Astronomy 74: Astrophysics
Fall 2024
Dartmouth College

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Paper discussion: Polarimetry of Cygnus X-1

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.

- Peering into the tilted heart of Cyg X-1 with high-precision optical polarimetry: `https://www.aanda.org/articles/aa/full_html/2023/10/aa46932-23/aa46932-23.html`

This paper focuses on Cyg X-1, the prototype of a class of objects called an x-ray binary, where there is a donor star and a compact remnant that accretes from the donor star. In this case, the donor is a blue supergiant of about 40 solar masses and the donor a 20 solar mass black hole; because the donor is a massive star, this is a *high mass X-ray binary.* The

Roche lobe defines the space in which material is gravitationally bound to an object. In the case of a binary star, it is tear-drop shaped. Because giant stars have such extended outer layers, material from the giant star can extend out to the Roche lobe. In an X-ray binary, that material can be funneled on to the compact object through the tip of the teardrop.

Your summary is due on **Wednesday October 25 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, October 18: 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?

Please don't spend too much time on Section 4!

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.

- This study is at optical wavelengths. In a high-mass X-ray binary, what is the origin of optical light? Why would this be different for a low-mass X-ray binary?
- What part of Cyg X-1 do optical polarization measurements probe?
- Observations
  - How were they able to achieve continuous observational coverage of Cyg X-1?
  - They measure "PD" and "PA" – what do these abbreviations stand for?
  - Which Stokes parameters do they measure?
  - There are three contributors to the polarization measurement. The smallest is the polarization from the instrument itself at $< 10^{-4}$; the polarization from Cyg X-1 is the middle; and the largest is interstellar. How do they correct for interstellar polarization?
  - With a quick google search, what is the origin of interstellar polarization? Which figure could you use to infer the orientation of the Galactic magnetic field towards Cyg X-1?
- Results
  - Describe the variability they see in the polarization degree and angle. Which figure(s) show this?
  - How large is the photometric variability (which we assume is unpolarized) from TESS? Why do they argue that the variation in the polarization degree can't be caused simply by the total amount of unpolarized light changing?
  - What process produces the polarized light?
  - What is the simplest model they consider? Under this model, how do the Stokes parameters behave?
  - The observed polarization variability is not purely a sinusoid. What do they say can be added to the model to produce non-sinusoidal effects?
  - Without trying to understand the details, what are the models presented §4.1, §4.2, and §4.3? Which one do they think is most likely?