Course: **The Physics and Evolution of Active Galactic Nuclei**
Reading report #4
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Paper name: **Experimental Indicators of Accretion Processes in Active Galactic Nuclei**
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Paper abstract:
Bright Active Galactic Nuclei are powered by accretion of mass onto the super massive black holes at the centers of the host galaxies. For fainter objects star formation may significantly contribute to the luminosity. We summarize experimental indicators of the accretion processes in Active Galactic Nuclei (AGN), i.e., observable activity indicators that allow us to conclude on the nature of accretion. The Galactic Center is the closest galactic nucleus that can be studied with unprecedented angular resolution and sensitivity. Therefore, here we also include the presentation of recent observational results on Sagittarius A* and the conditions for star formation in the central stellar cluster. We cover results across the electromagnetic spectrum and find that the Sagittarius A* (SgrA*) system is well ordered with respect to its geometrical orientation and its emission processes of which we assume to reflect the accretion process onto the super massive black hole.

Q1. What is this work all about? What is your overall impression on the quality of this work (poor, average, good, or great)? Explain briefly your assessment.

In this paper, a series of experimental indicators, which allow people to conclude on the nature of accretion processes in Active Galactic Nuclei (AGN), has been summarized by the authors in APCS2016 (Accretion Processes in Cosmic Sources, Sep 2016). They emphatically introduce star formation and black hole growth, relativistic radio jets, reverberation in order and give a basic overview over the general process of accretion towards the center. The authors also include the presentation of recent observational results on Sagittarius A*, the SMBH in central of MW, and the conditions for star formation in the central stellar cluster.

From my opinion, this paper is a good work. It is more like a review of the observational indicators in AGN accretion process. For a beginner, I do think it make it easier to have deeper understanding of the related field.

Q2. Why do the authors carry out this work?

AGNs are powered by accretion of mass towards their nuclei. As the accretion process play such an important part in the AGN and is not clear what the interplay between various mechanisms is that lead to the feedback, investigations of phenomena at vicinity of central SMBH are desiderated. On the other hand, the accretion disk itself and the immediate surroundings of the SMBH have characteristic spectral signatures that allow people to study the accretion process - supported by theory and observations.

In the past few years, with the demand and development of high angular resolution techniques, Sagittarius A* (the nucleus of our Galaxy), as an ideal target, allows observer to study the nuclear activity associated with accretion onto the SMBH and the possibility for star formation in its vicinity in an unprecedented at the same time to investigate the physics of the accretion process.

Among all the discovery, the DSO (Dusty S-cluster Object), which passed by SgrA* within ~150-160 AU in spring 2014, made so great contribution that people present a brief description of the accretion process acting onto SgrA* from a statistical analysis of emission at different wavelengths and summarize the exploration of the geometrical properties of SgrA* accretion flow and of the DSO via infrared polarimetry. (Shahzamanian et al. 2015, 2016).

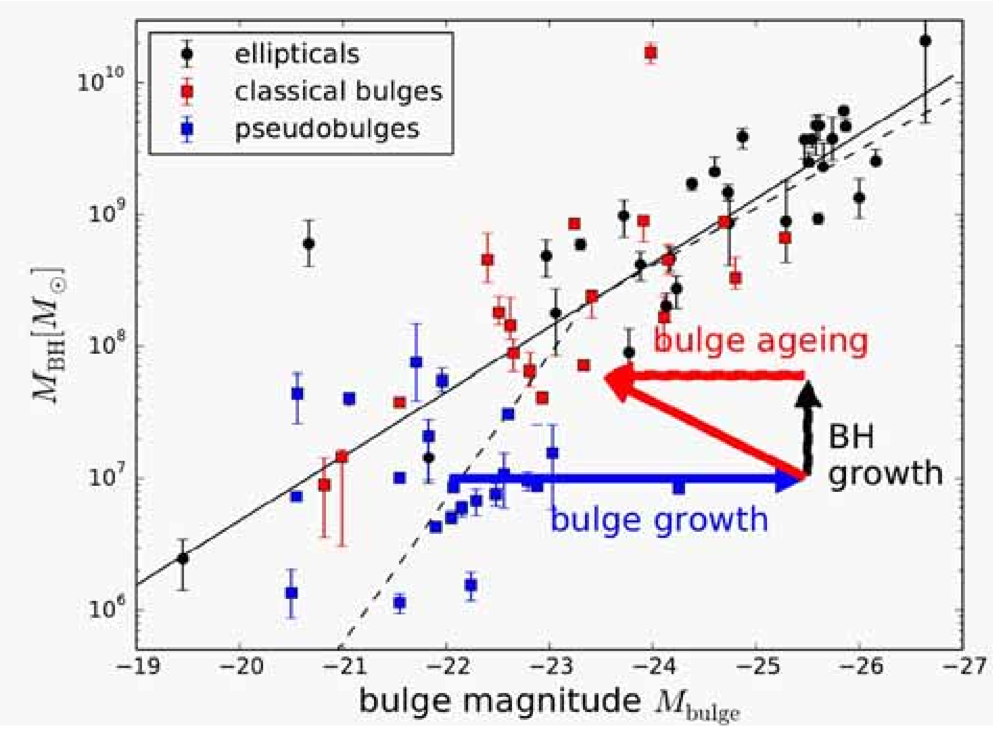
For all reason above, the authors carry out this work.

Q3. How do the authors manage to finish this work?

Q4. What are the main results and conclusions of this work? What are the differences/improvements of this work compared to previous relevant works?

As is mentioned before, this paper is more like a piece of review. So, I am not sure what "finish this work" means for this work, either the main results and conclusion. Therefore, I'll focus on the structure of this paper.

In Sec. 2, the authors put emphasis on the correlation and coevolution between galaxies and the central SMBHs. A small sample of the Hamburg/ESO survey for bright UV-excess QSOs has been selected from Busch et al. (2014) to perform multi-wavelength imaging. From the reduced images, they get 16 type-I QSQs' BH masses and bulge luminosities, which enables them come up with a possible evolutionary scenario in the black hole mass - bulge luminosity diagram as below. This points at possible evolutionary processes between the host bulge and the SMBH.



The authors give two possible reason to discuss this and bring up the definition of 'pseudobulges'. The first possibility is that much younger stellar populations contained in the bulges of active galaxies compared to the bulges of inactive galaxies moves the data points toward higher luminosities. A second possibility is that the BH of these AGN are under-massive compared to hosts of similar mass and luminosity, which indicate that further black hole mass accretion would move the sources toward higher black hole masses in the corresponding diagram. As for pseudobulges, being more disky implies higher rotation and lower velocity dispersion towards the center - resulting in a lower apparent bulge mass. But it is unclear in how far this effect needs to be considered in the case of LLQSOs. As a conclusion, they think that young stellar populations cause over-luminous bulges compared to inactive galaxies on the relation, black hole growth and aging of the stellar populations then move the objects back onto the relation, which is shown as accretion of matter onto the central region results into enhanced star formation and black hole growth.

In Sec. 3, they simply introduce the relativistic radio jets and talk about that what jets can indicate as an indicator, in the meantime, review the kinematical framework of jets. However, they frankly recognize that the physical nature of the jet-components as well as the launching mechanism are largely unknown. The MOJAVE (Monitoring Of Jets in Active galactic nuclei with VLBA Experiments) survey allowed for a long-term tracking of multiple jet components. Detailed modeling suggests that the jet features are launched under varying viewing angles into an ejection cone apparently also under the influence of some rotational motion in addition to the motion along the jet resulting into a helical jet structure. The observations can be explained by plasma moving along magnetic field lines of magnetic flux tubes. And several other model changes also have been mentioned. Part of the changes may be correlated with variations of the viewing angle of difference knots as well, while some of the changes could be traced back and seem to be correlated with optical and/or radio outbursts.

In Sec. 4, they systemically review the reverberation mechanism, which represents the immediate answer of the ionized gas surrounding the SMBH to the continuum variability of the accretion flow or disk. Handing the assumption that the variable radiation is indeed coming from the very nucleus of the corresponding source rather than secondary structures, people find reverberation signals from both: the BLR and the NLR revealing information on different size and time scales.

The NLR reverberation responses to long term variability. The low luminosity part of the NLR can be quite extended such that the NLRs in many nearby sources can be spatially resolved, so it is more difficult to find reliable information on the size of the high surface luminosity part of the NLR. At the same time, the luminous part of the NLR must be very compact, with a diameter in the range of 10 light-years since this dependence shown by 61 BLR and NLR sources from the literature is also strongly found in in the narrow line emission.

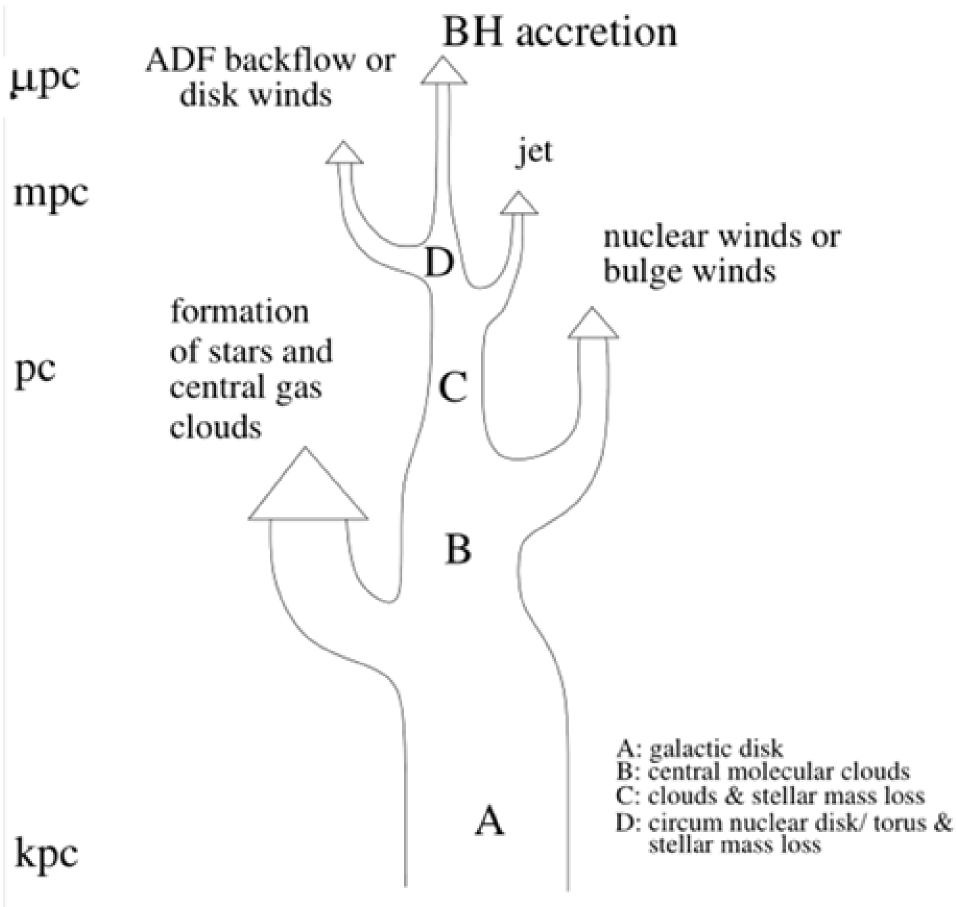
The broad emission line regions in AGNs are dominated by photoionizations from the central source. Whose structure could be investigated over short time intervals of hours to days reverberation mapping (Denney et al. 2016, Peterson 1993, Horne et al. 2004). The gas mass of the BLR is small compared to that of the NLR. At BLR radii the amount of 'contaminating' stellar mass is minimal. Hence, the black hole masses derived via this method belong to the most reliable estimates. The black hole mass M_{BH} is given by:

$$M_{BH} \sim f \times R_{BLR}(\sigma_{BLR})^2$$

The factor f reflects the exact shape of the BLR. Then, they review the variability and time lags.

In Sec. 5, they review the multi-wavelength data of Sagittarius A* and the monitoring of the DSO and find that the SgrA* system is well ordered with respect to its geometrical orientation and its emission processes of which they assume to reflect the accretion process onto the super massive black hole.

At last, the authors give s summary. The overview of the SMBH accretion process can be presented as a tree diagram as below, in which branching point of the tree means the interdependences between various mechanisms. The width indicates the amount of matter involved with the typical size scales decreasing from bottom to top.



Q5. What are the main contributions of this work?

This work reviews the development of experimental indicators of accretion processes in Active Galactic Nuclei during the past thirty years. It not only gives a basic overview over the general process of accretion towards the center, but also involves a large quantity of details about this process.

The diagram mapping in this paper is good for men who have some degree of academic background to specialize the observation of AGN accretion. In the meantime, it can also be used as a guide book to find the related work which you take interest in more quickly. The presentation of recent observational results on Sagittarius A* is a good sample for the following investigation. All these help people conclude on the nature of accretion.

Q6. Why can the authors make such contributions?

The basic reason is that the accretion disk itself and the immediate surroundings of the SMBH have characteristic spectral signatures that allow people to study the accretion process - supported by theory and observations. At the center of our Galaxy, which is close enough to our Earth, Sagittarius A* is a highly variable near-infrared and X-ray source associated with a 4×10^6 M⊙ super massive central black hole. As an ideal target, SgrA* can efficiently take use of the high angular resolution techniques needed by observation of compact SMBH.

For reasons above, a chain of teams gives quite a few great investigations of both the object and its secondary phenomena. Then we can see this work.

Q7. Can you think of some way to improve this work or to verify it?

As the next generation telescopes established, more and more multi-wavelength data will help the observation reach a new level. Among these, I think larger amount of finer IR data is of great importance to enhance the AGN accretion investigation. For the redshift and the selection effects, the large IR spectroscopic surveys are not yet available, but the diagnostics based on shorter wavelengths are not as reliable.