PROBLEM SET # 1

Astro 512 – Spring 2019
Extragalactic Astronomy

Problem 1: Tools of the Trade: ADS

There are two tools that I have found critical for research, the ADS Abstract Service and the NASA Extragalactic Database ("NED"). These are two simple exploratory exercises to familiarize yourself with some of their more useful but more obscure features.

ADS: While many people use ADS only to find specific papers, it is actually a much more powerful tool. By exploiting some key features, you can easily figure out the most influential papers on a topic of interest. In this example, you will try to identify the 3-5 most influential papers from the last 25 years in your chosen extragalactic specialty.

ADS is trying very hard to convince astronomers to use its shiny new interface at `https://ui.adsabs.harvard.edu/`. As a classic ADS power user, I find the new interface to be extremely limiting, and after sinking a couple hours into trying to convert the following exercise to something that works with the new interface, I found that I couldn't and gave up in frustration. So, this assignment will teach you how to use some near-obsolete tech that works much better than what it will be replaced by. The basic strategy will eventually work in the new system (hopefully), so you'll only have to learn which different buttons to press.

a) Go to ADS (`http://adsabs.harvard.edu/abstract_service.html`) and type in your topic under "Abstract Words", and then "send query".

b) You will get a lot of papers. Many of these will be abstracts and conference procedings. Go back and click on "All refereed journals" to narrow your results down. You may also have noticed that some papers about irrelevant topics have wandered into your results. Try putting some of your abstract words in quotes (i.e. "disk galaxy" or "galaxy formation") to require that the words appear in order in the abstract.

c) Scan through the titles and find one that seems most relevant to your topic.

d) Above the title of the article, you will see a series of letters (A, E, F, R, C, etc). Click on "R" to get all the references for that article. (Tip: this exercise will only be useful if the list of references comes back in ADS format, rather than dumping you to the journal directly. If the latter happens, pick a different, older article.)

e) Chances are that the article you picked references some of the key topics in the field. But which are they? Go to the bottom of the page of references and click on "Select All Records". Then set "Sort by" to "citation count" in the pull down menu. Then, "Retrieve selected records". This returns the list sorted by the number of times that an article has been cited, one measure of its influence.

f) Scan through the list of titles, and select 5 titles or so that seem most directly related to your topic, weighting your selctions to those closer to the top of the list (i.e. the heavily cited ones). You can

"select" these by clicking on the little square box to the left of the link to the abstract. Note, however, that older articles will naturally tend to be cited more. So, also consider picking some recent papers (less than 5 years old) that have higher than average citation rates – these are likely tracking some of the more exciting recent results. For very recent astro-ph papers, looking at the number of votes in vox-charta can give you some hints about which papers are generating a larger-than-typical share of interest.

g) Now go back down to the bottom of the page and click on "Find papers similar to the selected articles", to see if you can come up with an even more thorough list of relevant papers. ("Get also-read lists for selected articles" is another useful button to try for this as well, but the results are a bit broader). This search can take a while, since it's cross-comparing all the words in the abstract.

h) Again, sort the returned list by citation count. You can pretty much guarantee that many of the papers close to the top are worth reading (though some will be either enormous review papers or papers with important widely-used results that aren't actually that specific to your selected field). If the papers don't seem all that relevant, you can repeat steps (f)-(h) for a different paper. You can also sort the returned list by age, select all the relatively recent ones, then resort just those by citation count to get some "hot" recent work into your list.

i) Now, as a final check for completeness, you can click on "C" to get all the papers that have cited a particularly relevant paper. (This works best if you pick a paper from at least 10-15 years ago). Sort the resulting list by citation count again, and see if anything else interesting showed up. You can also search backwards from that same paper, by clicking on the "R" to get its references.

j) Based upon using all the above techniques, give me the list of your top 5 papers that you would recommend reading on this topic. You should probably read the abstracts of more than this to decide on what the best five to choose are.

k) Read one of them. You may want to avoid picking a 50 page review article, however.

l) Finally, you may want to start saving these papers in an on-line "private library". When you get a list of ADS search results, you'll find a small box on the left edge of every entry, between the "#" and "Bibcode" fields. Click on the box of any paper that seems to be of interest, then scroll down to near the bottom of the page (but above the section titled "Find papers related to the above articles"). You will find a button "Add selected articles to private library". When you click on the button, it will take you to page where you can either create a new library or add the selected papers to an existing library. This method is a good way to keep track of interesting papers that you may not yet be ready to read, but that you don't want to have to dig up again.

m) Other random tips: (1) If you click on "D" on the Results page, you'll be taken to on-line data available for the paper, allowing you to make your own plots; (2) if you put a " ^ " before an author's name on the search page, you will limit the search first author papers; (3) you can easily build bibtex libraries from a private library, by going to your library, clicking on the "Select All Records" button, then asking to return a "BibTeX Reference List" in the section "Retrieve the above records in other formats or sort order"; (4) you can add a minus sign before a word to exclude entries that contain that word, if you also click on the "simple logic" button (i.e., if you want stellar halos but not dark matter halos, you could put "halos -dark" into the "Abstract" search box).

Problem 2: Tools of the Trade: NED

The NASA/IPAC Extragalactic Database allows you to retrieve gobs of information about any astronomical topic. Go to `http://ned.ipac.caltech.edu/` to begin.

a) Click on "By Name" under the "Search Objects" menu.

b) Type in NGC 5128 (which is the Centaurus A Galaxy, or "Cen A" to its drinking buddies).

c) Admire the millions of different names this one galaxy has. Admire the vast amount of data neatly summarized about the galaxy under the different tabs. Note the galaxy's morphological classification under the "Classifications" tab.

e) Click on the "References" tab to get a list of all papers that have ever referred to this galaxy. (Cen A is obviously a popular galaxy, for being such a strange thing).

f) Click on the "Images" tab. Admire the vast number of images you can retrieve in many different wavebands. Compare the morphology of the galaxy in the optical, 2MASS Near-IR, radio, and x-ray images.

Problem 3: Classifying Galaxies

a) Much of extragalactic astronomy, is based on catalogs. Catalogs are rarely assembled randomly, and instead have been created by well-defined selection criteria (typically limits in size and/or apparent magnitude, tied to a specific imaging source). These selection criteria determine what kinds of galaxies are included, and more importantly, excluded from analysis. It is thus important to always understand what went into creating any catalog you use for research. For nearby galaxies, some of the most widely used catalogs are the NGC ("New General Catalog") and the RC3 ("Third Reference Catalog of Bright Galaxies"). Read about the origin of the NGC galaxy catalog and then the RC3 catalog here: NGC: `http://en.wikipedia.org/wiki/New_General_Catalogue`, RC3: `http://heasarc.nasa.gov/W3Browse/all/rc3.html`

b) Go to the SDSS image gallery of RC3 galaxies maintained by David Hogg: `http://cosmo.nyu.edu/hogg/rc3/`. Note that these galaxies often have multiple names, depending on the major catalogs they were included in (UGC = "Uppsala General Catalog", which is diameter-limited and thus less biased against low surface brightness galaxies; IRAS = "InfraRed Astronomical Satellite", which did an mid-IR all-sky survey; MCG = "Markarian Galaxies Catalog", which selected galaxies with UV bright nuclei, favoring starbursts; DDO = "David Dunlop Observatory Catalog", which cataloged dwarf galaxies; IC = "Index Catalog", which was a supplement to the NGC[1]

c) Classify around 20-30 of the galaxies, spanning a range of morphologies.

d) Plot the relationship between the galaxies' actual T-type and the one you derived. You can find the

[1]Unsurprisingly, Wikipedia maintains a "List of Astronomical Catalogs" if you ever are trying to track down the provenance of something: `https://en.wikipedia.org/wiki/List_of_astronomical_catalogues`

actual classification through NED (which you can query in batch mode) or through the RC3 link in part (a).

e) Briefly comment on your biases.

Problem 4: Extragalactic Scales

This is another exercise in orienting you to the extragalactic universe. I would like you to make a *single page* containing plots of the following quantities vs redshift – this will prove to be a very handy cheat sheet during the coming years. Please give me one copy, and post the others by your desk for reference during this quarter. As your default cosmology, use the "Best Cosmological Model" parameters from the latest WMAP or Planck release. To calculate many of the parameters, you will need to use the full formulas for a lambda cosmology. These can be found in the review article on Λ by Sean Carroll (ARA&A, 1992, 30, 499). You may also find many of the relevant formulas and a short pedagogical discussion at astro-ph/9905116.

Please use Python (or IDL) to make publication-quality plots the following quantities from a redshift of 0.001 out to redshift 10, on a *logarithmic x-axis*, using a logarithmic y-axis where appropriate. *Since you will be posting this on your wall, please put all 6 plots on a single sheet of paper!* Label your axes, just like you tell all your 101 students. Please do a sensibility check on your answers – I will take off points for anything that looks obviously incorrect or fails basic usability tests.

Also, you might want to inspect what typical values of various quantities are at: (1) 10 Mpc (which is considered to be "local volume"); (2) at $z = 1$ (where the rate of merging and high star formation begins to settle down); and (3) at $z = 6 - 8$ (where the highest redshift galaxies are currently being identified).

a) Luminosity distance in Mpc (defined so that $flux = luminosity/4\pi d_L^2(z)$).

b) Angular diameter distance in Mpc (defined so that $\theta = size/d_a(z)$).

c) The apparent magnitude of an L_* galaxy. Don't worry about k-corrections for now.

d) The angle (in arcseconds) subtended by 1 kiloparsec.

e) The "lookback time" (i.e. the number of Gigayears between now and some redshift).

f) The age of the universe. (i.e. the number of Gigayears between the beginning of the Universe and some redshift).