November 18, 2012

Dear Colleague,

It is my pleasure to send this letter in support of Shashank Shalgar's application for a postdoctoral position in your group. Shashank is a graduate student at Northwestern University and I am his thesis advisor. Shashank will defend his thesis in the Spring quarter and graduate before the start of the Summer of 2013.

I am quite familiar with his abilities as a student, having had him in one of my classes, and as a researcher. As a student, Shashank has always performed very well. He has a solid grasp of physics in general, and particle physics in particular. I can state that his understanding of particle physics and related topics is at least equivalent to what is expected from a senior theoretical particle physics student at any top US University.

I have had the opportunity to work with Shashank on several research projects, some of which I will describe in more detail in order to illustrate Shashank's abilities as a researcher. As a graduate student at Northwestern, Shashank has also written a research paper with Ian Low, and Ian will comment on that project in his letter.

Shashank came to Northwestern with a lot experience in neutrino oscillation phenomenology, especially atmospheric neutrinos and simulations of the INO detector, experience that he acquired as a student in the Harish-Chandra Research Institute in India. At Northwestern, he wanted to grow his research efforts in different directions, including collider physics and neutrino astrophysics. Indeed, the first paper he published after arriving in Evanston was on Higgs boson searches at hadron colliders and the MSSM.

The first research paper Shashank and I published, together with Wei-Chih Huang, a more senior graduate student at the time, was related to understanding the couplings between massive Majorana neutrinos and the Standard Model Higgs boson. Our results, which are not very well known but, in my opinion, are very interesting and illuminating, are presented in Phys. Rev. D84 (2011) 035011. This effort was lead by Wei-Chih, but Shashank, along with me, played an important supporting role and, along the way, learned a lot.

Next, Shashank and I teamed up together with Janet Conrad from MIT and Josh Spitz, an experimental graduate student at Yale at the time, and wrote a very nice paper about the capabilities of large liquid argon detectors to identify and measure properties of atmospheric tau neutrinos. Our results are presented in Phys. Rev. D82 (2010) 093012. Shashank was, together with Josh, the main driving force behind the paper while Janet and I played, for the most part, a supporting role. In the pursuit of this project, Shashank demonstrated his very solid grasp of experimental high energy physics tools, including certain aspects of detector simulations. This is one the characteristics that sets Shashank appart: he can understand and interact well with experimentalists of different stripes, a rare and very useful quality for a successful phenomenologist.

For the past twelve months or so, Shashank has been heavily involved in understand-

ing the oscillations of neutrinos deep inside the core of Supernova explosions, especially the recently uncovered, and still only partially understood, neutrino–neutrino induced matter effects that render the phenomenon nonlinear. This was entirely Shashank's decision and was made with only minor input from me (my input was mostly of the "if you are interested in this go ahead, I think it is a very challenging but very rich topic" kind). His performance here has been, to say the least, outstanding. He learned all of the relevant physics and astrophysics – he knows way more than I do about supernovae and supernova neutrinos – and, more importantly, developed, from scratch, his own code to properly compute the oscillations of supernova neutrinos. His first mission was to repeat, with good enough accuracy, the results obtained in the past. He passed this test with flying colors. For those not in the business, this is already nontrivial achievement. There are very few (less than 10) groups worldwide that have numerically computed, under the most simple of circumstances – the oscillation of supernova neutrinos including collective effects.

Shashank and I decided to pursue the effect of neutrino magnetic moments in the collective oscillations of supernova neutrinos (earlier, we considered studying nonstandard neutrino interactions but dropped the idea), concentrating on the hypothesis that neutrinos are Majorana fermions. The results Shashank obtained, published in JCAP 1210 (2012) 027, were new, somewhat unexpected, and very important. We found that nonzero magnetic moments can, just like a nonzero θ_{13}, trigger spectral-splits in the energy spectrum of supernova neutrinos with a well-defined flavor. More important, these effects "turn on" for magnetic moment values close to Standard Model (where we augment the standard model to include nonzero neutrino masses) expectations, some ten orders of magnitude away from current bounds. If our results are correct, we have uncovered the only physics observable capable of "seeing" Standard Model size Majorana neutrino magnetic moments! Our first results were obtained within the so-called single-angle approximation, and assuming there are only two neutrino flavors. These results are now starting to attract the attention of the worldwide community of supernova neutrino experts. We are in the process of concluding a preprint with three-flavor effects, and Shashank and hard at work to include multi-angle effects. I should add that only one or two groups worldwide have managed to compute multi-angle effects reliably and that Shashank will, very soon, join this select group of physicists.

On top of all of this, Shashank also has also had time to develop – and this is 100% his initiative – a very interesting computer software that computes neutrino oscillation probabilities as a function of baseline and energy for different model-parameters. The software is comprehensive but easy to use, and Shashank has been getting good feedback from the particle physics community. I know a couple of people that have used Shashank's software as a teaching tool, and others have taken advantage of it for their research. Shashank is also the person who maintains the valuable linux machines of the theoretical physics group at Northwestern and will be sorely missed when he is gone.

Finally, Shashank is an excellent speaker and is recognized as an outstanding teaching assistant at Northwestern. He has recently given talks at a few conferences that were very well received, and attended TASI a couple of years ago, an experience he enjoyed

very much.

Of all the students with whom I have collaborate since my arrival at Northwestern, Shashank is the most independent and entrepreneurial. He is by far the most unique and potentially valuable one. If you are looking for someone to work on supernova neutrinos, Shashank is, by far, the best candidate out there. Furthermore, he is easily in the top 10% if you are looking for someone to work on neutrino oscillation phenomenology, or someone who understands, and can interact with, experimentalists, or someone who can attack successfully complicated numerical problems.

Since I arrived at Northwestern, nine students have or will have graduated by the end of this academic year (including Shashank and another graduate students we anticipate will graduate this Spring). Shashank is clearly in the top three, especially when one considers his technical ability and his ability to work independently. The number four on that list is James Jenkins, who graduated several years ago and got a postdoc position at Los Alamos, where he currently holds a permanent position (outside of particle physics).

I am sure Shashank will be an outstanding postdoctoral fellow anywhere that is fortunate to attract him. I give him my highest recommendation. Please feel free to contact me for more information!

Sincerely,

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