Astronomy 74: Astrophysics
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Dartmouth College

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Paper discussion: Galaxies discovered through the SZ Effect

In this assignment, you will read a scientific paper and prepare a short review. The goal of this assignment is for you to see some of the radiative transfer concepts from class in action. In class, we will review the paper together in your discussion groups following the worksheet format. Following the discussion, each of you will write a short (3 paragraph, 1/2-3/4 of a page single spaced) summary of the article, including a description of the relevant radiative transfer and the key findings. Upload a pdf to Canvas. The target audience for this summary is you and your classmates prior to taking this course, which means, for example, that you should define any words that could be considered "jargon." Please be attentive to presenting the material clearly.

- The Atamaca Cosmology Telescope: Sunyaev-Zel'dovich-selected galaxy clusters at 148 GHz in the 2008 survey:
  `https://iopscience.iop.org/article/10.1088/0004-637X/737/2/61`

One of the galaxy clusters this study discovers, ACT-CL J0102−4915, is a very massive cluster, which was nicknamed "El Gordo" in the subsequent study of its x-ray properties. In the current paper, the authors compare El Gordo to the Bullet Cluster, a famous cluster that is also detected in this study through its SZ effect (labeled ACT-CL J0658−5557 at times in the paper).

If you're not familiar with the Bullet cluster, what a great day to learn about something cool! The Bullet cluster is actually two galaxy clusters colliding (see e.g. `https://astrobites.org/2016/11/04/the-bullet-cluster-a-smoking-gun-for-dark-matter/`). It's also a piece of evidence in favor of the existence of cold dark matter: by separately tracing the luminous matter and the total matter, you can see that dark matter must be present and must not have strong interactions. These studies get bonus points because part of the tracing of luminous matter is using brehmsstrahlung. The Bullet Cluster has been studied extensively, and El Gordo is starting to be as well.

Your summary is due on **Wednesday November 9 at 5pm** via Canvas. Your summary will be graded on three areas (10 points total):

- Scientific scope: did the summary cover the key areas of the article, without unnecessary detail? (3 points)
- Radiative transfer scope: did the summary cover the key radiative transfer concepts underpinning the research? The discussion questions can help guide. (3 points)
- Accuracy: was the summary factually accurate? (2 points)

- Clarity: was the summary coherent and understandable to the target audience? (2 points)

For Wednesday, November 2: Read the above articles (you won't understand everything!) before class. When you are reading the articles, consider the following questions:

- What motivated this study? What were the key discoveries?
- On what physics is this study based? Where and how do radiative transfer concepts get used?
- What questions did this paper bring up for you? What things didn't you understand? How would you go about answering them?

Questions for in class. These questions have a mix of goals: to zero-in on what I thought were key parts of the paper, to connect back to broader astrophysics context (e.g. A15/A25 material), and to highlight the specific radiative transfer connections.

- Why is it useful to study distant galaxy clusters?
- The SZ effect can be studied in galaxy clusters we already know to exist, or used to find new galaxies. When were the first discoveries of each of these types?
- Observations
  - What was the telescope used to make these observations? Where is it?
  - What were the type and wavelength/frequency of the observations used?
  - A matched filter is a method for detecting anomalies when you know what the shape of the anomaly should be. For example, if you have a image with lots of noise but you know there's a cat picture hidden in it, you could scan across your image with a template cat image and look for the place where the signal best matches your cat template. Why is the SZ effect a good application of a matched filter?
  - Part of their matched filter is a model of the cluster density profile, which they choose as a specific model called a β model (this is also the one used in the lecture notes to arrive at the final equation for the optical depth). It's not really important for understanding the bigger picture of this paper, but you'll see it in the final computational worksheet!
- Out of the 23 clusters they detect using their matched filter, how many are new detections and how many are detections of previously known clusters?
- Measurements
  - What are the SZ temperature decrements for ACT-CL J0102−4915 ("El Gordo") and the Bullet Cluster?
  - What's the equation that relates the Compton y parameter to the temperature decrement (there's one in the paper that we also had, and then the simpler version we end up with in the notes for the case $x << 1$).
  - What's the equation that relates the Compton y parameter to physical properties of the galaxy cluster?
- In §5 they investigate whether there's a correlation between the size of the SZ effect and the mass of the cluster. Fig. 7 shows that they do find a correlation. What is the meaning of the dashed and solid lines shown in the diagram?