Aravind Natarajan

Carnegie Mellon University,
Department of Physics, Wean Hall #7415,
5000 Forbes Avenue, Pittsburgh PA 15213

Born: Sep 27, 1978
Email: anat@andrew.cmu.edu
Phone: 412-352-9178

Education

- Ph.D (Physics) 2007, University of Florida, Gainesville
  Thesis supervisor: Pierre Sikivie.
  Thesis title: Inner caustics of cold dark matter halos.

- Master of Science (Physics) 2004, University of Florida, Gainesville
- Bachelor of Engineering (Electronics and Communication) 2000, Bangalore University, India

Academic positions

- McWilliams Postdoctoral Research Associate, Carnegie Mellon University, Sep 2009 - present.
- Postdoctoral Fellow, Bielefeld University (Germany), Oct 2007 - Aug 2009
- Graduate Assistant, University of Florida, Aug 2002 - Aug 2007

Awards and Fellowships

- *McWilliams Postdoctoral Fellowship Award*
  Carnegie Mellon University Center for Cosmology, 2009

- *Chuck Hooper Memorial Award for Distinction in Research and Teaching*
  Department of Physics, University of Florida, 2006

- *Award for Outstanding Academic Achievement by an International Student*
  University of Florida International Center, 2006

- *J. Michael Harris Fellowship Award*
  Department of Physics, University of Florida, 2005

Scientific Grants Applied:

- "Understanding the Nature of Dark Matter Using Astrophysical, Cosmological and Collider Data."
  Proposal #11-ATP11-0038
  Currently in review. *Submitted to NASA Astrophysics Theory Program, on June 1, 2011.*
  I am a Co-Investigator on the grant. Principal Investigator is Prof. Vladimir Savinov (University of Pittsburgh)

- "Understanding Cosmic Magnetism: Evolution and Signatures of Primordial Magnetic Fields."
  Proposal #11-ATP11-0035
  Currently in review. *Submitted to NASA Astrophysics Theory Program, on June 1, 2011.*
  I am a Co-Investigator on the grant. Principal Investigator is Prof. Tina Kahniashvili. (Carnegie Mellon University).

Research interests:

- **Dark matter detection, cosmology, and theory:**

  Studying the results of dark matter direct detection experiments. Searching for dark matter streams using current and future direct detection searches. Constraining dark matter properties by means of the CMB. Particle accelerator searches for dark matter. Testing supersymmetric theories using data from accelerator, CMB, and direct detection experiments.

  Testing the possibility of WIMP dark matter annihilation influencing the formation of primordial stars. Reionization from supermassive black holes produced by primordial stars, with and without dark matter. Axion dark matter searches and constraining the properties of axion-like particles using the CMB.

- **Intensity mapping of Hydrogen 21 cm radiation:**

  Studying neutral Hydrogen at redshift z=1 using radio telescopes. Cross correlation of Hydrogen 21 cm maps with optical catalogs from galaxy surveys. Studying the evolution of the neutral Hydrogen fraction with redshift. Constraining the neutral Hydrogen fraction and galaxy bias. Studying star and galaxy formation using radio and optical data.

Professional activities:

2011 - present: Member, American Physical Society.

2011 - present: Member, American Astronomical Society.

2011 - present: Seminar organizer for weekly journal club at Carnegie Mellon University.

2011: Referee for the Astrophysical Journal (ApJ)

2009: Co-organizer of the “International Workshop on Cosmic Structure and Evolution” held in Bielefeld, Germany.

2009: Chair of the Editorial Board for the Proceedings of the “International Workshop on Cosmic Structure and Evolution”, published by Proceedings of Science http://pos.sissa.it/cgi-bin/reader/conf.cgi?confid=97

2009: Referee for the Monthly Notices of the Royal Astronomical Society (MNRAS)

2008: Referee for the Journal of Cosmology and Astroparticle Physics (JCAP)

2007: Referee for the Monthly Notices of the Royal Astronomical Society (MNRAS)

References:

1. Pierre Sikivie (Thesis supervisor)
   Professor, Department of Physics, University of Florida,
   Gainesville, FL 32611
   Email: sikivie@phys.ufl.edu Ph: (1-352) 392 1923

2. Dominik Schwarz
   Professor, Fakultät für Physik, Universität Bielefeld,
   Universitätsstraße 25, Bielefeld 33615, Germany
   Email: dschwarz@physik.uni-bielefeld.de Ph: (49-521) 106 6226

3. Jeffrey Peterson
   Professor, Department of Physics, Carnegie Mellon University,
   5000 Forbes Avenue, Pittsburgh PA 15213
   Email: jbp@cmu.edu Ph: (1-412) 268 278

4. Jonathan Tan
   Assistant Professor, Department of Astronomy,
   University of Florida, Gainesville, FL 32611
   Email: jt@astro.ufl.edu Ph: (1-352) 392 2052 x 254

Publications:

14. *"Probing dark matter streams with CoGeNT"*
A. Natarajan, Christopher Savage, Katherine Freese,
http://arxiv.org/abs/1109.0014

We examine the future sensitivity of CoGeNT to the presence of dark matter streams and find that consideration of streams in the data may lead to differences in the interpretation of the results. We show the allowed particle mass and cross section for different halo parameters, assuming spin-independent elastic scattering. As an example, we choose a stream with the same velocity profile as that of the Sagittarius stream (and in the Solar neighborhood) and find that, with an exposure of $\sim$ 10 kg year, the CoGeNT results can be expected to exclude the SHM-only halo in favor of an SHM+stream halo at the 95% (99.7%) confidence level provided the stream contributes 3% (5%) of the local dark matter density. The presence of a significant stream component may result in incorrect estimates of the particle mass and cross section unless the presence of the stream is taken into account. We conclude that the CoGeNT experiment is sensitive to streams and care should be taken to include the possibility of streams when analyzing experimental results.

13. *"Mass varying neutrinos, quintessence, and the accelerating expansion of the Universe"*
G.Y. Chitov, T. August, **A. Natarajan**, and T. Kahniashvili; Physical Review D 83, 045033 (2011)
http://arxiv.org/pdf/0911.1728v3

Abstract: We analyze the mass varying neutrino scenario. We consider a minimal model of massless Dirac fermions coupled to a scalar field, mainly in the framework of finite-temperature quantum field theory. We demonstrate that the mass equation we find has nontrivial solutions only for special classes of potentials, and only within certain temperature intervals. We give most of our results for the Ratra-Peebles dark energy (DE) potential. The thermal (temporal) evolution of the model is analyzed. Following the time arrow, the stable, metastable, and unstable phases are predicted. The model predicts that the present Universe is below its critical temperature and accelerates. At the critical point, the Universe undergoes a first-order phase transition from the (meta)stable oscillatory regime to the unstable rolling regime of the DE field. This conclusion agrees with the original idea of quintessence as a force making the Universe roll towards its true vacuum with a zero Λ term. The present mass varying neutrino scenario is free from the coincidence problem, since both the DE density and the neutrino mass are determined by the scale M of the potential. Choosing $M=10^{-3}$ eV to match the present DE density, we can obtain the present neutrino mass in the range 10^{-2} - 1 eV and consistent estimates for other parameters of the Universe.

12. *"DAMA and the self similar infall halo model"*
A. Natarajan, Physical Review D 83, 043517 (2011)
http://arxiv.org/pdf/1011.3966

Abstract: The annual modulation in the rate of weakly interacting massive particle (WIMP) recoils observed by the DAMA Collaboration at high significance is often analyzed in the context of an isothermal Maxwell-Boltzmann velocity distribution. While this is the simplest model, there is a need to consider other well motivated theories of halo formation. In this paper, we study a different halo model, that of self-similar infall which is characterized by the presence of a number of cold streams and caustics, not seen in simulations. It is shown that the self-similar infall model is consistent with the DAMA result both in amplitude and in phase, for WIMP masses exceeding ≈ 250 GeV at the 99.7% confidence level. Adding a small thermal component makes the parameter space near $m_\chi = 12$ GeV consistent with the self-similar model. The minimum χ^2 per degree of freedom is found to be 0.92(1.03) with(without) channeling taken into account, indicating an acceptable fit. For WIMP masses much greater than the mass of the target nucleus, the recoil rate depends only on the ratio σ_p/m_χ which is found to be ≈0.06 femtobarn/TeV. However, as in the case of the isothermal halo, the allowed parameter space is inconsistent with the null result obtained by the CDMS and XENON experiments for spin-independent elastic scattering. Future experiments with directional sensitivity and mass bounds from accelerator experiments will help to distinguish between different halo models and/or constrain the contribution from cold flows.

11. *"Caustics, Cold Flows, and Annual Modulation"*
A. Natarajan, Advances in Astronomy, vol. 2011, id. #285346
http://arxiv.org/pdf/1006.5716

Abstract: We discuss the formation of dark matter caustics, and their possible detection by future dark matter experiments. The annual modulation expected in the recoil rate measured by a dark matter detector is discussed. We consider the example of dark matter particles with a Maxwell-Boltzmann velocity distribution modified by a cold stream due to a nearby caustic. It is shown that the effect of the caustic flow is potentially detectable, even when the density enhancement due to the caustic is small. This makes the annual modulation effect an excellent probe of inner caustics. We also show that the phase of the annual modulation at low recoil energies does not constrain the particle mass unless the velocity distribution of particles in the solar neighborhood is known.

10. *"Distinguishing standard reionization from dark matter models"*
A. Natarajan and D.J. Schwarz; Physical Review D 81, 123510 (2010)
http://arxiv.org/pdf/1002.4405

Abstract: The Wilkinson Microwave Anisotropy Probe (WMAP) experiment has detected reionization at the 5.5σ level and has reported a mean optical depth of 0.088±0.015. A powerful probe of reionization is the large-angle EE polarization power spectrum, which is now (since the first five years of data from WMAP) cosmic variance limited for 2≤l≤6. Here we consider partial reionization caused by weakly interacting massive particle dark matter annihilation, and calculate the expected polarization power spectrum. We compare the dark matter models with a standard two-step reionization theory, and examine whether the models may be distinguished using current, and future cosmic microwave background (CMB) observations. We consider dark matter annihilation at intermediate redshifts (z<60) due to halos, as well as annihilation at higher redshifts due to free particles. In order to study the effect of high redshift dark matter annihilation on CMB power spectra, it is essential to include the contribution of residual electrons (left over from recombination) to the ionization history. Dark matter halos at redshifts z<60 influence the low multipoles l<20 in the EE power spectrum, while the annihilation of free particle dark matter at high redshifts z>100 mainly affects multipoles l>10.

9. *"Dark matter annihilation and its effect on CMB and Hydrogen 21 cm observations"*
A. Natarajan and D.J. Schwarz; Physical Review D 80, 043529 (2009)
http://arxiv.org/pdf/0903.4485

Abstract: If dark matter is made up of weakly interacting massive particles, the annihilation of these particles in halos results in energy being released, some of which is absorbed by gas, causing partial ionization and heating. Dark matter annihilation may result in partial ionization and gas heating at high redshifts, even before the formation of the first stars. It is shown that early ionization results in a transfer of power to higher multipoles in the large angle CMB polarization power spectra. Future CMB experiments may be able to place constraints on certain light dark matter models. We also investigate the effect of gas heating on the expected H21 cm power spectrum. Heating by particle annihilation results in a decrease in the amplitude of the H21 cm power spectrum as the gas temperature T becomes comparable to the CMB temperature T_cmb, and then an increase as T>T_cmb. The result is a minimum in the power spectrum at the redshift for which T≈T_cmb. Only certain models (low particle masses ~10 GeV, or favorable halo parameters) show this effect. Within these models, observations of the H21 cm power spectrum at multiple redshifts can help us obtain constraints on dark matter particle and halo properties.

8. *"Dark matter annihilation and primordial star formation"*
A. Natarajan, J.C. Tan and B.W. O'Shea; Astrophysical Journal 692, 574 (2009)
http://arxiv.org/pdf/0807.3769

Abstract: We investigate the effects of weakly-interacting massive particle (WIMP) dark matter annihilation on the formation of Population III.1 stars, which are theorized to form from the collapse of gas cores at the centers of dark matter minihalos. We consider the relative importance of cooling due to baryonic radiative processes and heating due to WIMP annihilation. We analyze the dark matter and gas profiles of several halos formed in cosmological-scale numerical simulations. The heating rate depends sensitively on the dark matter density profile, which we approximate with a power law $\rho_\chi \sim r^{-\alpha\chi}$, in the numerically unresolved inner regions of the halo. If we assume a self-similar structure so that $\alpha\chi \sim 1.5$ as measured on the resolved scales ~1 pc, then for a fiducial WIMP mass of 100 GeV, the heating rate is typically much smaller ($<10^{-3}$) than the cooling rate for densities up to $n_H=10^{17}$ cm^{-3}. In one case, where $\alpha\chi = 1.65$, the heating rate becomes similar to the cooling rate by a density of $n_H = 10^{15}$ cm^{-3}. The dark matter density profile is expected to steepen in the central baryon-dominated region <~ 1 pc due to adiabatic contraction, and we observe this effect (though with relatively low resolution) in our numerical models. From these we estimate $\alpha\chi \sim 2.0$. The heating now dominates cooling above $n_H \sim 10^{14}$ cm^{-3}, in agreement with the previous study of Spolyar, Freese & Gondolo. We expect this leads to the formation of an equilibrium structure with a baryonic and dark matter density distribution exhibiting a flattened central core. Examining such equilibria, we find total luminosities due to WIMP annihilation are relatively constant and ~ 10^3 L_{sun}, set by the radiative luminosity of the baryonic core. We discuss the implications for Pop III.1 star formation, particularly the subsequent growth and evolution of the protostar. Even if the initial protostar fails to accumulate any additional dark matter, its contraction to the main sequence could be significantly delayed by WIMP annihilation heating, potentially raising the mass scale of Pop III.1 stars to masses >> 100 solar masses.

7. *"The effect of early dark matter halos on reionization"*
A. Natarajan and D.J. Schwarz; Phys. Rev. D 78, 103524 (2008)
http://arxiv.org/pdf/0805.3945

Abstract: The annihilation of dark matter particles releases energy, ionizing some of the gas in the Universe. We investigate the effect of dark matter halos on reionization. We show that the effect depends on the assumed density profile, the particle mass, and the assumed minimum halo mass. For Navarro-Frenk-White halos and typical WIMPs, we find the effect to be quite small. However, light dark matter candidates in the MeV range can contribute significantly to reionization and can make an important contribution to the measured optical depth. This effect may be used to constrain light dark matter models. We also study the effect of varying the halo density profile on reionization.

6. *"Further look at particle annihilation in dark matter caustics"*
A. Natarajan and P. Sikivie; Phys. Rev. D 77, 043531 (2008)
http://arxiv.org/pdf/0711.1297

Abstract: Dark matter caustics are small scale, high density structures believed to exist in galaxies like ours. If the dark matter consists of weakly interacting massive particles, these caustics may be detected by means of the gamma rays produced by dark matter particle annihilation. We discuss particle annihilation in outer and inner caustics and provide sky maps of the expected gamma ray distribution.

5. *"Does the second caustic ring of dark matter cause the Monoceros ring of stars?"*
A. Natarajan and P. Sikivie; Phys. Rev. D 76, 023505 (2007)
http://arxiv.org/pdf/0705.0001

Abstract: Caustic rings of dark matter were predicted to exist in the plane of the Galaxy at radii a_n = 40 kpc / n for n = 1,2,3 ... The recently discovered Monoceros Ring of stars is located near the n=2 caustic, prompting us to consider a possible connection between these two objects. We identify two processes through which the Monoceros Ring of stars may have formed. One process is the migration of gas to an angular velocity minimum at the caustic leading to enhanced star formation there. The other is the adiabatic deformation of star orbits as the caustic slowly grows in mass and radius. The second process predicts an order 100% enhancement of the density of disk stars at the location of the caustic ring.

4. *"Weakly interacting massive particle annihilation in caustics"*
A. Natarajan; Phys. Rev. D 75, 123514 (2007)
http://arxiv.org/pdf/astro-ph/0703704

Abstract: The continuous infall of dark matter with low velocity dispersion from all directions in a galactic halo leads to the formation of caustics which are very small scale (parsec) high density structures. If the dark matter is made up of supersymmetric neutralinos, the annihilation of these particles produces a characteristic spectrum of gamma rays which, in principle, could be detected. The annihilation signal at different energy bands is computed and compared with the expected gamma ray background.

3. *"Inner caustics of cold dark matter halos"*
A. Natarajan and P. Sikivie; Phys. Rev. D 73, 023510 (2006)
http://arxiv.org/pdf/astro-ph/0510743

Abstract: We prove that a flow of cold collisionless particles from all directions in and out of a region necessarily forms a caustic. A corollary is that, in cold dark matter cosmology, galactic halos have inner caustics in addition to the more obvious outer caustics. The outer caustics are fold catastrophes located on topological spheres surrounding the galaxy. To obtain the catastrophe structure of the inner caustics, we simulate the infall of cold collisionless particles in a fixed gravitational potential. The structure of inner caustics depends on the angular momentum distribution of the infalling particles. We confirm a previous result that the inner caustic is a "tricusp ring" when the initial velocity field is dominated by net overall rotation. A tricusp ring is a closed tube whose cross section is a section of an elliptic umbilic catastrophe. However, tidal torque theory predicts that the initial velocity field is irrotational. For irrotational initial velocity fields, we find the inner caustic to have a tent-like structure which we describe in detail in terms of the known catastrophes. We also show how the tent caustic transforms into a tricusp ring when a rotational component is added to the initial velocity field.

2. *"Robustness of discrete flows and caustics in cold dark matter cosmology"*
A. Natarajan and P. Sikivie; Phys. Rev. D 72, 083513 (2005)
http://arxiv.org/pdf/astro-ph/0508049

Abstract: Although a simple argument implies that the distribution of dark matter in galactic halos is characterized by discrete flows and caustics, their presence is often ignored in discussions of galactic dynamics and of dark matter detection strategies. Discrete flows and caustics can in fact be irrelevant if the number of flows is very large. We estimate the number of dark matter flows as a function of galactocentric distance and consider the various ways in which that number can be increased, in particular by the presence of structure on small scales (dark matter clumps) and the scattering of the flows by inhomogeneities in the matter distribution. We find that, when all complicating factors are taken into account, discrete flows and caustics in galactic halos remain a robust prediction of cold dark matter cosmology with extensive implications for observation and experiment.

1. *"Role of the Cesium Antimonide layer in the Na2KSb/Cs3Sb photocathode"*
   A. Natarajan, A.T. Kalghatgi, B.M. Bhat, and M.Satyam; J. App. Phys., 90, 6434 (2001)

Abstract: When radiation of sufficiently high energy is incident on the surface of a semiconductor photocathode, electrons are excited from the valence band to the conduction band and these may contribute to the photocurrent. The photocurrent in a single-layer cathode is found to be small, because of collisions within the cathode material, the electron affinity condition, etc. It is observed that when a thin layer of n-type cesium antimonide (Cs_3Sb) is deposited over a p-type layer of sodium potassium antimonide (Na_2KSb), there occurs a sharp rise in the photocurrent. The causes for the dramatic increase in the photocurrent obtainable from a sodium potassium antimonide cathode, by depositing a thin layer of cesium antimonide are analyzed in this article. It has been shown that the interface between sodium potassium antimonide and cesium antimonide can result in lowering of the electron affinity to a level below the bottom of the conduction band of sodium potassium antimonide. The drift field that arises at the heterointerface enables the electrons to reach the surface, leading to the emission of almost all the photogenerated electrons within the cathode. The processes involved in photoemission from such a double-layer cathode are examined from a theoretical point of view. The spectral response of the two-layer cathode is also found to be better than that of a single-layer cathode.

published in conference proceedings:

1. *"Dark matter annihilation and Hydrogen 21 cm cosmology"*
   Aravind Natarajan and Dominik J. Schwarz, Proceedings of the International Workshop on Cosmic Structure and Evolution, Sep 23-25 2009, Bielefeld, Germany, (2009)
   http://pos.sissa.it/archive/conferences/097/025/Cosmology2009_025.pdf

Abstract: If dark matter is made up of Weakly Interacting Massive Particles, the annihilation of these particles results in partial ionization and heating before the formation of the first stars. We investigate the effect of gas heating on the expected Hydrogen 21 cm power spectrum. Heating by particle annihilation results in a minimum in the power spectrum of 21 cm fluctuations at the redshift at which the gas temperature equals the CMB temperature. Such a minimum is not expected in the standard theory since the gas temperature in the absence of luminous sources or dark matter heating is always below the CMB temperature. Thus observations of the Hydrogen 21 cm power spectrum at multiple redshifts may help us obtain constraints on dark matter particle and halo properties.

2. *"Dark matter caustics"*
   Aravind Natarajan, Axions 2010: AIP Conference Proceedings, Volume 1274, p. 97 (2010)

Abstract: The continuous infall of dark matter with low velocity dispersion in galactic halos leads to the formation of high density structures called caustics. Dark matter caustics are of two kinds : outer and inner. Outer caustics are thin spherical shells surrounding galaxies while inner caustics have a more complicated structure that depends on the dark matter angular momentum distribution. The presence of a dark matter caustic in the plane of the galaxy modifies the gas density in its neighborhood which may lead to observable effects. Caustics are also relevant to direct and indirect dark matter searches.

Conference talks:

- "Probing dark matter streams with DAMA and CoGeNT."
(in preparation)
COSMO-2011, Porto, Portugal, Aug 2011

- "DAMA and non-standard halo models."
PHENO-2011, Phenomenology Symposium, Madison, WI, May 2011
http://indico.cern.ch/getFile.py/access?contribId=103&sessionId=11&resId=0&materialId=slides&confId=121170

- "DAMA and non-standard halo models."
Rust Belt Cosmology Workshop, SUNY Buffalo, Jan 2011

- "Distinguishing standard reionization from dark matter models."
COSMO/CosPA 2010 Sep 2010, Tokyo, Japan.
http://www.resceu.s.u-tokyo.ac.jp/symposium/cosmocospa2010/abst/F2.pdf

- "Dark matter annihilation and Hydrogen 21 cm cosmology."

International Workshop on Cosmic Structure and Evolution, Sep 2009, Bielefeld, Germany.
http://www.physik.uni-bielefeld.de/igs/cosmology2009/bielefeld_Sep_25.pdf

- "The effect of WIMP annihilation on CMB and Hydrogen 21cm observations."

Kosmologietag, May '09 Bielefeld, Germany.
http://www.physik.uni-bielefeld.de/igs/schools/cosmology/2009/Natarajan.pdf

- "The effect of dark matter halos on reionization."
- Dark Matter at the Crossroads, Sep 29 - Oct 2, '08 DESY, Hamburg, Germany.

http://th-workshop2008.desy.de/sites/site_th-workshop2008/content/e44/e49/e198/infoboxContent206/Natarajan.pdf

- "The effect of early dark matter halos on reionization."

Kosmologietag, May '08 Bielefeld, Germany.
http://www.physik.uni-bielefeld.de/igs/schools/cosmology/2008/aravind_natarajan.pdf

- "Dark matter annihilation in clumps."

DESY ENTApP workshop on dark matter, Feb '08 Hamburg, Germany.
http://www.desy.de/~covil/entapp/aravind_natarajan.pdf

- "The effect of early dark matter halos on reionization."

COSMO-2008, Aug 2008, Madison, WI.

- "Dark matter caustics in galaxies."

Aspen winter conference on astrophysics, Jan 2006, Aspen, CO.

- "Detecting galactic caustics."

UF-FSU conference on high energy phenomenology, Dec 2005 Gainesville, FL

- "Caustics in galactic halos."

TeV particle astrophysics conference, July 2005 Fermilab.
http://www-astro-theory.fnal.gov/Conferences/TeV/Natarajan.pdf

- "Applying catastrophe theory to dark matter."

PHENO-2005, May 2005 Madison, WI.

- "Cold dark matter caustics."

UF-FSU conference on high energy phenomenology, Dec 2004 Tallahassee, FL

Seminar Talks:

- "DAMA and the self similar infall halo model."

Jan 2011, High Energy Theory Seminar, University of Florida, Gainesville,

- "Dark matter annihilation and its effect on Hydrogen 21 cm cosmology"

Cosmology seminar, Sep 2009, McWilliams Center for Cosmology, Carnegie Mellon University.

- "The effect of dark matter halos on reionization and the H21 cm line."

Particle Astrophysics seminar, September '08, Dept. of Physics and Astronomy, Case Western Reserve University, Cleveland.

- "The effect of dark matter halos on reionization and the H21 cm line."

ISCAP noon Seminar, September ’08, Dept. of Physics/Astronomy, Columbia University, New York

- "The effect of dark matter halos on reionization and the H21 cm line."

High Energy Theory Seminar, September ’08, Dept. of Physics, University of Florida, Gainesville.

- "Dark matter caustics and their relevance to dark matter searches"

Particle Theory Seminar, October ’07, Dept. of Physics, Bielefeld University, Germany.

- "Caustics and the search for dark matter"

Astrophysics Theory Lunch Seminar, March ’07, Dept. of Physics, University of Florida, Gainesville.

- "Can a dark matter caustic form a ring of stars?"

Astrophysics Theory Lunch Seminar, October ’06, Dept. of Astronomy, University of Florida, Gainesville.

- "Can a dark matter caustic form a ring of stars?"

High Energy Theory Seminar, October ’06, Dept. of Physics, University of Florida, Gainesville.

Poster presentations.

- “Dark Matter Caustics.”

Axions 2010 Workshop, Jan 2010, Gainesville, FL

- “Dark Matter Caustics.”

Astrophysical probes of the nature of dark matter, May 2007, Irvine, CA.
http://www.physics.uci.edu/Astrophysical-Probes/talks/natarajan.pdf

- “Caustics in galactic halos.”

TeV particle astrophysics conference, July 2005, Fermilab.