

Rensselaer Physics Department

Activities

JAN 2006 – MAR 2006

(Rensselaer Students are underlined)

HONORS AND AWARDS

T.-M. LU

- Patent: “Siloxane epoxy polymers for low K dielectric applications”, P.-I. Wang, T.-Ming Lu, and R. Ghoshal, US Patent 7019386 (2006).

H. NEWBERG

- Martin and Beate Block Winter Fund award, February 2006
- Chaired “New Surveys and Future Probes” session of Local Group Cosmology Conference, Aspen, CO, February 10, 2006
- Chaired a session at the SEGUE collaboration meeting in Santa Fe, New Mexico, March 2006

C. WETZEL

- Program Committee Member Conference on Laser Electro-Optics (CLEO) 2005, Feb 12+13, 2006, Alexandria VA.
- Program Committee Member Electronic Materials Conference (EMC) 2006, Feb 1-3, 2006.

INVITED TALKS

S.-K. EAH

- Modification of a single metal nanoparticle’s light scattering rate by a remote mirror, 36th Winter Colloquium on the Physics of Quantum Electronics (Snowbird, Utah), Jan. 2-6, 2006
- Two Radiating Dipoles: from Interference to Purcell Effect by a Remote Mirror, Department of Physics, The University of Vermont, (Burlington, Vermont), Feb. 22, 2006

F. SCHUBERT

- (Invited short course) E. F. Schubert “Light-emitting diodes and solid-state lighting” Centro de Investigacion Y De Estudios Avanzados del I.P.N. (Center for Research and Advanced Studies) Mexico City, Mexico, Jan. 12 – 13 (January 2005)

- (Invited colloquium, IEEE Distinguished Lecture Program) E. F. Schubert and Jong Kyu Kim “Innovations in light-emitting diodes” Centro de Investigacion Y De Estudios Avanzados del I.P.N. (Center for Research and Advanced Studies) Mexico City, Mexico, Jan. 12 – 13 (January 2005)
- (Invited colloquium) E. F. Schubert and Jong Kyu Kim “Innovations in light-emitting diodes” Optical Science Center, University of Arizona, Tucson, January 19 (2006)
- (Invited colloquium) E. F. Schubert “Innovations in light-emitting diodes” Nanotechnology Seminar, Wayne State University, Detroit MI, February 7 (2006)
- (Invited colloquium) E. F. Schubert “Material challenges for solid-state lighting” Department of Materials Science and Engineering, Rensselaer Polytechnic Institute, Troy NY, February 23 (2006)
- (Invited) E. F. Schubert “Material challenges for solid-state lighting” March Meeting of the American Physical Society (APS), Baltimore MD, March 13 (2006)
- (Invited press conference presentation) E. F. Schubert “Material challenges for solid-state lighting” March Meeting of the American Physical Society (APS), Baltimore MD, March 13 (2006)
- (Invited colloquium) E. F. Schubert “Innovations in light-emitting diodes for solid-state lighting applications” New Jersey Institute of Technology together with the IEEE NJ Section Electron Devices, Circuits and Systems; New Jersey Institute of Technology (NJIT), Newark NJ, March 22 (2006)

T.-M. LU

- “Physical self-assembly and 3D integrated nanostructures”, seminar, Materials Science and Engineering, Louisiana State University, Baton Rouge, Louisiana.

H. NEWBERG

- “In Search of the Stellar Spheroid, from SDSS and SEGUE,” AAS Meeting, Washington, DC, Jan 11 , 2006
- “The Milky Way’s Spheroid,” SEGUE Meeting, Santa Fe, NM, March 25, 2006

C. WETZEL

- "Efficiency in Piezoelectric GaInN/GaN Green Light Emitting Diodes", **C. Wetzel**, American Physical Society Meeting, Baltimore, MD, March 13, 2006.

X.-C. ZHANG

- “THz technology and applications,” Short Course, SPIE Photonic West, Jan. 23, 2006.
- “New horizons of THz technology for industrial applications,” Opening Tutorial Lecture, Fraunhofer Institute of Physical Measurement Techniques, 2nd International Forum on THz Technology, the Technical University of Kaiserslautern, Germany, March 1, 2006.
- “Recent development of THz wave sensing, imaging science, technology, and applications,” APS March Meeting, Baltimore, March 15, 2006.
- “THz wave emission microscope,” Government Microcircuits Applications & Critical Technology Conference (GoMacTech-06), Tutorial Series of THz-Frequency Sensing for the Future, Paradise Point Resort, San Diego, March 20, 2006.
- “Advanced THz Technology,” NATO THz ET presentation, Jan. 30, 2006.
- “THz technology for military applications,” NATO THz ET presentation, Jan. 30, 2006.
- “Real-time explosive specific chemical sensor,” MURI review, Big Sky, Montana, Feb. 8, 2006.

MEETING ATTENDANCE

S.-K. EAH

- 36th Winter Colloquium on the Physics of Quantum Electronics, Snowbird, Utah, Jan. 2-6, 2006

H. NEWBERG

- American Astronomical Society meeting, January 8-12, 2006, Washington DC
- Local Group Cosmology, February 5-11, 2006, Aspen, CO
- SDSS II Collaboration Meeting, March 23-25, 2006, Santa Fe, NM
- SEGUE Meeting, March 25-28, 2006, Santa Fe, NM

C. WETZEL

- Program Committee Meeting Conference on Laser Electro-Optics (CLEO) 2005, Feb 12+13, 2006, Arlington, VA.
- U.S. Department of Energy workshop on Solid-State Lighting, Orlando, Florida, Feb 1-3, 2006
- Tech Valley High School - A Conversation with James Baldwin, Business/Education Partnership Breakfast, February 9, Albany
- American Physical Society Meeting, Baltimore, MD March 12-17, 2006.

OTHER PROFESSIONAL TRAVEL

T. DETCHPROHM

- Agilent Technology, Palo Alto, CA. Disintegrated and prepared MOCVD reactor model AIX-2000 donated by Avago Technologies for transportation to RPI. Coordinated and conducted the transportation for such system. Jan & Feb 2006.

C. WETZEL

- LandMark Optoelectronics, Tainan, Taiwan, Inspection of MOVPE equipment. Mar 7 – 10, 2006

D. WHITTET

- on sabbatical leave at RIT for the spring semester.

M. YAMAGUCHI

- “High pressure Studies of Optical Dephasing in Polymer Glasses,” M.J. McIntire, M. Yamaguchi, M.A. Kol’chenko, Y.Go. Vanier, and E.L. Chronister, J. Phys. Chem. B, 110, 227-233 (2006)

X.-C. ZHANG

- MURI review, Big Sky, Montana, Feb. 7, 2006.
- Kaiserslautern, Germany, 2nd International Forum on THz Technology, March 1, 2006.

PRESENTATIONS

S.-K. EAH

- “Freely-Suspended Monolayers of Gold Nanocrystals: Fabrication and Elastic Properties”, Klara Elteo, Xiao-Min Lin, Sang-Kee Eah, and Heinrich Jaeger, APS March meeting, Baltimore, March 13-17, 2006
(note that K. Elteo is not Dr. Eah’s student)

H. NEWBERG

- “In Search of the Stellar Spheroid, from SDSS and SEGUE,” Local Group Cosmology, poster, February 5-11, 2006, Aspen, CO

M. YAMAGUCHI

- M. Yamaguchi, “Polaritonics”, THz Science and Technology, RPI, March 29, 2006

PAPERS PUBLISHED

T. KARABACAK

- "Water electrolysis activated by Ru nanorod array electrodes", S. Kim, N. Koratkar, T. Karabacak, T.-M. Lu, *Appl. Phys. Lett.*, submitted.
- "Dynamic evolution of mounds during thin film growth", M. Pelliccione, T. Karabacak, and T.-M. Lu, *Phys. Rev. Lett.*, submitted.
- "Low temperature melting of copper nanorod arrays", T. Karabacak, J. S. DeLuca, D. Ye, P.-I. Wang, G.-C. Wang, and T.-M. Lu, *J. Appl. Phys.*, 99, 064304 (2006).
- "Texture of Ru columns grown by oblique angle sputter deposition", P. Morrow, F. Tang, T. Karabacak, P.-I. Wang, D.-X. Ye, G.-C. Wang, and T.-M. Lu, *J. Vac. Sci. Technol. A*, 24, 205 (2006).
- "Dielectric barriers, pore sealing, and metallization", J. S. Juneja, P.-I. Wang, T. Karabacak, and T.-M. Lu, *Thin Solid Films*, 504, 239 (2006)
- "Formation of body-centered cubic tantalum on low-k dielectrics at low temperatures", D.-L. Bae, T. Karabacak, J. J. Senkevich, and T. S. Cale, *J. Vac. Sci. Technol. B*, 24, 534 (2006).

T.-M. LU

- "Low temperature melting of copper nanorod arrays", T. Karabacak, J. S. DeLuca, D. Ye, P.-I. Wang, G. Ten Eyck, G.-C. Wang, and T.-M. Lu, *J. Appl. Phys.*, 99, 064304 (2006).
- "Self-assembled monolayer growth on chemically modified polymer surfaces", S. Pimanpang, Pei-I Wang, G.-C. Wang, and T.-M. Lu, *Appl. Surf. Sci.* 252, 3532 (2006).
- "Very low-refractive-index optical thin films consisting of an array of SiO₂ nanorods", J.-Q. Xi, Jong Kyu Kim, E. F. Schubert, Dexian Ye, T.-M. Lu, and Shawn-Yu Lin, *Optics Letters* 31, 601 (2006).
- "Electroless copper on refractory and noble metal substrates with an ultra-thin plasma-assisted atomic layer deposited palladium layer" Young-Soon Kim, Hyung-Il Kim, Joong-Hee Cho, Hyung-Kee Seo, M. A. Dar, Hyung-Shik Shin, Gregory A. Ten Eyck, Toh-Ming Lu, and Jay J. Senkevich, *Electrochimica Acta*, 51(12), 2400, 2006
- "Investigation of the electrical properties of novel polycarbosilane-based polymer as low-k dielectric", Pei-I Wang, Zhizhong Wu, T.M. Lu, and L. V. Interrante, *J. Electrochem. Soc.* 153 (4), G267 (2006).
- "Stability of Cu on epoxy silosane polymer under bias temperature stress", Pei-I Wang, J.S. Juneja, S. P. Murarka, T. -M. Lu, C. Jezewski, Ram Ghoshal, Rajat Ghoshal, and H. Bakhru, *J. Electrochem. Soc.* 153 (4), G358 (2006).

- “Texture of Ru columns grown by oblique angle sputter deposition”, P. Morrow, F. Tang, T. Karabacak, P.-I. Wang, D.-X. Ye, G.-C. Wang, and T.-M. Lu, *J. Vac. Sci. Technol. A*, 24, 235 (2006).
- “Bias-Temperature Stability of Ti–Si–N–O Films”, Y. C. Ee, Jasbir S. Juneja, Pei-I Wang, T.-M. Lu, H. Bakhru, Chan, S. B. Law, Clare Yong, Z. Chen, and S. Xue, *J. Electrochem. Soc.* 153, G470 (2006).
- “Dielectric barriers, pore sealing, and metallization”, J. S. Juneja, P.-I. Wang, T. Karabacak, and T.-M. Lu, *Thin Solid Films*, 504, 239 (2006).
- “Copper drift in high-dielectric-constant tantalum oxide thin films under bias temperature stress”, Pushkar Jain, Jasbir S. Juneja, A. Mallikarjunan, E. J. Rymaszewski, and T.-M. Lu, *Appl. Phys. Lett.* 88, 143502 (2006).
- “Power-law scaling during shadowing growth of nanocolumns by oblique angle deposition, T. Karabacak*, F. Tang, L. Li, M. Pelliccione, G.-C. Wang, and T.-M. Lu, submitted.
- "Atomic Layer Deposition of Pd on an Oxidized Metal Substrate" Gregory A. Ten Eyck, Samuk Pimanpang, Hassaram Bakhru, Gwo-Ching Wang, and Toh-Ming Lu, *Chemical Vapor Deposition*, submitted.
- “Low Temperature Melting of Copper Nanorod Arrays” Tansel Karabacak, James S. DeLuca, Pei-I Wang, Gregory A. Ten Eyck, Dexian Ye, Gwo-Ching Wang, and Toh-Ming Lu, *J. Appl. Phys.*, submitted.
- “Surface Characterization of Copper Electroless Deposition on Atomic Layer Deposited Palladium on Iridium and Tungsten” Young-Soon Kim, Gregory A. Ten Eyck, De-Li Liu, Samuk Pimanpang, Joong-Hee Cho, Hyung-Shik Shin, Jay J. Senkevich, Toh-Ming Lu, *Surface Coatings and Technology*, submitted.
- “Breakdown of dynamic scaling in surface growth under shadowing”, M. Pelliccione*, T. Karabacak, and T.-M. Lu. *Phys. Rev. Lett.*, submitted.
- “Three-dimensional Magnetic Recording – An Emerging Technology”, S. Khizroev, Y. Hijazi, N. Amos, D. Doria, A. Lavrenov, R. Chomko, T.-M. Lu, D. Litvinov, submitted to *J. of Nanoelectronics and Optoelectronics*.

H. NEWBERG

- “The Fourth Data Release of the Sloan Digital Sky Survey,” Adelman-McCarthy et al., *Ap. J. Suppl.*, 162, 38, 2006
- “A Spectroscopic Study of the Ancient Milky Way: F- and G-Type Stars in the Third Data Release of the Sloan Digital Sky Survey,” Allende Prieto et al., *Ap. J.*, 636, 804, 2006

F. SCHUBERT

- Kim J. K., Gessmann T, Schubert E. F., Xi J.-Q., Luo H. Cho J., Sone C., Park Y., “GaInN light-emitting diode with conductive omnidirectional reflector having a low-refractive index indium-tin oxide layer” *Appl. Phys. Lett.* 88, 013501 (January 2006)
- Kim J. K., Luo H., Xi Y., Shah J. M., Gessmann T., and Schubert E. F. “Light extraction in GaInN light-emitting diodes using diffuse omnidirectional reflectors” *Journal of the Electrochemical Society* 153, G105 (January 2006)
- Xi J.-Q., Kim J. K., Schubert E. F., Ye D., Lu T.-M., Lin S.-Y., and Juneja J. S. “Very low-refractive-index optical thin films consisting of an array of SiO₂ nanorods” *Optics Letters* 31, 601 (March, 2006)

G.-C. WANG

- “Perpendicular giant magnetoresistance of electrodeposited Co/Cu-multilayered nanowires in porous alumina templates”, X.-T. Tang, G.-C. Wang, and M. Shima, *J. Appl. Phys.* 99, 033906 (2006).
- “Self-assembled monolayer growth on chemically modified polymer surfaces”, S. Pimanpang, Pei-I Wang, G.-C. Wang, and T.-M. Lu, *Appl. Surf. Sci.* 252, 3532 (2006).

X.-C. ZHANG

- Hua Zhong, Jingzhou Xu, Xu Xie, Tao Yuan, Ron Reightler, Eric Madaras, and Xi-Cheng Zhang, "Nondestructive Defect Identification With Terahertz Time-of-Flight Tomography ", *IEEE Sensor*, 5, 203 (2005).
- Hai-Bo Liu, Yunqing Chen, Glenn J. Bastiaans, X.-C. Zhang, “Detection and identification of explosive RDX by THz diffuse reflection spectroscopy,” *Optical Express*, 14, 415-423 (2006).
- Kai Liu, Jingzhou Xu, Tao Yuan, and X.-C. Zhang, “THz radiation from InAs induced by carrier diffusion and drift,” *PRB*, in press (2006).
- Xu Xie, Jingzhou Xu, and X.-C. Zhang, “Terahertz generation from CdTe crystal characterized by excitation frequency,” *Optics Letters*, 31 978 (2006).
- Xu Xie, Jianming Dai, and X.-C. Zhang, “Coherent control of THz wave generation in ambient air,” *Phys. Rev. Letts.*, 96 075005 (2006).
- Fatemah M. Al-Douseri, Y.C. Chen, and X.-C. Zhang,” invited paper, *Journal of Infrared and Millimeter Waves*, in press. (2006).
- Jingzhou Xu, and X.-C. Zhang, “Terahertz wave reciprocal imaging,” *Appl. Phys. Letts.*, in press (2006).
- Jingzhou Xu, and X.-C. Zhang, “Terahertz science and technology,” this Chinese book will be published by Peking University Press, (2006).
- A. Redo and X.-C. Zhang, “THz photonics,” book chapter, submitted (2006).

- Hua Zhong, Nick Karpowicz, and X.-C. Zhang, "Terahertz emission profile from laser-induced-air-plasma," submitted to Applied Physics Letters, (2006).
- Weili Zhang, Abul K. Azad, Jingzhou Xu, Jian Chen, and X.-C. Zhang, "Direct observation of transition of surface plasmon resonance from photonic crystal effect," submitted to Physics Review Letters, (2006).
- Hai-Bo Liu, Yunqing Chen, X.-C. Zhang, "Characterization of anhydrous and hydrated pharmaceutical materials with THz time-domain spectroscopy," submit it to Journal of Pharmaceutical Science, (2006).
- Hai-Bo Liu, George Plopper, Sarah Earley, Yunqing Chen, Bradley Ferguson, X.-C. Zhang, "Sensing minute changes in biological cell monolayers with THz differential time-domain spectroscopy," Biosensor and Bioelectronics, in press (2006).
- Hai-Bo Liu, X.-C. Zhang, "Dehydration kinetics of a poly-crystalline hydrate studied using THz time-domain spectroscopy: a study of D-glucose monohydrate," submitted to Applied Physics Letters (2006).
- Hai-Bo Liu, Hua Zhong, Nicholas Karpowicz, Yunqing Chen and X.-C. Zhang, submitted to IEEE Special Issue on T-Ray (2006).
- Lantao Guo, Ying Hu, Yan Zhang, and Cunlin Zhang, Yunqing Chen and X. -C. Zhang, "Vibrational spectrum of g-HNIW investigated using terahertz time-domain spectroscopy," Optical Express, in press. (2006).

PROPOSALS (SUBMITTED or GRANTED)

S.-K. EAH

- Acquisition of Surface-Enhanced Confocal Raman-AFM, Jan. 26, 2006 (submitted) PI=Chang Ryu, co-PIs=Sang-Kee Eah, Pulickel Ajayan, Robert Linhardt, Richard Siegel, \$535,522, National Science Foundation

G.-C. WANG

- MRI: Development of Backward Wave Oscillator Tunable Broadband THz Source for Terahertz Electronics Research, THz-Materials Research and THz-Imaging, Wilke, Shur, Zhang, Yamaguchi, and Wang, \$400 K, NSF, Jan. 27, 2006.
- MRI: Acquisition of surface-enhanced confocal Raman-AFM, PI, Ryu (Chem.), Ajayan, EAh, Lindhardt, Siegel, and a dozen participants, \$550 K, NSF, Jan. 27, 2006.
- MRI: Acquisition of a Multipurpose X-ray Diffractometer System for Advanced Materials Research and Education, G. Ramanath(PI, MS&E), Linda Schadler (MS&E), Toh-Ming Lu (Physics), O. Nalamasu (Chemistry), I. Bhat (EE), P.M. Ajayan (MS&E), R.W. Siegel (NSEC, RNC), D. Duquette (MS&E), D. Lewis (MS&E), B. Watson (Physics), P. Dutta (EE), J. Plawsky (ChemE), G.C. Wang (Physics), M. Shima (MMSE), D. Gall (MS&E), Y. Akpalu (Chemistry), L. Interrante (Chemistry), etc., \$600K, NSF, Jan. 27, 2006.

C. WETZEL

- High Performance Green LEDs by Homoepitaxial MOVPE, 3/2006 – 2/2009, Department of Energy, \$ 1,795,520. granted
Received equipment donation "Aixtron 2000 HT" appraised at \$1,221,000.00
- Ultraviolet Source Platform Technology for Water Purification, NYSTAR TTIP submitted, 8/2006 – 7/2008, \$652,540
- Systems of High Quantum Efficiency, NSF ECS, 3 years, \$331,495

M. YAMAGUCHI

- "MRI: Development of Backward Wave Oscillator Tunable Broadband THz Source for Terahertz Electronics Research, THz-materials Research and THz-Imaging" I, Wilke, **M. Yamaguchi**, G.-C. Wang, M. Shur, NSF submitted.
- "Non-contact thermal transport measurements in nanotubes/nanowires", **M. Yamaguchi**, T.-M. Lu, and P. Ajayan, Interconnect Focus Center, white paper submitted.

X.-C. ZHANG

- HSAPAR, "Portable High Sensitivity THz Scanning Device for Low Vapor Pressure Chemicals" RPI, SC&A, and Princeton Nanotechnology System (PNTS), Phase I - \$1.23M, RPI's share is \$400K: one year. Awarded.
- HSARPA SBIR Phase II: "Polychromic Imaging for Standoff Detection of Explosives and Weapons," with Intelligent Optical Systems, \$750k for two years. Two years. RPI share \$250k. Awarded.
- ONR, "THz wave standoff distance detection of explosives (>100m) using the air as an emitter & sensor," \$900k, with co-PI Yamaguchi and Dai, three years (2006). Recommended for Award.
- ONR, "Understanding phonon signatures of explosives," \$750k, with co-PI Nayak and Chen, three years (2006). Recommended for Award.
- ONR, "THz camera," \$1M, with PI Shur, three years (2006). Recommended for Award.
- Army Night-vision, "Portable, Real Time, Explosive Specific, Chemical Sensing at Standoff Distances," \$1.05M, three years (2006). Recommended for Award.
- AFOSR-DURIP, "THz fiber laser," \$101k, (2006). Awarded.
- Monsanto, \$12.5k, (2006). Received.
- NSF/DARPA Photonics Technology Access Program, the White Cell for THz spectroscopy, \$8,720. (2006). Awarded.
- Corning, "THz technology," \$5,000. (2006). Received.

- Army Benet Lab., “Terahertz-wave imaging technology” \$106k for 9 months. (2006). Recommended for Award.
- HSARPA/CenSSIS, with co-PI Yamaguchi, \$550,000, two years (2006). Recommended for Award.
- NSF, THz wave photonics, \$300k, three years (2006). Submitted.
- Gerber Scientific International, \$250k, two years (2006). Submitted.
- Lockheed Martin, \$100k, one year (2006). Submitted.
- DARPA, RIERID, teaming with APL/JHU and Rockwell Scientific International (total \$8M, RPI’s share is \$2.5M), (2006). Submitted.
- Navy, NAVEODTECHDIV, “Handheld THz explosive detector,” teaming with Zomega THz Corp. \$2.25M. Submitted.
- NASA Langley Flight Center, “NONDESTRUCTIVE EVALUATION OF FLAWS IN POLYURETHANE FOAM BY USING CW TERAHERTZ RADIATION (PHASE III)”, \$3.25M, 4.5 year, (2006). Submitted.
- Zomega THz Corp., \$20k gift, (2006). Requested.

SIGNIFICANT RESULTS OBTAINED OR NEW RESEARCH AFFILIATES

VISITORS TO RENSSELAER

H. NEWBERG

- Peter Mack, from ACE, came to Rensselaer on March 20, 2006 to start the process of refurbishing the 16” B&C telescope that is the centerpiece of the Hirsch Observatory. He will be back towards the end of May to complete the restoration.

X.-C. ZHANG

- 17 invited participants from 4 NATO countries came.
- 5 HSARPA managers and supporting staff members visited THz Center for THz Research.
- 7 GE scientists came for THz research.

GE visitors are:

Jeffrey M. Ashe
 Manager
 RF & Photonics Lab
 518-387-5302
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Charles A. Becker
 Chief Technologist
 Micro & Nano Structure Technologies
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NON-PROFESSIONAL ACTIVITIES

IMPORTANT ACTIVITIES OF STUDENTS

H. NEWBERG

- Nate Cole gave a talk entitled “Maximum Likelihood fits to stellar streams/halo” on March 27, 2006 at the SEGUE meeting in Santa Fe, NM.

X.-C. ZHANG

- Built and tested our portable pulsed THz imager for NASA on Jan. 12, 2006. It is installed in NASA Marshall Flight Research Center now.
- Built and tested our portable CW THz imager for Lockheed Martin / NASA project. It is installed in Lockheed Martin, New Orleans now.
- Built and tested a pulsed THz unit for Naval Research Lab in Feb. 2006.
- Organizing 1st NATO SET THz exploratory team business meeting at the Center for THz Research at Rensselaer, Jan. 30-31, 2006.
- HSARPA Kickoff Meeting at the Center for THz Research at Rensselaer, Feb. 1, 2006.
- Nick Karpowicz and Tao Yuan received Coherent Award. (\$750 each)

OTHER

H. NEWBERG

- Interviewed live on air for Brian Shaw of SuccessFM radio in Eugene, Oregon on January 4, 2006.
- Appeared in December issue of Discover Magazine on Milky Way discoveries. Also, Dec 12, 2005 WAMC “To the Best of our Knowledge” show on the dark matter highway.