List of Topics with References

Week 2 (March 3):

Strongly lensed galaxies by galaxy clusters (2 students)

Faculty contact: Dandan Xu

One of the main goals of the JWST is to study the first galaxies in the Universe. This can be achieved in combination with the most power cosmic telescope – gravitational lensing of galaxy clusters! So far there have been a number of extremely high redshift galaxies (z>10) detected this way. Through lens reconstruction, we can even infer basic physical properties for the infant baby galaxies. This however relies on faithful reconstruction using accurate lens model. How robust is the method? What are the assumptions and limitations for the cluster lens modelling? Please read suggested papers and give your opinion on this.

https://ui.adsabs.harvard.edu/abs/2022arXiv220707101M/abstract

https://ui.adsabs.harvard.edu/abs/2022ApJ...938L...6P/abstract

https://ui.adsabs.harvard.edu/abs/2022ApJ...940L..53V/abstract

https://ui.adsabs.harvard.edu/abs/2023MNRAS.519.1201A/abstract

https://ui.adsabs.harvard.edu/abs/2023MNRAS.519.3064F/abstract

Week 3 (March 10):

Hunting for the first galaxies with JWST (2-3 students)

Faculty contact: Cheng Li & Zheng Cai

When, where and how were the first galaxies formed? These are among the most interesting questions in astronomy and cosmology. Astronomers have made lots of efforts in the past decades, by using the most power observing facilities and applying clever and efficient techniques. Shortly after the launch of the JWST, we have seen a significant number of papers claiming to have found very high redshift galaxies, up to z~16 or even higher! Listed below are the several most-cited papers of this topic in the literature. Please start from these papers, and try to summarize the up-to-date results from JWST.

https://ui.adsabs.harvard.edu/abs/2022ApJ...940L..14N/abstract

https://ui.adsabs.harvard.edu/abs/2022ApJ...940L..55F/abstract

https://ui.adsabs.harvard.edu/abs/2023MNRAS.518.4755A/abstract

https://ui.adsabs.harvard.edu/abs/2023MNRAS.519.1201A/abstract

https://ui.adsabs.harvard.edu/abs/2022arXiv220802794N/abstract

Week 4 (March 17):

High-redshift Galaxy Formation and their morphologies using JWST (2 students)

Faculty contact: Zheng Cai, Dandan Xu

JWST revolutionize our understanding of galaxy formation in the early Universe. JWST identified a large population of z>7 galaxies, a large fraction of z>3 star forming disks. JWST's IR wavelength coverage makes the identification of large population of quiescent galaxies in the early Universe. The ideal JWST resolution makes the galaxy morphology study entering in a new stage. Given the variety of high-z galaxy morphologies, including irregular/clumpy star-forming galaxies, compact and extended star-forming disks, and compact quiescent galaxies, as revealed by many exciting high-z observations, it is highly timely to address a few key questions, such as what are the gas and star-forming condition in these high-z galaxies? How early did they already host AGN activities? How did some of the galaxies already establish cold stellar dynamics at that early epoch? What are the underlying evolution connection among the different morphologies? And would they evolve into present-day massive quenched galaxies via a transition through compact quenched galaxies as theoretically expected? Please read the suggested papers and references there in and give your thoughts on this.

https://ui.adsabs.harvard.edu/abs/2023MNRAS.518..592K/abstract

https://ui.adsabs.harvard.edu/abs/2022arXiv221204480R/abstract
https://iopscience.iop.org/article/10.3847/2041-8213/aca086
https://arxiv.org/abs/2207.09428
https://arxiv.org/abs/2208.00986

Week 5 (March 24):

Clouds in Exoplanet Atmospheres -- observational implications (1-2 students)

Faculty contact: Chris Ormel

Characterization of planet's atmosphere strongly relies on identifiying atomic or molecular features in transmission spectra of exoplanet atmospheres. However, by blocking light from deeper layers clouds can suppress or even erase the spectral signature, frustrating characterization efforts. How often does this happen? Starting from recent JWST observations, discuss how prevalent contamination by clouds is at various wavelengths. Focus your discussion both towards giant planets (hot-Jupiters) and smaller, terrestrial planets.

Sample references:

https://ui.adsabs.harvard.edu/abs/2022arXiv220811692T/abstract
https://ui.adsabs.harvard.edu/abs/2023ApJ...943L..10C/abstract
https://ui.adsabs.harvard.edu/abs/2023arXiv230104191L/abstract
https://ui.adsabs.harvard.edu/abs/2022arXiv221110493F/abstract
https://ui.adsabs.harvard.edu/abs/2022arXiv220900620M/abstract

Clouds in Exoplanet Atmospheres -- theoretical models (1-2 students)

Faculty contact: Chris Ormel

By blocking light from deeper layers clouds can have a major effect on the spectral signature of exoplanet atmospheres. It is therefore essential to understand cloud formation. In the literature a variety of models for the formation of clouds and hazes has appeared -- some simple, others more advanced -- which can now be tested, at least in principle, by JWST. Review the literature on cloud models and haze formation and identify which cloud models scientist use while fitting JWST spectra and what we have learned about the nature of clouds in exoplanets.

Sample references:

https://ui.adsabs.harvard.edu/abs/2023ApJ...943L..10C/abstract
https://ui.adsabs.harvard.edu/abs/2017MNRAS.471.4355P/abstract
https://ui.adsabs.harvard.edu/abs/2022arXiv221110493F/abstract

Week 6 (March 31):

Molecular line emission from the inner protoplanetary disks (1-2 students)

Faculty contact: Xuening Bai

The warm surface layer at the inner few AU of protoplanetary disks can emit a plethora of molecular lines at near and (mostly) mid infrared. These lines contain rich information about disk dynamics and chemistry, and represent an important probe of the early stages of planet formation. The exquisite spectral capability of JWST at infrared wavelengths is going to revolutionize our understandings over past studies using Spitzer, and it already demonstrated remarkable data quality at its early data release. Starting from the references below (and potentially dig further into the literature), please provide an overview of the science in this area, highlighting the role of JWST.

https://ui.adsabs.harvard.edu/abs/2023AJ....165...72B/abstract
https://arxiv.org/abs/2212.08047
https://arxiv.org/abs/2301.08770
https://ui.adsabs.harvard.edu/abs/2022ApJ...941..187J/abstract

Direct imaging of exoplanets with JWST (1-2 students)

Faculty contact: Xuening Bai

The powerful instruments onboard JWST makes it an extraordinary telescope for direct imaging of exoplanets that well exceed the capability of current ground-based facilities. While new discoveries are yet to be made, the following three references outline the new exciting discovery space that can potentially be achieved by JWST in the coming years.

https://ui.adsabs.harvard.edu/abs/2022PASP..134j4401S/abstract
https://ui.adsabs.harvard.edu/abs/2022MNRAS.516..506C/abstract
https://ui.adsabs.harvard.edu/abs/2023MNRAS.519.2718R/abstract

Week 7 (April 7):

What would JWST tell us about the atmospheres of temperate rocky planets? (2-3 students)

Faculty contact: Sharon Wang

Detecting the atmospheres of small planets is challenging even for JWST. Temperate rocky planets are of particular interest due to the highly sought-after potential biosignatures. What can we learn given the limited sample of such planets in nearby systems suitable for such studies and JWST's capabilities? Focus on why this is (perhaps surprisingly to some people) challenging even for JWST, the biomarkers within the JWST coverage, some signature planets/systems, and the key results we hope to see.

https://ui.adsabs.harvard.edu/abs/2017ApJ...850..121M/abstract
https://ui.adsabs.harvard.edu/abs/2018ApJ...856L..34B/abstract
https://ui.adsabs.harvard.edu/abs/2019AJ....158...27L/abstract

For references or for fun but maybe not read thoroughly:

https://ui.adsabs.harvard.edu/abs/2020ApJ...901L...1K/abstract
https://ui.adsabs.harvard.edu/abs/2018AJ....156..114K/abstract
https://ui.adsabs.harvard.edu/abs/2021ApJ...923..144P/abstract
https://ui.adsabs.harvard.edu/abs/2023arXiv230104191L/abstract

Week 8 (April 14):

Mapping out young massive star-forming regions in nearby disk galaxies (2-3 students)

Faculty contact: Hui Li & Cheng Li

Star formation and its subsequent feedback process are the key physical ingredients of galaxy formation. However, star-forming regions, especially the youngest ones, are highly obscured and therefore not visible to optical/UV. With unprecedented sensitivities and spatial resolutions in the infrared band, JWST will map out, for the first time, the youngest stellar population and dusty interstellar medium for a wide range of galaxies out to tens of Mpc. These observations, together with HST (opt/UV), VLT/MUSE (IFU), and ALMA (molecular lines), will 1) shed lights on the physical conditions of embedded star-forming regions in different galactic environments 2) constrain the spatial distribution and duration of star formation, 3) quantify various statistics of star cluster populations, and map out the most extreme environments such as galactic nucleus. Some early results of JWST have already demonstrated the crucial roles that JWST will play on revealing the star formation activities in their earliest phase in the near future. Below are a few relevant references:

https://ui.adsabs.harvard.edu/abs/2022ApJ...940L...8E/abstract
https://ui.adsabs.harvard.edu/abs/2022arXiv221212039W/abstract

Specifically, the PHANGS (Physics at High Angular resolution in Nearby GalaxieS) survey is making high resolution observations for a sample of 19 nearby galaxies with several telescopes. Observations of nearby galaxies will be utilized to understand how physics at or near the “cloud” scale are affected by galaxy-scale conditions, how they affect still smaller scale processes, and how these influence the evolution of whole galaxies. A series of papers have come out based on the joint analysis of PHANGS an JWST data, and can be found by searching "PHANGS-JWST First Results" on the publication page of the PHANGS survey:

https://sites.google.com/view/phangs/publications

Please read those papers and have an overview of the new results, highlighting the role of JWST. Before diving into those papers, you may want to start by reading the following short paper for a brief introduction to the survey and a summary of the first results:

https://ui.adsabs.harvard.edu/abs/2022arXiv221202667L/abstract

Week 9 (April 21):

Elemental imprints of high-z galaxies revealed by JWST (2 students)

Faculty contact: Junjie Mao

Interstellar media (ISM) of galaxies are enriched with metals. These metals are sourced from stellar winds and/or supernova explosion of dying stars. Previous studies on nearby galaxies found the (gas phase) metallicity depends on the stellar mass and star-formation rate, namely the (SFR-)MZR relations. For high-z galaxies, with the metal lines shifted to the NIR band, the (SFR)-MZR relation at high-z are poorly constrained prior to the era of JWST. Please overview recent outcomes of decoding the metallically of high-z galaxies using JWST.

References:

Nakajima et al. 2023, ApJS submitted

https://ui.adsabs.harvard.edu/abs/2023arXiv230112825N/abstract

Tucker et al. 2023, ApJL submitted

https://ui.adsabs.harvard.edu/abs/2023arXiv230107126J/abstract

Arellano-Cordova et al. 2023, ApJL, 940, 23

https://ui.adsabs.harvard.edu/abs/2022ApJ...940L..23A/abstract

Week 10 (April 28):

The galaxy UV luminosity function and cosmic star formation history at the pre-reionization epoch (2-3 students)

Faculty contact: Cheng Li

One of the most important goals of modern astronomy is to understand the formation and evolution of galaxies. Despite of decades of deep observations of galaxy images and spectra at different redshifts, significant questions remain open, particularly regarding the abundance and formation efficiency of the galaxies in the early universe. The field is expected to dramatically advance thanks to the JWST which is observing samples of galaxies up to redshifts from z~8 up to z~15, allowing the UV luminosity function and the cosmic density of star formation rate to be measured at the pre-reionization epoch. Listed below are the most recent JWST-based papers on this topic: one was submitted in November 2022, and the other two were submitted in July (published now) and August (accepted now) in 2022. Please read these papers and the relevant references therein to have an overview of this topic, in particular emphasizing the improvement relative to the pre-JWST studies. An early review of this topic can be found in Madau & Dickinson (2014, ARA&A; https://ui.adsabs.harvard.edu/abs/2014ARA%26A..52..415M/abstract) and may be helpful to junior students.

https://ui.adsabs.harvard.edu/abs/2022arXiv221102607B/abstract

https://ui.adsabs.harvard.edu/abs/2022arXiv220801612H/abstract

https://ui.adsabs.harvard.edu/abs/2023MNRAS.518.6011D/abstract

Week 12 (May 12):

Can High-Redshift Galaxies Discovered by JWST Challenge Cosmology? (2 students)

Faculty contact: Song Huang

Shortly after the launch of JWST, a series of a breakthrough in the high-redshift universe has already reshaped astronomy. Early observations by JWST have uncovered a large number of infant galaxies (candidates) at extremely high redshift (z>10). These discoveries are exciting but are also a little surprising since many astronomers did not expect to find them in such abundance. Moreover, the initial estimates of their stellar mass suggest they are already quite “mature”. According to some astronomers, these galaxies should not exist under the standard LCDM cosmology. Hence these JWST observations could potentially challenge our cosmology model. What do you think?

- Schrodinger's Galaxy Candidate: Puzzlingly Luminous at z≈17, or Dusty/Quenched at z≈5? https://arxiv.org/abs/2208.02794
- Two Remarkably Luminous Galaxy Candidates at z≈10−12 Revealed by JWST https://arxiv.org/abs/2207.09434
- Has JWST already falsified dark-matter-driven galaxy formation? https://arxiv.org/abs/2210.14915
- Can Cosmological Simulations Reproduce the Spectroscopically Confirmed Galaxies Seen at z ≥ 10? https://arxiv.org/abs/2212.12804

Week 13 (May 19):

Strongly lensed stars in the distant universe (2 students)

Faculty contact: Wei Zhu, Shude Mao

Massive stars in the high-redshift universe can be seen if they are being gravitationally lensed by foreground objects (e.g., galaxy clusters). Such lensing systems, once observed, can provide unique opportunity for people to study the stellar evolution and black hole formation in the high-redshift universe. Moreover, this could also enable potential detections of population III massive stars at high-redshift, and thus provides constraints on the star formation at high-redshift. The current record holder of such systems is Earendel, which is a highly magnified star at redshift 6.2 identified by HST, although it remains a controversial system for many good reasons. With JWST, people are expecting to better resolve the Earendel system and find more at similar or even higher redshifts. Starting from the references below (and potentially dig further into the literature), please provide an overview on the issue and discuss the potential and early discoveries of JWST.

1. Kelly et al. 2018, Nature Astronomy, 2, 334
2. Chen, W. Et al. 2019, 881, 8
3. Diego, J. M. 2022, https://arxiv.org/abs/2210.06514

https://ui.adsabs.harvard.edu/abs/2022Natur.603..815W/abstract
https://ui.adsabs.harvard.edu/abs/2022ApJ...940L...1W/abstract
https://ui.adsabs.harvard.edu/abs/2023ApJ...944L...6M/abstract

Week 14 (May 26):

CHOOSE YOUR OWN TOPICS (2-3 students)

Faculty contact: H. Li

Week 15 (June 2):

Nature of passive massive galaxies at high redshift (2-3 students)

Faculty contact: Song Huang, Dandan Xu

Massive galaxies at low redshift are mostly quiescent. Or, they are dead. “Dead” means they have stopped making new stars (in large amounts) over a long, long time. We are still arguing about the life story of these galaxies: What physical processes quenched their star formation in the first place? How could they build up such massive amounts of stars so quickly at early epoch of the Universe and quenched ever since? And, recently, the advance of observations at high redshift suggests that there are potentially more massive quiescent galaxies already in place at >10 Gyr ago. Will they keep quenching since and become progenitors of today’s “dead” massive galaxies? Or it could be only a transient phase for some of them during their episodic star formation history, and after a while they would acquire new gas supplement and be "rejuvenated" again at some point? Please give us a quick summary of this topic and let us know your thoughts.

- Massive quiescent galaxies at z 3: A comparison of selection, stellar population, and structural properties with simulation predictions: https://arxiv.org/abs/2201.09068
- A surprising abundance of massive quiescent galaxies at < z < 5 in the first data from JWST CEERS: https://arxiv.org/abs/2208.00986
- A massive quiescent galaxy at redshift 4.658: https://arxiv.org/abs/2301.11413
- MAGAZ3NE: High Stellar Velocity Dispersions for Ultramassive Quiescent Galaxies at $z \gtrsim 3$ https://arxiv.org/abs/2208.04329
- The Number Densities and Stellar Populations of Massive Galaxies at $3 < z < 6$: A Diverse, Rapidly Forming Population in the Early Universe: https://arxiv.org/abs/2010.04725

Week 16 (June 9):

The Prospective of High Redshift Spectroscopic Surveys for Cosmology (2-3 students)

Faculty contact: Song Huang

As you may know, Tsinghua is building a 6.5-m spectroscopic survey telescope called the MUltiplexed Survey Telescope, or MUST. MUST will carry out the next generation of cosmology surveys using its unprecedented multiplexed spectroscopic capability. With 20,000 fiber positioners placed over a 5-7 square degree field-of-view, MUST can bring us to the new frontier of cosmology. Many cosmologists anticipate that high redshift galaxies, such as the Lyman Break Galaxies (LBG) or Lyman-alpha Emitters (LAE), can become promising cosmology tracers. They could reveal the matter distributions in the early universe and help us understand the origin of dark energy. However, we still know little about these galaxies' physical properties and even less about the dark matter halos they live in. It could be risky to bet the future of our billion-¥ project on these difficult targets. What do you think?

- Cosmology at high redshift - a probe of fundamental physics https://arxiv.org/abs/2106.09713 (Long paper warning!)
- Cosmological Fisher forecasts for next-generation spectroscopic surveys: https://arxiv.org/abs/2301.02289