Universidad Andrés Bello

Facultad de Ciencias Exactas

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Topics of Astrophysics **2023**

Exam Questions

Professor in charge: Dante Minniti *Student: Ian Baeza Mardones*

1.- Claudio Caceres

Explain why it is possible to find different types of structures when observing the same protoplanetary disk at different wavelengths (e.g., a ringed structure in the NIR vs. a flat structure at mm wavelengths).

Because two reasons, first we actually have different structures within the disk that varies with the evolution of the disk itself (photo-evaporation, planets, etc) and we are essentially tracing different components of the disk that has their own temperatures if we measure different wavelengths.

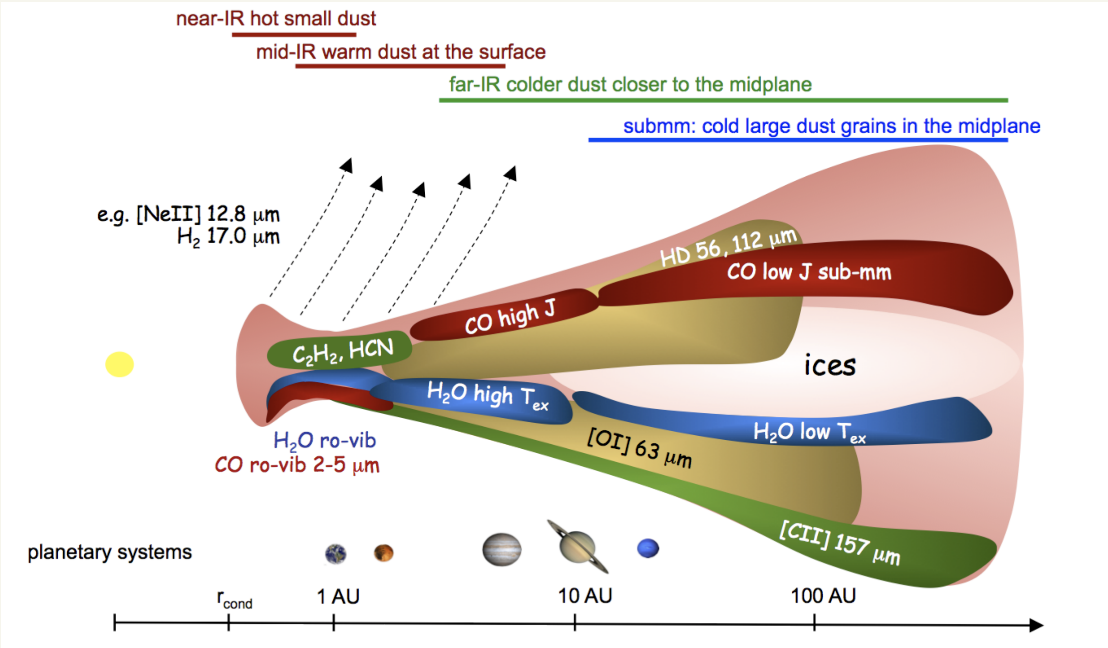

Figure 1: Illustrative picture of different wavelength tracing different parts of the disk. (extracted from Kamp et al. (2018))

In the specific example considering Near Infrared we consider for example scattered light, this imply that we are tracing areas of the disk that are more exposed to the light of the central core/star (or the environment where they are embedded) in the other hand mm wavelength traces much lower temperatures it means that we are looking at part of the disk that must be protected from external radiation, regrading the wavelength that we measure we will be able to trace different materials that are within the disk, the figure (1) is very illustrative in this regard (also in slide number 48 Professor Claudio show us a real measure in different wavelengths).

2.- Matias Gomez

a) Following the discussions during the lecture, what kind of information can be obtained from GC spectroscopy?
Mention at least two of them, one for low signal-to-noise spectra, and one for moderate/ high S/N.
What science goal can be addressed in each case?

b) Does the GCLF depend on global parameters of the host galaxies? If so, how?

a) We can obtain a lot of information from spectra, for instance in low SNR we can obtain the radial velocities which will help us to determine where the GC belongs (certain galaxy for example), also a couple of years ago the so called "Lick indices" were used to estimate some properties considering ratios between them.
On the other hand high SNR allow to measure dispersion velocities σ and abundances (equivalent widths) these information could be contrasted with theoretical models to infer properties such age of the system (even if the professor discussed that there's degeneracy between the models due the different process that affect the lines are not directly dependant of just one physical condition, like the age)

b) Yes, there's at least one parameter that depends on the parent galaxy , this is the luminosity and the behaviour is with respect to the σ of the GCLF is tighly constraing for very bright galaxies while for the fainter ones there's a large spread in the values found as can be seen in fig (2)

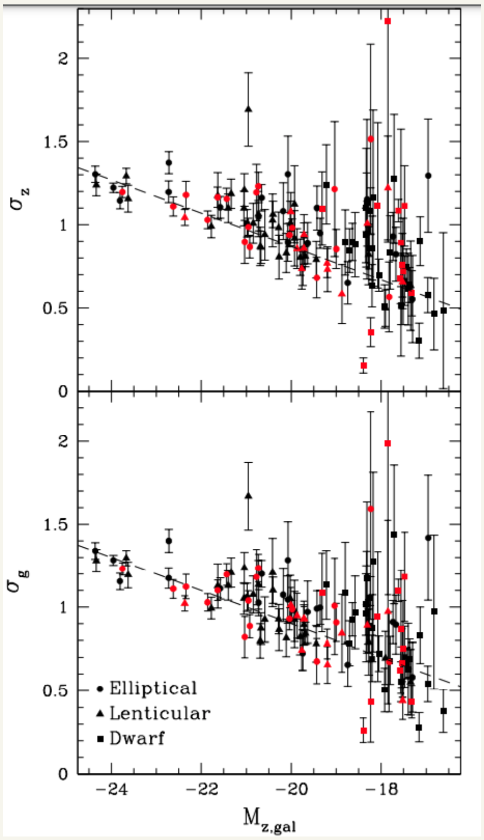

Figure 2: The relation between the σ_{GCLF} and the Luminosity of the host galaxy. (figure taken from Villegas et al. (2010))

3.- Julie Nantais

a) Why are galaxies with recent star formation blue in rest-frame optical color and passive galaxies red? Please be specific in answering, with regard to stellar astrophysics.

b) Name two ways a galaxy can remain actively star-forming for an extended period of time.

c) Describe at least one way a massive spiral galaxy can stop forming stars independent of its environment, and one way that depends on being in an intermediate- to high-density environment (group or cluster).

a) Regarding just to stellar astrophysics this is simply due that the most abundant blue bright stars are massive, this means that they live for a very short period, due this fact the passive galaxies are depleted of these kind of stars since they have experienced their star formation long ago hence there's been time enough to let all the massive blue stars already die, leaving just the less massive stars that evolves slowly in comparison and they are red.

b) This is highly dependant on the environment and the evolution of the galaxy, one way to maintain a galaxy forming stars is that the galaxy is constantly accreting cold gas from their surroundings via direct cold gas of the intergalactic medium or by cannibalism of other galaxies with cold gas.

Another way to keep the star formation for a while would be that the galaxy (if is not in an environment that is making it running out of gas, e.g entering into dense part of a galaxy cluster) could recycle the gas from the remnants of the other stars (warm gas ejected from Super nova or planetary nebulae from AGB stars, etc.)

c) Spiral galaxy can stop their star formation without external intervention through negative feedback, in the last item I mention that SN inject material that can be used to produce new stars but if the SN are too much or very frequently (for example during a starburst event) it will heat and remove the gas of the galaxy. Another internal feedback that could stop the star formation would AGN feedback again heating and ejecting gas from the galaxy.

On the other hand there are several process that can stop he star formation that depends on the environment, Ram pressure stripping in regions of high density in the clusters of galaxies which makes the gas being pushed from the galaxy (jelly fish galaxies). In more moderate neighbourhoods like in groups merger events could generate that the star formation get stopped.

4.- Lorenzo Monaco

Describe how "objective prism surveys" were used as instruments to discover metal-poor stars between the 80s and 90s.
In particular, indicate the hypotheses on which these surveys are based and the facilities used to carry out this type of search.

In the context of look for very metal poor stars in the most efficient possible way the *"objective prism surveys"* emerged in the 80's-90's using relatively small telescopes with a wide area of coverage (order of degrees) they make the light go through this objective prism which generates a low resolution spectra for each source in the field of view as can be seen in fig(3). The spectra was centered at HK calcium lines since they are the most prominent lines in the optical and we can expect that should be correlated with the overall metallicity, as more metal poor the star less strength appear in the lines. One caveat to these approach initially was that at that time they don't have information about the color of the stars and there's degeneracy due the surface temperature of the stars, in the 90's with Hamburg ESO they got the color information directly form the spectra.

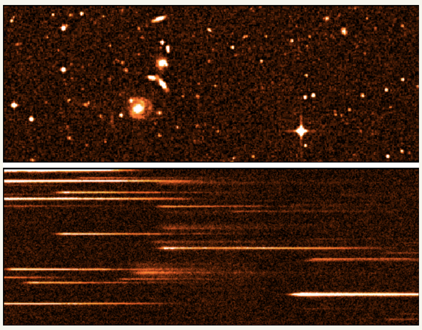

Figure 3: Hamburg ESO objective prism image. (figure taken from Reimers and Wisotzki (1997))

5.- Lucia Guaita

How could we detect Lya emission at high-z and what can tell us about the galaxy environment?

We can employ several techniques to study Lyα emission, including combinations of broad and narrow-band photometry filters. Ultra-deep observations have been conducted with the Hubble Space Telescope (HST), employing spectroscopy and Integrated Field Unit measures (spectra per pixel). Particularly for redshifts around 3, detection can be achieved using ground-based telescopes.

In the case of resolved galaxies, valuable information about the extent of the gas surrounding the galaxy can be obtained by comparing it with UV emission, as Lyα is scattered by neutral hydrogen.

At higher redshifts, spectroscopy allows us to model the complex behavior and asymmetries in the line, providing insights into the immediate surroundings of the galaxy. This includes details about the amount of dust, gas distribution, dynamics, and galactic winds. Additionally, through Lyα forest analysis, we can retrieve information about the material in the line of sight.

6.- Isabelle Gavignaud

Reverberation mapping.
This problem deals with the broad line emission region observed in type 1 AGN.
Figure (4) represents the central AGN light source, an accretion disk with small size in comparison to the distance r where the ionized gas clouds responsible for emitting the light for the broad emission lines, that is considered a point light source.
When a light flash is emitted by the accretion disk, the cloud ring at a distance r is ionized by the flash after a time $t = r/c$. The recombination time of the gas is quasi instantaneous.
a) Write down the delay τ between the light flash emitted by the accretion disk and the light flash re-emitted by the ionized gas as function of the angle θ as seen by an observer.
b) Using that find the function $r(\tau, \theta)$ for a surface of isodelay τ (surface by which the delay time is τ).

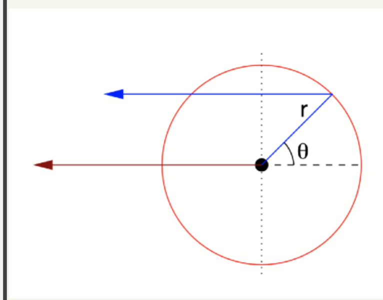

Figure 4: schematic representation of the time delay

a) Lets establish that the time from a light ray that comes directly toward us (red) is given by $\tau_1 = T_0 + \frac{r}{c}$ where T_0 is the time that the light take to travel from the edge of the disk to the observer and $\frac{r}{c}$ is the time that takes the light to travel from the center to the edge of the disk.

Now the time that it takes for the light that is being reflected from the back part of the disk (blue) is given by $\tau_2 = T_0 + 2\frac{r}{c} + \frac{r}{c}\cos(\theta)$ (in this case we have 2 times that the light have to travel the distance from the center to the edge once when is emitted and another when pass at a parallel line from the red line, the component of cosine is due the projection of the line after being reflected and before to reach the middle distance (dotted line)).

Finally the time delay comes from $\Delta\tau = |\tau_1\text{-}\tau_2| = (1+\cos(\theta))\frac{r}{c}$

b) To get the isodelay we simply do $r = \frac{c \cdot \Delta\tau}{1+\cos(\theta)}$ ploted some curves in fig (5)

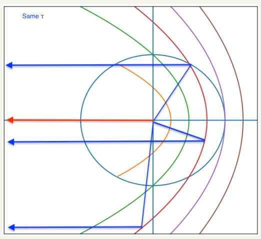

Figure 5: Isodelays

7.- Bruno Dias

Explain how and when did the Magellanic Bridge form, how many substructures it has, and describe its contents of gas, star and star clusters.

It is believed that the Magellanic Bridge was formed 150 Myr ago during a close encounter (7 kpc) between the Large Magellanic Cloud (LMC) and the Small Magellanic Cloud (SMC), as predicted by simulations. However, it is not entirely clear if this is accurate, as at least three branches of the bridge have been identified.

One branch, which is considered young, contains clusters no older than the assumed age of the bridge. The main population of stars has similar ages and this branch also matches the distribution of the stream of neutral hydrogen. On the other hand, the remaining two branches are associated with older populations. One branch was identified through RR-Lyrae stars, and the other was identified from red clump stars. Surprisingly, these two branches are entirely separate from each other.

By studying the clusters in different areas connected with the SMC, has been discovered that each branch exhibits a unique chemical pattern. These pattern could be associated with the injection of pristine gas at different epochs (e.g. Oliveira et al. (2023)).

8.- Laurent Chemin

Explain how the Gaia Collaboration has estimated the corotation radius of the stellar bar of the Milky Way from data of the 3rd Gaia Data Release, and how the corresponding bar pattern speed of the bar, as well as the location of the Outer Lindblad resonance, have been inferred.

Thanks to Gaia we are able to get 6D coordinates of the stars. By convert the coordinate system with respect to the cylindrical coordinates of the galaxy they were able to see a clear Quadrupole pattern at low radius from the center in the V_r component, this patter is well known from numerical simulations that comes from interaction of the bar, then with this information they made a simplified approximation (through a Fourier decomposition up two the second term, Gaia (2023)) getting

$$V_{x,mod}(R,\phi) = \bar{V}_x(R) + A_x(R)\cos\left(2(\phi - \phi_x(R))\right) \tag{8.1}$$

for the V_r and for V_ϕ, this trace the amplitude (A_x) of the bisymmetry and the angle (ϕ_x) of perturbation , they noticed from the simulation that the ϕ_r and ϕ_ϕ are linked to the direction of the bar perturbation ($\phi_{b,x}$) and also that when this $\phi_{b,x}$ reach its minimum that's the corotation radius, by analogy then they were able to determine the angle of the milky way bar and when measure where the parameter $\phi_{b,x}$ reach its minimum getting in this way the *corotation radius*.

By definition the corotation radius is the point when the frequency of rotation is the same that the bar, and since the frequency of rotation can be directly derived they were able to get the velocity of the bar just by match the point where the corotation is taking place with the respective frequency measures at that point, also from getting this value they can obtain the Outer Lindblad resonance considering the epicyclic frequency and again simply matching where the frequency that match the observable you can retrieve at which point this would occur, and fascinatingly this match a pattern in outer part of the disk (this could also be due the arms but still is completely possible to be due this effect).

9.- Maria Celeste Artale

a) What is the condition needed for a system to be considered as 'collisionless' (i.e., in terms of the relaxed time)? Give examples of systems that can be considered collisionless and non-collisionless
b) Why do we need subgrid physics in hydrodynamical cosmological simulations? Give at least two examples

a) The condition needed to be able of consider a system collisionless is that the time of relaxation must be less than the Hubble time (in strict rigor should be significantly less than the time scale that we want to test/run the simulation). Globular Clusters can not be considered as collisionless systems in cosmological simulations since they relaxation time is very short in compared to the Hubble time, on the other hand stars in Galaxies can be considered as collisionless due the inverse behaviour.

b) Subgrid physics is required to account for relevant processes too small to be handled by simulating the interaction between adjacent points. Processes that are not account with the solution of the equations of gravity and/or hydrodynamics in order to get relevant information of physical properties that would be happening in unresolved scales that not just contains relevant information of the evolution (that it is what we want to retrieve) but could affect the evolution itself of the simulation. To consider Gas cooling , Star formation, stellar and AGN feedback, conditions in the ISM, etc., all of these are treated through Subgrid physics

10.- Keiichi Ohnaka

a) What is the order of the angular resolution required to resolve the surface of stars other than the Sun?
b) Explain the principle of astronomical interferometry — what the observable directly measured is and how images are obtained.

a) This depends on the solid angle that covers the star in the sky, for now we are able to see just near Red Giants that cover the order of 30-40 mili-arcseconds (mas) so in order to resolve a star other than the sun we need less than that. e.g. VLT (8 meters telescope) has 17mas as the diffraction limit at 550nm, so considering current capabilities I would say that the order of 20mas is the required to resolve other stars.

b) In interferometry what we are measuring are the visibility's (or fringes), which is the interference pattern that produces the light when it pass by different slits (in this case telescopes) as in the double slit experiment of Young.

These values are the complex Fourier transform of the object hence in order to recover the image we have to apply the inverse Fourier transform to the information of amplitude and phase measured in order to recover the image.

The problem with these is that to recreate the true image we need to get access to the whole plane and this is not the case, so could exits a certain degeneracy between models that are able to reproduce the visibility's.

11.- Juan Carlos Beamin

a) Brown dwarfs populate a particular low luminosity region in the color magnitude diagram (CMD), from black body radiation we expect that objects get redder as they cool down? Explain why T dwarfs become bluer than L dwarfs in the Near IR CMD.
b) Briefly describe two mechanisms of brown dwarf formation.
c) Age, mass, luminosity degeneracy in brown dwarfs is one of the key problems to better understand Brown dwarfs. Explain why this degeneracy happens.

a) This behaviour is due the extreme absorption lines of molecules that are more prominent in the redder part of the infrared spectra, hence at the time of compare through filter we measure more flux in the blue part. In the class in specific was mentioned the absorption of methane

b) These objects could be form by ejection of an embryo in a multiple system, also has been proposed that their formation could be similar to the planets by instabilities within a disk, but seem to be more likely an scenario of turbulent fragmentation of the molecular cloud, but this still under study.

c) Accordingly to the study of Burrows et al. (2001) the problem is that the stars share properties at different stages of they life and since it's hard to retrieve precise information from these objects since due that they are so faint and have properties that difficult the distinction between them (extreme absorption, similar radius since they are supported by electron degeneracy instead of the radiation pressure, etc)

12.- Roberto Saito

A fundamental problem in astrophysics is the determination of distances, such as for stars, galaxies, etc. It was only with Edwin Hubble in 1923, when he determined the distance of the so-called spiral nebulae, that Humanity realized the scale of the Universe.
a) Which stars can be used as distance indicators within the Milky Way and what kind of information can we obtain from their spatial distribution?
b) How can one collect a large number of those distance indicators even in the highly obscured regions of the Milky Way?

a) Depending of the distance we can consider different stars , for example at very short distances we can simply use parallax so there's no need for any special kind of star (more than being able to see it), for further distance whe parallax is not possible there's a few ways of get distance information, from RR-Lyrae stars or other kind of variables (LPVs, δ Scutis, Cepheids, etc.), we can use stellar associations (Clusters) and contrast with theoretical models and we can use red clump stars (but we must consider reddening effects specially for the two last methods mentioned). Targeting different kind of stars (associated with different populations) will trace different structures, from this we can model our galaxy.

b) Through the use of infrared measurements (surveys) we can obtain reliable information of photometry and the variations of these measures, considering extinction maps, windows of low extinction also are we can use the red clump stars (if you have enough data you can fit the own extinction law to correct the known distribution).

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