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# DIVISION J GALAXIES & COSMOLOGY

*GALAXIES & COSMOLOGIE*

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**DIVISION J COMMISSIONS**

**J1 Galaxy Spectral Energy Distributions**
**J2 Intergalactic Medium**

**INTER-DIVISION COMMISSIONS**

**H4 Stellar Clusters throughout Cosmic Space and Time**
**X1 Supermassive Black Holes, Feedback and Galaxy Evolution**

**TRIENNIAL REPORT 2015 – 2018**

## 1. Introduction

Division J covers a wide range of topics dealing with the physics of the Universe, and the physics of galaxies composing it, but not in particular the Milky Way, which is relevant to Division H ("Interstellar Matter and Local Universe"). Also, some of the topics will be shared with Division D ("High Energy Phenomena and Fundamental Physics").

The main topics can be listed in four categories:

- *Physics and content of the Universe*

The early Universe, cosmological models; baryonic and non-baryonic matter, dark matter and dark energy.

- *Evolution of structures*

Cosmic backgrounds (CMB, and all backgrounds from radio to gamma-rays); populations of galaxies, galaxy clusters and groups, intergalactic medium.

- *Formation and evolution of galaxies*

Reionization, first objects (AGN, starbursts), history of star formation; physics of galaxies at all redshifts, role of the environment.

- *Spatially resolved galaxies*

Star formation laws in galaxies, resolved stellar population; dynamics of sub-structures (bulges, disks, spiral structure).

## 2. Major activities within the past triennium

Members of the Steering Committee of Division J enabled and participated in various IAU related activities.

• Reviewed symposium proposals, provided letters of support and ranked all proposals during each year.

• Served as the coordinating division for these Symposia between the 2015 GA and end of 2018: S315, S319, S321, S329, S333, S336, S341, S342, S343, S344, S347, S348, S349.

• Served as the coordinating division for these Focus Meetings during the GA:
– 2015: FM5, FM10, FM18, FM22
– 2018: FM2, FM3, FM6, FM7, FM8, FM11, FM15

• Reviewed Ph.D. Prize applications and recommended Fabio Pacucci (2017) and Max Gronke (2018).

• Created the Division Day program for the Vienna GA:
– Ph.D. Prize talks and poster presentations
– Meeting of Commission J1
– Mini-symposium "Build-up of Galaxy Clusters"

• Supported three commissions (J1, J2, X1) and one new WG (Religas) and recommended continuation.

• Actively encouraged the community to apply for membership and serve on the Steering Committee.

• Sent regular emails to members to keep them engaged, including a detailed and wide-ranging member survey questionnaire. A summary of the survey results is available here: `http://www.stsci.edu/science/starburst99/docs/Questionnaire_Report.pdf`.

• Contributed to the report on Astronomy's Greatest Discoveries in the 20th century.

• Contributed to the formulation and writing of the IAU Strategic Plan.

• Contributed to revisions of the IAU Code of Conduct.

## 3. Publications between 2016 and 2018

Division J has publications in a wide range of topics. The numbers of publications in refereed journals give some indication of the proportion of work in various sub-fields. For the period from 2016 to 2018 (prior to this writing date of April 2018), the SAO\NASA Astrophysical Data Service tallies these counts according the appearance of key words in the abstracts:

• galaxies: 20826
• cosmology: 11847

## 4. Scientific developments within the past triennium

Integral Field Spectroscopic Observations in the optical and near-infrared as well as ALMA CO observations have been increasingly used to investigate the feeding and feedback processes around AGN. Although the majority of the papers have concentrated on the calculation of feedback, a few have reported the detection of inflows. Using ALMA, Hsieh, P.-Y. et al. 2017, ApJ , 847 , 3, have found molecular gas feeding the circumnuclear disk of the Milky Way center, while Espada, D. et al. 2017, ApJ , 843 , 136 reported inflows towards the inner 10 pc of Centaurus A., and Maccagni, F. M. et al. have found signatures of inflows towards the nucleus of a nearby radio galaxy. ALMA observations of intracluster gas has shown plenty of molecular gas that may be accreting into cluster galaxies; in many cases the molecular gas encase radio bubbles (e.g., Russel, H. R. et al. 2017, ApJ, 836, 130), suggesting that it is being compressed by these bubbles. In the optical and near-infrared, in observations of nearby Seyfert galaxies Schnorr-Müller et al. 2016, MNRAS 457, 972 and 2017, MNRAS, 466, 4370, have found inflows along a nuclear bar and a nuclear spiral while Fisher, T. et al. 2017, ApJ, 834, 30, have found outflows off fueling flows.

In the most popular subject of AGN feedback, a number of studies have been questioning the actual power of AGN outflows, as huge uncertainties affect the determination of physical quantities used in the calculations, such as, the mass outflow rate (how much mass is outflowing?), gas densities and filling factors, the extent and geometry of the outflow and outflow velocities, besides the different methods used in this calculation. Husemann, B. et al. 2016, A&A, 594, 44 have evaluated the effect of beam smearing in the observations of distant AGN in the calculation of the power of the outflows, showing that it can lead to overestimations of up to two orders of magnitude. Sun, A.L, Greene, J. & Zakamska, N. L., 2017, ApJ, 835, 222 report that the outflow powers of a sample of luminous AGN at $z \sim 0.1$ can vary by many orders of magnitude: $0.007\% < \dot{E}/L_{Bol} < 7\%$ due to the above uncertainties. Harrison, C. M. et al. 2018, Nature Communications, 2, 198, discussing such calculations over the last 20 yrs, pointed out not only the range of resulting powers depending of assumptions and methods ($0.001\% < \dot{E}/L_{Bol} < 10\%$), but the limitations of the observations that are usually of only one gas phase, and do not account for all possible feedback really occurring.

Another interesting finding reported in the last few years is the detection of positive feedback from AGN: e.g. Santoro, F. et al. 2016, A&A, 590, 37, who found star formation in filaments in the extended narrow-line region of Centaurus A, and Maiolino, R. et al. 2017, Nature, 544, 202, who also found a starburst inside a galactic outflow.

Large samples of galaxies (AGN and non-AGN) have been studied using SDSS data, such as Woo, J. H., Son, D., Bae, H.J. 2017, ApJ, 839, 120, who found that the fraction of AGNs with a signature of outflow kinematics increase with AGN luminosity and Eddington ratio.

Regarding SDSS-IV and in particular, the MaNGA (Mapping Nearby Galaxies at APO) Integral Field Survey (that should target ∼10,000 galaxies until the year 2020), looking for papers in ADS that have in their titles the word MaNGA, 56 papers have been published since 2015, with topics ranging from resolved stellar population properties in all galaxies observed so far to resolved gas properties in emission-line galaxies, focusing in a range of samples, including star-forming, quiescent and active galaxies.

Using data from the Sloan Digital Sky Survey, the Baryonic Oscillation Spectroscopic Survey and the XQ-100 sample, measurements of the Lyman-alpha forest flux power spectrum have been used to constrain the nature of dark matter, the mass of neutrinos and a variety of cosmological parameters. QSOs from the Sloan Digital Sky Survey DR12 were used to make the first detection of Baryon Acoustic Oscillations in the Intergalactic Medium. Combined with previous other measurements, the detection has made it possible to make an accurate determination of the cosmological parameters, independent of Cosmic Microwave Background measurements. The results confirm a Lambda-CDM cosmology (Irsic et al. 2017a, MNRAS, 466, 4332; Irsic et al. 2017b, PhRvD, 96b, 3522; Palanque-Delabrouille et al. 2015, JCAP, 11, 011; Yeche et al. 2017, JCAP, 06, 047; Baur et al. 2017, JCAP, 12, 013; Bautista et al. 2017, 2017A&A, 603, 12).

The Multi-Unit Spectroscopic Explorer (MUSE) optical integral field spectrograph on the VLT has opened a new window onto the circumgalactic medium. MUSE has enabled the detection of Lyman-alpha emission around individual, low-mass galaxies at high redshift. Much more extended Lyman-alpha haloes are detected around each of 17 bright, radio-quiet quasars. While the physical origin of the emission is still debated, it is clear that the spatially and spectrally resolved Lyman-alpha nebulae are powerful new probes of the neutral circumgalactic gas that was previously only accessible in absorption (Wisotzki et al. 2016, A&A, 587, 98; Borisova et al. 2016, ApJ, 831, 39).

In the last three years, the distance limit for galaxies in the epoch of reionization has been pushed to just 400 Myr after the Big Bang, with a $10^9$ solar mass star-forming galaxy now identified at $z = 11.1$. There are several other galaxies now found at redshifts well into reionization (z¿8), and with HST imaging of galaxy clusters, by exploiting lensing, UV luminosity functions of galaxies beyond redshift $z > 6$ have been constructed. Results suggest a steep faint-end slope, confirming the notion that faint galaxies are driving reionization at high redshifts. It is now possible to directly observe the candidate galaxies responsible for reionizing the Universe (Oesch et al. 2016, ApJ, 819, 129O; Brett et al. 2018, arXiv1801:03103; Zitrin et al. 2015, ApJ, 810, L12; Livermore et al. 2017, ApJ, 835, 113).

Lyman continuum emission is now being observed with HST at redshift $z > 3$, enforcing the idea that escape fractions of ionizing photons can be high, as high as needed to reionize the Universe with faint low-mass galaxies (Vanzella et al. 2016, ApJ, 825, 41).

A careful joint analysis of BICEP2/Keck/Planck collaboration data disproved the idea, proposed in 2014, that the B mode oscillation signature in the all-sky polarization data was due to inflation. This new analysis provided extremely tight limits for the nature of cosmic inflation, consistent with predictions for a small tensor-to-scalar ratio (A&A, 594, 20, [2016]; PhRvL, 114, 1301 [2015]).

Over the last three years, we have better understood the nearest galactic nucleus, Sgr $A^\star$ in the center of the Milky Way: there are new models for the dynamical evolution of the molecular clouds, the sharpest images of the magnetic fields ever achieved, and protostars within 1 pc of the black hole (Kruijssen et al. 2015, MNRAS, 447, 1059; Roche et al. 2018, MNRAS, 476, 235; Yusef-Zadeh et al. 2017, ApJ, 850, 30).