Writing with Purpose

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The Basic Idea

Writing a journal article, a proposal, a response to a referee, a research statement for a job application—what do these have in common?

1. Know the audience

2. Have clearly identified goals

3. Bring the reader along with you

Proposal | Goals

1. Why is the proposed research exciting?
2. How is the proposed research relevant, beyond its immediate objectives?
3. What is the feasibility of the proposed research?

Your writing must be clear and concise. Suppose the chair of the panel has to represent your proposal in a meeting with other panel chairs. Will she be able to quickly extract relevant details from your proposal?

Proposal | Audience

Who is **not** reviewing your proposal? Close collaborators who know your work inside and out, and with whom you could talk for hours about the details.

The panel is constructed of scientists (could be postdocs!) working in the same **broad** area. There will possibly be 1–2 people who are generally familiar with the *specific* topic of your proposal, and the program officer may have your proposal reviewed by a couple people with deep knowledge of your research topic.

Will these individuals all read your proposal in the same way?

1 Objectives and Expected Significance

Neutron stars are the unique natural laboratory to study quantum chromodynamics (QCD) at finite density and low temperature. Our understanding of the densest matter in the observable universe has been driven by X-ray observatories such as *RXTE*, *Chandra*, and *XMM*, γ-ray satellites such as *Integral* and *Swift*, proposed instruments such as the *International X-ray Observatory*, and the promise of gravitational wave detectors such as *LIGO*. To quote the 2010 Decadal Survey [1] *New Worlds, New Horizons in Astronomy and Astrophysics*: "Measuring neutron star masses and radii yields direct information about the interior composition [of neutron stars] that can be compared with theoretical predictions." In the past few years, a number of recent observational, theoretical, and experimental developments have led to a new understanding of, and new questions about, the internal constitution of neutron stars. Of especial interest are the following.

1) The short crust cooling timescale of quasi-persistent transients [2, 3, and references therein] suggest that the neutron star crust has a high thermal conductivity [4, 5] and is relatively cold. This is potentially at odds with observations of long X-ray bursts [6, 7, 8].
2) Measurements of the Eddington limiting flux and the flux normalization from bursting neutron stars with well-measured distances have been used to construct a mass-radius relations for neutron stars [9, 10, 11, 12].
3) The recent discovery of a two solar mass neutron star [13], which has strong implications for the presence of exotic matter [14].
4) Ongoing and planned experimental and theoretical efforts in nuclear physics [for a brief overview, see 15, and references therein] such as the lead radius experiment (PREx) at Jefferson Lab, are leading to better constraints on the equation of state (EOS) of neutron-proton symmetric nuclear matter at densities 0.4–4 ρ_0, where $\rho_0 \approx 3 \times 10^{14}$ g cm^{-3} is the nuclear saturation density (the density of matter within a nucleus).

These efforts depend on the EOS and transport properties of matter over a range of densities, from sub-nuclear to several times saturation, and from nearly symmetric (roughly equal neutron and proton abundances) to nearly pure neutron matter. Our proposed work advances the frontier of neutron star physics by combining observational constraints on the neutron star mechanical structure (masses and radii) and observational constraints on the neutron star thermal structure (interior temperatures and cooling timescales) to form a new picture of neutron star structure and the EOS of dense matter. Along the way, this work will address what surface phenomena (X-ray bursts, superbursts, and cooling transients) imply about the physics of nuclear matter.

- What is the nature of matter at several times nuclear density? Is there a transition to an exotic phase of matter in the cores of some neutron stars?
- What is the nature of matter at at sub-saturation densities? Does the composition depend on the accretion history of the source?

It is essential that these two questions are tackled in concert. The EOS at super-nuclear densities dictates the mass and radius, and hence the surface gravity and crust thickness, as well as the efficiency of cooling via neutrinos. Both of these affect the temperature in the neutron star crust. The observations of crustal cooling, in addition to constraining matter at sub-saturation densities, also offer a complementary constraint on matter at higher densities.

Combining laboratory experiments and astronomical observations to determine the cold EOS for bulk nuclear matter from sub- to super-nuclear densities is an exciting possibility within a few years. This proposal describes a directed theoretical effort towards this goal.

Broad contextual statement

What are recent discoveries/puzzles that motivate this work?

What are we proposing to do? What questions are we addressing?

The journal article

Quoting Thorne, K.S. (1987) *Some Specific Tips about Technical Writing*—

- The title is read by a huge audience.
- The abstract is read by a large audience.
- The introduction will be read by a moderately a large audience.
- The figures will be glanced at and often studied by an audience nearly as large as read the abstract.
- The body of the article is directed at…the specialists.

What are your goals for each section? How does this inform your tone?

Responding to referees

The referee is not paid to exhaustively examine your paper word-by-word; to fix your sloppy, imprecise writing; or to suggest improvements to your presentation. The referee is not a gatekeeper, jealously guarding the honor of the journal. The referee is a colleague responding to a request, probably coming at an inconvenient time, to evaluate your paper on a short deadline without compensation.

The referee is probably representative, however, of your audience. If the referee misunderstands or mischaracterizes your paper, how will it be received at a journal club?

Responding to referees

1. Keep it professional. Keep it collegial.

2. Focus on what you changed in the manuscript in response to the referee's comments. For example, if you are writing a long explanation to the referee on how Fig. 2 should be interpreted—well, maybe that should go in the paper.

sample responses

“Increasing the accretion rate in our models would not bring our models into agreement with the results of ******* (and we demonstrate this in section 3.2, because the accretion rate (or deep heating rate) is allowed to increase well above the values assumed in section 2).

“The reason is that we require an inverted temperature gradient in the outer crust to match the observed lightcurves at early times. We have added a curve to Fig. 7 to demonstrate this point. We increased the outburst accretion rate to 3.5e17 g/s, so that the heating in the inner crust was comparable to that used by ********. There remains a discrepancy at early times (the first observation). This is evident in *****’s figures as well, but note they are using substantially larger error bars, which tends to mask this discrepancy.

“We have reworded the paragraph in the conclusions where we compare our findings with ******* to reflect the update to Fig. 7.”

sample responses

“We thank the referee for this discussion. We have restructured the argument in that paragraph to incorporate the points suggested by the referee, and have split the paragraph into two parts: the first addresses the onset of direct Urca (see the point raised below) and the second addresses the possibility of a pion condensate.”

“This is absolutely true, and thermal emission will not produce such a power law tail. However, the presence of thermal emission does not preclude another mechanism from producing such a hard luminosity. We have added a paragraph (end of section 3.1) discussing this tail, and its possible origin.”

“The referee is correct that there are additional uncertainties, for example within the direct Urca rate and the equation of state; these require more detailed calculations outside the scope of this letter. We will present this in a forthcoming paper.”

Summary and discussion points

Common themes in technical writing

1. Have clearly identified, specific goals

2. Know the audience

You are bringing the reader along on a journey. Be a good tour guide. Write clearly.

Summary and discussion points

How can you improve your writing?

1. Ask colleagues for copies of their successful proposals/research statements
2. Have your proposal/research statement/article reviewed by colleagues well in advance of submission
3. Serve on a review panel