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BERKELEY, CALIFORNIA 94720

October 17, 1997

Howard A. Smith
Code SR
Astrophysics Division
National Aeronautics and Space Administration
Washington, DC 20546–0001

Dear Dr. Smith:

This letter is my progress report for the Astrophysics Theory grant "Physics of Rotation Powered Pulsars and Their Nebulae" (NASA NAG5-3073), for which I am Principal Investigator. The first goal of the research supported by this grant is to produce a time dependent theory of the unsteady relativistic collisionless shock wave terminating the relativistic wind from a pulsar, and compare the predicted surface brightness fluctuations to Hubble Space Telescope observations of the wisps in the Crab Nebula. The second goal is to model the production of electron-positron pairs over the polar caps of rotation powered pulsars, and use the results to predict the heating of the surface due to particle trapping and bombardment of the atmosphere at the base of the polar field lines.

Arons and graduate student Anatoly Spitkovsky have succeeded in creating a one dimensional hybrid code, in which the electron-positron pairs incident on the shock structure are modeled as a relativistic, adiabatic, ideal MHD fluid, while the heavy ions are treated as particles using a particle-in-cell algorithm. The electromagnetic fields are evaluated from the currents and charge densities in the pairs and the ions, while the particles and the fluid accelerate in response to the computed self-consistent electromagnetic fields. The results are promising, in that the underlying ion cyclotron instability generates finite amplitude, *propagating* magnetosonic waves in the pairs, whose wavelengths and frequencies, when translated into physical units, are comparable to the observed running waves of brightness observed by HST near the Crab pulsar. The code is undergoing a number of tests, to assure us that this preliminary correspondence is not an artifact. In the coming year, the observational appearance of the models will be computed and compared to the HST observations of th Crab now in hand, and used to predict the HST results which will be obtained the year after next.

Arons and graduate student Johann Hibschman have developed a one dimensional cascade theory for pair creation over pulsars' polar caps. A linear integral equation describing the synchrotron cascade has been derived and solved by iterative techniques, in the case when a high energy electron moving parallel to a star centered dipole magnetic

field initiates the cascade through curvature gamma ray emission. The results have been favorably compared to Harding's Monte Carlo calculations of some years ago — in fact, the semi analytic results are better, in the sense that they do a better job on the low energy gamma spectrum ($\varepsilon < 10$ MeV) that is observed by Comptel and will be studied by Integral than the Monte Carlo calculations can do. The pair distribution functions calculated show the interesting and important result of having a very steep rise to a lower peak momentum $\sim$ 20 MeV/c, with power law behavior at higher energies. The calculations are being extended to study the emergent gamma ray spectrum and the pair outflow distributions, when the initiating high energy electron radiates gamma rays by inverse Compton scattering of the thermal photons coming from the stellar surface. Once these calculations are complete, the results will be applied to calculations of particle trapping and polar cap heating, in preparation for upcoming AXAF observations of rotation powered pulsars.

Publications so far are of related research completed with previous NASA support. For the record, the publication list is as follows.

J. Arons, 1996, "Pulsars as Gamma Ray Sources: Nebular Shocks and Magnetospheric Gaps," *Space Science Reviews*, **75**, 235–255

R.I. Klein, J. Arons, G. Jernigan and J.J.-L. Hsu, 1996, "Photon Bubble Oscillations in X-Ray Pulsars", *Astrophys. J. (Letters)*, **457**, L85–89

R.I. Klein, J. G. Jernigan and J. Arons, 1996, "GRO J1744–28 and Sco X-1: First Evidence for Photon Bubble Oscillations and Turbulence", *Astrophys. J. (Letters)*, **469**, L119–123

J. Arons, 1996, "Pulsars as Gamma Ray Sources", *Astronomy and Astrophysics (Supplement)*, **120**, 49–60 (C49–C60)

M. Tavani, J.E. Grove, W. Purcell, W. Hermsen, L. Kuiper, P. Kaaret, E. Ford, R.B. Wilson, M. Finger, B.A. Harmon, S.N. Zhang, J. Mattox, D. Thompson and J. Arons, 1996, "High Energy Emission from the PSR B1259–63 System near Periastron", *Astronomy and Astrophysics (Supplement)*, **120**, 221–226 (C221–C226)

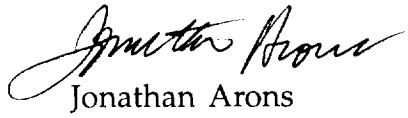
J. Arons, 1996, "Pulsar Winds", in *Proc. IAU Colloq. 160— Pulsars: Progress and Problems*, M. Bailes, S. Johnston and M. Walker, eds. (San Francisco: Astronomical Society of the Pacific), 401–408

M. Hirayama, F. Nagase, M. Tavani, V.M. Kaspi, N. Kawai and J. Arons, 1996, "Post-Periastron ASCA Observation of the PSR B1259–63 System", *Publ. Astron. Soc. Japan*, **48**, 833–840

M. Tavani and J. Arons, 1997, "Theory of High-Energy Emission from the Pulsar/Be Star System PSR 1259–63. I. Radiation Mechanisms and Interaction Geometry", *Astrophys. J.*, **477**, 439–464

J.J.-L. Hsu, J. Arons and R.I. Klein, 1997,"Numerical Studies of the Photon Bubble Instability in a Magnetized, Radiation Dominated Atmosphere", *Astrophys. J.*, **478**, 643–677

Sincerely yours,



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