dobbs & Burkert (2012). Another structure that might plausibly be visible as a star-forming ring to an outside observer is the Near/Far Three-Kiloparsec Arm (van Woerden, Rougoor, & Oort 1957, Dame & Thaddeus 2008). Simulations of gas flow in a gravitational potential consistent with the Galactic bar (Bissantz et al. 2003, Englmaier & Gerhard 1999, Fux 1999) predict that these two structures should form an oval around the bar. Although early searches of this structure showed no evidence for star formation (Lockman 1980), recent surveys of class II methanol masers and HII regions indicate a significant amount of massive star formation (Green et al 2009, Anderson et al 2014). An excess of OH/IR stars (Sevenster 1999) and enhanced near-infrared star counts of bright stars, $m_K < 9$, (Lopez-Corredoira et al. 2001) have been noted at l = 338. Both authors noted the coincidence of this direction with the tangency direction of the Near Three-Kiloparsec arm and suggested that this might be part of a ring, even before the discovery of the Far Three Kiloparsec Arm! I will review what is known about interstellar and stellar structure of the Near and Far Three Kiloparsec Arms and discuss what further work should be done to resolve whether this structure truly is a ring.

A Ring-like Stellar Overdensity Structure in the Large Magellanic Cloud

31 May 14:50 20 min

Yumi Choi[1], David Nidever[2], Knut Olsen[2], Gurtina Besla[1], Robert Blum[2], Cliff Johnson[3], Dennis Zaritsky[1] and the SMASH team
[1]University of Arizona; [2]NOAO; [3]Northwestern University; SMASH team

We explore stellar number density structures in the southern disk of the Large Magellanic Cloud (LMC) and detect a ring-like stellar overdensity at around 5 kpc from the LMC center. This structure does not have any symmetric counterpart in the northern disk, but very similar structures can be seen in numerical simulations of the interaction of the Magellanic Clouds with each other. We find that the stellar populations associated with the overdensity are intermediate age which is consistent with an increase in the star formation rate at 3.5 Gyr ago in both galaxies. This suggests that the LMC

overdensity structure is likely a product of the tidal interaction with SMC and not with the Milky Way.

Unravelling the Origin of the Monoceros Ring - Detailed abundances in the Southern Structure

31 May 15:10 20 min

Thomas Bensby
Lund Observatory

The Milky Way outer disk contains a plethora of stellar overdensities and structures that we currently do not know the origin of. For instance, the largest structure, the Monoceros Ring, has since its discovery more than 10 years ago been attributed to an accreted dwarf galaxy, the warp of the Milky Way disk, or just the Milky Way spiral arms. However, the SDSS and PANSTARRS1 surveys now show indications that the Monoceros Ring could be ripples in the disk, caused by a dwarf galaxy that plunged through the disk. Using VLT and the FLAMES multifibre spectrograph we have obtained high-resolution spectra to determine detailed elemental abundances and stellar ages for stars in the Monoceros structures to see if they differ from the Milky Way field stars. This allows us to put constraints on the nature of the Monoceros Ring stars and if they are of Galactic or extra-galactic origin.

Session XIV - Secular Processes in Disk Galaxies

Spiral arms, the warp & the stream in M33 as a result of an interaction with M31

31 May 16:00 15 min

Marcin Semczuk[1], Ewa L. Lokas[1], Jean-Baptiste Salomon[1], E. Athanassoula[2], Elena D'Onghia[3]
[1]Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences; [2]Laboratoire d'Astrophysique de Marseille; [3]University of Wisconsin-Madison

The Triangulum Galaxy (M33) possesses several morphological traits suggesting its past interaction with the Andromeda Galaxy (M31). These are: the gaseous warp, its stellar counterpart called the stream and the predominant 2-armed spiral structure. In addition to the morphology of M33, a peak has been found in star formation histories of both galaxies 2 Gyr ago. We present results of N-body/SPH simulations of the recent interaction between M33 and M31 in which these features of M33 are qualitatively reproduced. In our simulations M33 is modeled as a gaseous and stellar disk embedded in a dark matter halo. The potential of M31 is approximated with a live dark matter

halo. M33 is passing M31 on an orbit with a pericenter distance of 37 kpc and its relative velocity at the end of the simulation is consistent with the estimates of proper motions of both M33 and M31 known from the literature. Tidal forces from M31 induce the gaseous warp, the stellar stream and grand-design spiral arms in M33 during the pericenter passage. These features survive until the present time and have similar shapes as the observed ones. We also find that tidal forces were sufficent to compress the gas in M33 and trigger a star formation burst at radii similar to where it is observed.

Black Hole Mass Scaling Relations for Spiral Galaxies Determined from Pitch Angles and Multicomponent Structural Decompositions

31 May 16:15 20 min

Benjamin Lee Davis[1], Alister Graham[1], Marc Seigar[2], Ewan Cameron[3]

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In an effort to derive accurate bulge magnitudes for the current full sample of 43 spiral galaxies with directly measured supermassive black hole masses, we have analyzed their images and light profiles in exquisite detail. We found that it was important to account for not just the bars, but also the rings and partial rings, i.e. ansae, at the ends of these bars. We have additionally performed a careful measurement of the spiral-arm pitch angles for these galaxies. This has enabled us to revise the black hole scaling relations for spiral galaxies, using more accurate measurements than ever before, and with a sample size which is double that of previous works. While presenting this work, I will discuss ideas about the AGN-galaxy (feedback) connection, the efficacy of these scaling relations for predicting black hole masses including intermediate-mass black holes in galaxies with X-ray AGN and implications for the longevity of bars.

Black Hole Growth in Disk Galaxies Mediated by the Secular Evolution of Short Bars

31 May 16:35 20 min

Min Du[1], Victor P. Debattista[2], Juntai Shen[3], Luis C. Ho[1],Peter Erwin[4]

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In a series of papers (Du et al. 2015, 2016, 2017a), we have developed realistic "bars within bars" (S2B) systems using N-body simulations. The short bars of sub-kiloparsec radius have been hypothesized to be an important mechanism for driving gas inflows efficiently to small scale, feeding central BHs in the secular evolution. The growth of

black holes (BHs) in disk galaxies lacking classical bulges, which implies an absence of significant mergers, appears to be driven by such secular processes. We quantify the maximum BH mass allowed by this mechanism with our numerical S2B models (Du et al. 2017b). We find that short bars can be destroyed quickly when BHs of mass Mbh 0.05%-0.2% of the total stellar mass (M*) are present. Thus, the dissolution of short inner bars is possible, perhaps even frequent, in the universe. An important implication of this result is that inner-bar-driven gas inflows may be terminated when BHs grow to 0.1%M* . We predict that 0.2%M* is the maximum mass of BHs allowed if they are fed predominately via inner bars. This value matches well the maximum ratio of BH-to-host-galaxy stellar mass observed in galaxies with pseudo-bulges and most nearby active galactic nucleus host galaxies. This hypothesis provides a novel explanation for the lower Mbh/M* in galaxies that have avoided significant mergers compared with galaxies with classical bulges.

A combined photometric and kinematic recipe for evaluating the nature of bulges using the CALIFA sample

31 May 16:55 15 min

Justus Neumann[1], L. Wisotzki[1], O. Choudhury[1], D. Gadotti[2], C.J. Walcher[1], J. Bland-Hawthorn[3], R. Garcia-Benito[4], R.M. Gonzales-Delgado[4], B. Husemann[5], R.A. Marino[6], I. Marquinez[5], S.F. Sanchez[7], B. Ziegler[8] and CALIFA collaboration

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Understanding the nature of bulges in disc galaxies can provide important insights into the formation and evolution of galaxies and their secular structures. For instance, the presence of a classical bulge suggests a relatively violent history, in contrast, the presence of simply an inner disc (also referred to as “pseudobulge”) indicates the occurrence of secular evolution processes in the main disc. However, we still lack criteria to effectively categorize bulges, limiting our ability to study their impact on the evolution of the host galaxies and their secularily built structures. In this talk, I will present a recipe to separate inner discs from classical bulges by combining four different parameters from photometric and kinematic analyses. I will also show the results of applying that recipe to a sample of 45 galaxies from the integral-field spectroscopic survey CALIFA. To aid in categorizing bulges within these galaxies, we performed 2D image decomposition to determine bulge Sersic index, bulge-to-disc light ratio, surface brightness and effective radius and we used growth curve analysis to derive a new concentration index, $C_{20,50}$. We further extracted the stellar kinematics from CALIFA data cubes and analyzed the radial velocity dispersion profile. The results of the different approaches are in good agreement and allow a safe classification for approximately 95% of the galaxies. In particular, we found that our new concentration index performs better than the traditionally used $C_{50,90}$ when yielding the nature of bulges. We also found that a combined use of this index and the Kormendy relation gives a robust indication of the physical nature of the bulge.

The Dust Forecast, Predicting the Dust Attenuation in Spiral Disk Galaxies

31 May 17:10 20 min

Benne Willem Holwerda[1], Bill Keel[2], and the Galaxy Zoo team
[1]University of Louisville; [2]The University of Alabama

Interstellar dust is still a dominant uncertainty in Astronomy, limiting precision in e.g., cosmological distance estimates and models of how light is re-processed within a galaxy. When a foreground galaxy serendipitously overlaps a more distant one, the latter backlights the dusty structures in the nearer foreground galaxy. Such an overlapping or occulting galaxy pair can be used to measure the distribution of dust in the closest galaxy with great accuracy. The STARSMOG program uses Hubble to map the distribution of dust in foreground galaxies in fine (<100 pc) detail. Integral Field Unit (IFU) observations will map the effective extinction curve, disentangling the role of fine-scale geometry and grain composition on the path of light through a galaxy. The overlapping galaxy technique promises to deliver a clear understanding of the dust in galaxies: geometry, a probability function of dimming as a function of galaxy mass and radius, and its dependence on wavelength.

Friday, June 1, 2018

Session XV - Rings and other Galaxy Structure in Simulations

Ring galaxies in the nearby and distant Universe

01 June 09:00 40 min

Frederic Bournaud

CEA Saclay, France

A large number of ring galaxies are observed in the nearby Universe, but also in high-redshift surveys such as the Hubble UDF, CANDELS, etc. Rings can form by several mechanisms: galaxy collisions and interactions, resonances in barred galaxies, internal instabilities. I propose to review the expected signatures of formation mechanisms, based both on observations of nearby ring galaxies and hydrodynamic simulations, and compared to the observed properties of ring galaxies at high redshift.

Warps, waves and rings in the stellar discs of Auriga cosmological simulations

01 June 09:40 20 min

Facundo Ariel Gomez[1], Simon D.M. White[2], Robert J.J. Grand[3], F. Marinacci[4], V.Springel[3], R. Pakmor[3]

[1]University of La Serena; [2]Max Planck Institute für Astrophysics; [3]Heidelberger Institut für Theoretische Studien; [4]Massachusetts Institute of Technology

During this talk I will present an overview of our recent work which aims to characterize the impact of host-satellite interactions on the observable properties of Milky Way-like galaxies. We use a suite of fully cosmological high resolutions simulations from the Auriga Project to analyze the present-day vertical structure of individual Milky Way-sized models. At redshift zero, about 70% of our galactic discs show strong vertical patterns, with amplitudes that can exceed 2 kpc. Half of these are typical 'integral sign' warps. The rest are corrugation patterns, similar to those observed in the Milky Way. The associated mean vertical motions can be as large as 30 km/s. These perturbations have a variety of causes such as close encounters with satellites or accretion of misaligned cold gas from halo infall or from mergers. More interestingly, I will show examples of how the halo dark matter component can react to distant fly-by interactions by developing overdensity wakes. These responses can induce strong perturbations on a galactic disc, such as warps and lopsidedness and ringing, that can be used to study unseen structure in the outskirt of galaxies.

Galactic bars and galaxy interactions in the Illustris simulation

01 June 10:00 20 min

Nicolas Peschken
Nicolaus Copernicus Astronomical Center, Warsaw, Poland

Central galactic bars have been found to be very common in late-type galaxies, being observed in about 60-70 % of local disc galaxies. Their formation mechanisms are diverse, as they can form in secular evolution, or be triggered by external perturbers. I propose to present my current work about how bars form and evolve in a cosmological context, in particular when the disc galaxy hosting the bar is interacting with other galaxies. To do this, I use the Illustris simulation, which is a large hydrodynamical cosmological simulation based on the moving mesh code AREPO, reproducing many observational results in the area of galaxy formation and evolution. I examine the properties of bars in Illustris disc galaxies at different redshifts, their formation mechanism, and the evolution of the bar fraction with time, stellar mass and gas content. Furthermore, I investigate how bars can be formed by tidal forces from galaxy interactions such as flybys, and how the characteristics of the newly formed bar depend on the nature of the interaction. In the case of a pre-existing bar, galaxy interactions can reinforce it, weaken it or even destroy it. Those cases can be studied by deriving the bar strength over time, and looking at the effect of interactions on its evolution. For a flyby, the bar is affected differently depending on how strong the interaction is, and whether the orbit of the encounter is prograde or retrograde with respect to the bar rotation (Peschken & Lokas, to be submitted soon).

Tidally induced bars in gas-rich dwarf galaxies orbiting the Milky Way

01 June 10:20 15 min

Grzegorz Gajda[1], Ewa L. Lokas[1], Lia Athanassoula[3]
[1]Nicolaus Copernicus Astronomical Center, Poland; [2]Laboratoire d'Astrophysique de Marseille

In the Local Group of galaxies we can distinguish two categories of dwarf galaxies. Those which are far away from the Milky Way and Andromeda are predominantly classified as dwarf irregulars (dIrr), while the ones which are close to them are labelled as dwarf spheroidals (dSph). The dIrr galaxies exhibit certain degree of rotation and contain gas, whereas the dSph galaxies have spheroidal shapes supported by random motions of stars and are devoid of gas. The spatial separation of the two groups points to a possible evolutionary relation between them. In the tidal stirring scenario initially disky dwarf galaxies are transformed into spheroids due to repeated tidal interactions with the host galaxy. An intermediate stage of this process involves the formation of a tidally induced bar in the stellar disc of the dwarf. I will present results of two N-body+SPH simulations following the evolution of a gas-rich dwarf galaxy orbiting in a

potential resembling a Milky Way-like host. In the two runs two different gas fraction were used and the result will be compared to a pure N-body simulation. In all cases, bars form in the stellar component during the first pericenter passage, while the gaseous component remains approximately axisymmetric. The bars in the hydro runs are only slightly weaker and have similar lengths compared to the collisionless case. After the formation, the bars are stable and steadily rotating until the second pericenter passage. The further evolution depends on the gas fraction. In the runs with little or no gas the bars survive until the end, however the exact outcome of further encounters with the host depend on the exact position angle of the bar during the interaction. Depending on the relative orientation of the bar with respect to the direction to the host, the bar may be spun up and weakened or spun down and strengthened. In the gas-rich dwarf the bar is weakened at the second pericenter and practically disappears afterwards. During the simulations the discs thicken and lose a significant part of their rotation. The results presented here may be useful for modeling satellites of the Milky Way, such as Sagittarius, Ursa Minor and Carina, whose elongated shapes can be explained by the existence of a bar.

Bar formation in cosmological simulations

01 June 10:35 15 min

Tommaso Zana[1], Massimo Dotti[2], Francesco Haardt[1], Pedro R. Capelo[3], Lucio Mayer[3], Silvia Bonoli[4]
[1]University of Insubria; [2]University of Milano-Bicocca; [3]University of Zurich; [4]CEFCA

I will detail the physical processes behind the formation and growth of the galactic bar in a fully cosmological context, including the possible effect of the most recent dynamical events (minor mergers and flybys after redshift 1). I will present the analysis of the Eris-BH and Eris-2k runs (Bonoli et al. 2016, Sokowlowska et al. 2016), two high resolution zoom-in cosmological simulation which result in the formation of two slightly different Milky way like barred galaxy. I will show that the tidal interactions analyzed play a minor role in the formation process, but their influence, in general, work against the coherent growth of the structures.

Session XVI - Secular Structures in a Cosmological Context

Galaxy Morphology from Galaxy Zoo

01 June 11:15 40 min

Karen L Masters
Haverford College

The Galaxy Zoo project (www.galaxyzoo.org) has provided quantitative visual morphologies for over a million galaxies (including the entire Sloan Digital Sky Surveys, or SDSS Main Galaxy Sample, all public HST surveys, UKIDSS, GAMA and most recently the Illustris Simulation), and has been part of a reinvigoration of interest in the morphologies of galaxies and what they reveal about the evolution of galaxies. The morphological information collected by Galaxy Zoo has shown itself to be a powerful database for studying galaxy evolution, and Galaxy Zoo continues to collect classifications - currently serving imaging from DECaLS. I will review how to make best use of the morphologies from Galaxy Zoo, and highlight some of the results from the last 10 years of the project. I will also look forward to future plans and projects in the Galaxy Zoo family.

Redshift evolution of bars, rings and spiral arms

30 May 11:55 25 min

Preethi Nair
The University of Alabama

Understanding the physical processes responsible for the growth of galaxies is one of the key challenges in extragalactic astronomy. The assembly history of a galaxy is imprinted in its detailed morphology. The bulge-to-total ratio of galaxies, the presence or absence of bars, rings, spiral arms, etc, all have implications for the past merger, star formation, and feedback history of a galaxy. Here, I present a visually classified catalog of bars and rings from the HST COSMOS Survey. Using this sample and my visually classified sample from SDSS, I will present results on the evolution of the bar and ring fractions since $z\sim1$ and the impact of bars/rings on the evolution of SFR in disk galaxies over the last 6 billion years.

Session XVII - Discussion and Concluding Remarks

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