GG 671B, Fall 2003 **Vicky Hamilton**
Remote Sensing – Planets

Abridged Bibliographies

Lectures VEH1 and VEH2

Most of these are dense, technical theoretical treatments; those of you using IR spectroscopy in your research should delve into a few of these. You don't need to know this stuff in gory detail, but perusing these works will give you: 1) an awareness of how spectroscopy really works, and how much we do/don't know, and 2) a place to look for more detail if/when you ever need it.

Harris, D.C., and M.D. Bertolucci, *Symmetry and Spectroscopy: An Introduction to Vibrational and Electronic Spectroscopy*, Dover, New York, 1989.

Hapke, B., Bidirectional reflectance spectroscopy I. Theory, *J. Geophys. Res.*, *86*, 3039-3054, 1981.

Hapke, B., and E. Wells, Bidirectional reflectance spectroscopy II. Experiments and observations, *J. Geophys. Res.*, *86* (No. B4), 3055-3060, 1981.

Hapke, B., Combined Theory of Reflectance and Emittance Spectroscopy, in *Remote Geochemical Analysis: Elemental and Mineralogical Composition*, edited by C.M. Pieters, and P.A.J. Englert, pp. 31-42 (Ch. 2), Cambridge University Press, New York, 1993.

Wilson, E.B., Jr., J.C. Decius, and P.C. Cross, *Molecular Vibrations: The Theory of Infrared and Raman Vibrational Spectra*, Dover, New York, 1980.

Lecture VEH3

These references cover emissivity calibration, linear mixing of mineral/rock spectra, and the origin of the Christiansen feature.

Christensen, P.R., and S.T. Harrison, Thermal infrared emission spectroscopy of natural surfaces: Application to desert varnish coatings on rocks, *J. Geophys. Res.*, *98* (B11), 19,819-19,834, 1993. [Describes two-temperature calibration method.]

Conel, J.E., Infrared emissivities of silicates: Experimental results and a cloudy atmosphere model of spectral emission from condensed particulate mediums, *J. Geophys. Res.*, *74*, 1614-1634, 1969. [Info on Christiansen feature.]

Lyon, R.J.P., W.M. Tuddenham, and C.S. Thompson, Quantitative mineralogy in 30 minutes, *Econ. Geol.*, *54*, 1047-1055, 1959. [A classic! If not the first, close to it.]

Ruff, S.W., P.R. Christensen, P.W. Barbera, and D.L. Anderson, Quantitative thermal emission spectroscopy of minerals: A technique for measurement and calibration, *J. Geophys. Res.*, *102*, 14,899-14,913, 1997. [One-temperature calibration method.]

Thomson, J.L., and J.W. Salisbury, The mid-infrared reflectance of mineral mixtures (7-14 μm), *Remote Sens. Environ.*, *45*, 1-13, 1993.

Salisbury, J.W., Mid-infrared spectroscopy: Laboratory data, in *Remote Geochemical Analysis: Elemental and Mineraliogical Composition*, edited by C.M. Pieters, and P.A.J. Englert, pp. 79-98 (Ch. 4), Cambridge University Press, New York, 1993.

Salisbury, J.W., and L.S. Walter, Thermal infrared (2.5-13.5 μm) spectroscopic remote sensing of igneous rock types on particulate planetary surfaces, *J. Geophys. Res.*, *94* (B7), 9192-9202, 1989.

Walter, L.S., and J.W. Salisbury, Spectral characterization of igneous rocks in the 8-12 μm region, *J. Geophys. Res.*, *94* (B7), 9203-9213, 1989.

Lecture VEH4

These references cover linear deconvolution and its application to laboratory spectra.

Ramsey, M.S., and P.R. Christensen, Mineral abundance determination: Quantitative deconvolution of thermal emission spectra, *J. Geophys. Res.*, *103*, 577-596, 1998. [Explanation of technique, initial testing, and general detection/uncertainty info.]

Hamilton, V.E., P.R. Christensen, and H.Y. McSween, Jr.,, Determination of martian meteorite lithologies and mineralogies using vibrational spectroscopy, *J. Geophys. Res.*, *102* (E11), 25,593-25,603, 1997. [Illlustrative, but somewhat out of date; in revision.]

Feely, K.C., and P.R. Christensen, Quantitative compositional analysis using thermal emission spectroscopy: Application to igneous and metamorphic rocks, *J. Geophys. Res.*, *104* (E10), 24195-24210, 1999.

Wyatt, M.B., V.E. Hamilton, H.Y. McSween, Jr., and P.R. Christensen, Analysis of terrestrial and martian volcanic compositions using thermal emission spectroscopy: I. Determination of mineralogy, chemistry, and classification strategies, *J. Geophys. Res.*, *106* (E7), 14,711-14,732, 2001. [Advanced approaches to using deconvolution data; mineral-by-mineral uncertainty calculation.]

Lecture VEH5

These papers describe physical and environmental effects on thermal IR spectra.

Aronson, J.R., and A.G. Emslie, Spectral reflectance and emittance of particulate materials. 2: Application and results, *Appl. Opt.*, *12*, 2573-2584, 1973.

Christensen, P.R., and S.T. Harrison, Thermal infrared emission spectroscopy of natural surfaces: Application to desert varnish coatings on rocks, *J. Geophys. Res.*, *98* (B11), 19,819-19,834, 1993.

Hunt, G.R., and L.M. Logan, Variation of single particle mid-infrared emission spectrum with particle size, *Appl. Opt.*, *11*, 142-147, 1972.

Moersch, J.E., and P.R. Christensen, Thermal emission from particulate surfaces: A comparison of scattering models with measured spectra, *J. Geophys. Res.*, *100*, 7,465-7,477, 1995. [Applicability of Hapke, Mie, and a hybrid theory to fine particulates.]

Salisbury, J.W., and J.W. Eastes, The effect of particle size and porosity on spectral contrast in the mid-infrared, *Icarus*, *64*, 586-588, 1985. [Hint: should be read in conjuction with *Salisbury and Wald* (1992).]

Salisbury, J.W., and A. Wald, The role of volume scattering in reducing spectral contrast of reststrahlen bands in spectra of powdered minerals, *Icarus*, *96*, 121-128, 1992. [Update and "correction" to *Salisbury and Eastes* (1985).]

Salisbury, J.W., A. Wald, and D.M. D'Aria, Thermal-infrared remote sensing and Kirchhoff's law 1. Laboratory measurements, *J. Geophys. Res.*, *99*, 11897-11911, 1994. [A consideration of the effects of non-lab conditions on Kirchhoff's law.]

Salisbury, J.W., and L.S. Walter, Thermal infrared (2.5-13.5 μm) spectroscopic remote sensing of igneous rock types on particulate planetary surfaces, *J. Geophys. Res.*, *94* (B7), 9192-9202, 1989.

Vincent, R.K., and G.R. Hunt, Infrared reflectance from mat surfaces, *Appl. Opt.*, *7*, 53-59, 1968.

Lecture VEH6

References describing thermal inertia, albedo, and rock abundance at Mars.

Christensen, P.R., The spatial distribution of rocks on Mars, *Icarus*, *68*, 217-238, 1986.

Christensen, P.R., Global albedo variations on Mars: Implications for active aeolian transport, deposition, and erosion, *J. Geophys. Res.*, *93*, 7611-7624, 1988.

Jakosky, B.M., M.T. Mellon, H.H. Kieffer, P.R. Christensen, E.S. Varnes, and S.W. Lee, The thermal inertia of Mars from the Mars Global Surveyor Thermal Emission Spectrometer, *Journal of Geophysical Research*, *105*, 9643-9652, 2000.

Kieffer, H.H., T.Z. Martin, A.R. Peterfreund, B.M. Jakosky, E.D. Miner, and F.D. Palluconi, Thermal and albedo mapping of Mars during the Viking primary mission, *J. Geophys. Res.*, *82*, 4249-4292, 1977.

Mellon, M.T., B.M. Jakosky, H.H. Kieffer, and P.R. Christensen, High resolution thermal inertia mapping from the Mars Global Surveyor Thermal Emission Spectrometer, *Icarus*, *148*, 437-455, 2000.

Palluconi, F.D., and H.H. Kieffer, Thermal inertia mapping of Mars from 60°S to 60°N, *Icarus*, *45*, 415-426, 1981.

Pleskot, L.K., and E.D. Miner, Time variability of martian bolometric albedo, *Icarus*, *45*, 179-201, 1981.

Lecture VEH7

TIR remote sensing instruments for Mars

Christensen, P.R., D.L. Anderson, S.C. Chase, R.N. Clark, H.H. Kieffer, M.C. Malin, J.C. Pearl, J. Carpenter, N. Bandeira, F.G. Brown, and S. Silverman, Thermal Emission Spectrometer experiment: The Mars Observer Mission, *J. Geophys. Res.*, *97*, 7719-7734, 1992.

Christensen, P.R., J.L. Bandfield, J.F. Bell III, V.E. Hamilton, M.A. Ivanov, B.M. Jakosky, H.H. Kieffer, M.D. Lane, M.C. Malin, T. McConnochie, A.S. McEwen, H.Y. McSween Jr., J.E. Moersch, K.H. Nealson, J.W. Rice Jr., M. Richardson, S.W. Ruff, M.D. Smith, and T.N. Titus, Morphology and composition of the surface of Mars: Mars Odyssey THEMIS results, *Science*, *300*, 2056-2061, doi:10.1126/science.1080885, 2003.
[This is not the THEMIS instrument paper, which is not yet published, but it has a basic description of the instrument.]

Hanel, R., B. Schlachman, E. Breihar, R. Bywaters, F. Chapman, M. Rhodes, D. Rogers, and D. Vanous, Mariner 9 Michelson interferometer, *Appl. Opt.*, *11* (11), 2625-2634, 1972.

Kieffer, H.H., G. Neugebauer, G. Munch, S.C. Chase Jr., and E. Miner, Infrared thermal mapping experiment: The Viking Mars Orbiter, *Icarus*, *16* (1), 47, 1972.

Lecture VEH8

Introductory papers to initial results from MGS TES and surface-atmosphere separation

Christensen, P.R., and J. Pearl, Initial data from the Mars Global Surveyor Thermal Emission Spectrometer experiment: Observations of the Earth, *J. Geophys. Res.*, *102*, 10,875-10,880, 1997.

Christensen, P.R., J.L. Bandfield, M.D. Smith, V.E. Hamilton, and R.N. Clark, Identification of a basaltic component on the Martian surface from Thermal Emission Spectrometer data, *J. Geophys. Res.*, *105* (E4), 9609-9621, 2000.

Smith, M.D., J.L. Bandfield, and P.R. Christensen, Separation of atmospheric and surface spectral features in Mars Global Surveyor Thermal Emission Spectrometer (TES) spectra, *J. Geophys. Res.*, *105* (E4), 9589-9607, 2000.

Lecture VEH9

Mineral maps, alternative interpretations about what is Surface Type 2, and TIR identification of crystalline hematite

Bandfield, J.L., Global mineral distributions on Mars, *J. Geophys. Res.*, *107* (E6), doi: 10.1029/2001JE001510, 2002.

Christensen, P.R., J.L. Bandfield, R.N. Clark, K.S. Edgett, V.E. Hamilton, T. Hoefen, H.H. Kieffer, R.O. Kuzmin, M.D. Lane, M.C. Malin, R.V. Morris, J.C. Pearl, R. Pearson, T.L. Roush, S.W. Ruff, and M.D. Smith, Detection of crystalline hematite mineralization on Mars by the Thermal Emission Spectrometer: Evidence for near-surface water, *J. Geophys. Res.*, *105* (E4), 9623-9642, 2000.

Christensen, P.R., R.V. Morris, M.D. Lane, J.L. Bandfield, and M.C. Malin, Global mapping of Martian hematite mineral deposits: Remnants of water-driven processes on early Mars, *J. Geophys. Res.*, *106* (E10), 23,873 - 23,885, 2001.

McLennan, S.M., Sedimentary silica on Mars, *Geol. Soc. Am. Bull.*, *31* (4), 315-318, 2003.

Rogers, D., and P.R. Christensen, Age relationship of basaltic and andesitic surface compositions on Mars: Analysis of high-resolution TES observations of the northern hemisphere, *J. Geophys. Res.*, *108* (E4), 5030, doi:10.1029/2002JE001913, 2003.

Wyatt, M.B., and H.Y. McSween, Jr., Spectral evidence for weathered basalt as an alternative to andesite in the northern lowlands of Mars, *Nature*, *417*, 263-266, 2002.

Lecture VEH10

Olivine and Martian meteorite-like lithologies on Mars

Hamilton, V.E., P.R. Christensen, H.Y. McSween, Jr., and J.L. Bandfield, Searching for the source regions of Martian meteorites using MGS TES: Integrating Martian meteorites into the global distribution of volcanic materials on Mars, *Met. Planet. Sci.*, *38* (6), 871-885, 2003.

Hoefen, T.M., R.N. Clark, J.L. Bandfield, M.D. Smith, J. Pearl, and P.R. Christensen, Discovery of olivine in the Nili Fossae region of Mars, *Science*, *302* (5645), 627-630, 2003.

Mustard, J.F., and J.M. Sunshine, Seeing through the dust: Martian crustal heterogeneity and links to the SNC meteorites, *Science*, *267*, 1623-1626, 1995.

Mustard, J.F., S.L. Murchie, S. Erard, and J.M. Sunshine, In situ compositions of Martian volcanics: Implications for the mantle, *J. Geophys. Res.*, *102*, 25605-25615, 1997.

Lecture VEH11

Mars surface dust composition and carbonate detection

Bandfield, J.L., and M.D. Smith, Multiple emission angle surface-atmosphere separations of Thermal Emission Spectrometer data, *Icarus*, *161* (1), 47-65, 2003.

Bandfield, J.L., T.D. Glotch, and P.R. Christensen, Spectroscopic identification of carbonates in the Martian dust, *Lunar Planet. Sci.*, *XXXIV*, Abstract #1723, Lunar and Planetary Institute, Houston (CD-ROM), 2003.

Hamilton, V.E., and R.V. Morris, Thermal emission spectra of altered tephras and constraints on the composition of Martian dust, *Lunar Planet. Sci.*, *XXXIV*, Abstract #1936 (CD-ROM), 2003.

Pollack, J.B., T.L. Roush, F. Witteborn, J. Bregman, D. Wooden, C. Stoker, O.B. Toon, D. Rank, B. Dalton, and R. Freedman, Thermal emission spectra of Mars (5.4-10.5 μm): Evidence for sulfates, carbonates, and hydrates, *J. Geophys. Res.*, *95* (B9), 14595-14627, 1990.

Murchie, S., J. Mustard, J. Bishop, J. Head, C. Pieters, and S. Erard, Spatial variations in the spectral properties of bright regions on Mars, *Icarus*, *105*, 454-468, 1993.

Lecture VEH12

THEMIS results and the use of TIR spectroscopy at Mercury and the Moon

Christensen, P.R., J.L. Bandfield, J.F. Bell III, V.E. Hamilton, M.A. Ivanov, B.M. Jakosky, H.H. Kieffer, M.D. Lane, M.C. Malin, T. McConnochie, A.S. McEwen, H.Y. McSween Jr., J.E. Moersch, K.H. Nealson, J.W. Rice Jr., M. Richardson, S.W. Ruff, M.D. Smith, and T.N. Titus, Morphology and composition of the surface of Mars: Mars Odyssey THEMIS results, *Science*, *300*, 2056-2061, doi:10.1126/science.1080885, 2003.

Cooper, B., A. Potter, R. Killen, and T. Morgan, Midinfrared spectra of Mercury, *J. Geophys. Res.*, *106* (E12), 32,803-32,814, 2000.

Nash, D.B., J.W. Salisbury, J.E. Conel, P.G. Lucey, and P.R. Christensen, Evaluation of infrared emission spectroscopy for mapping the Moon's composition from lunar orbit, *J. Geophys. Res.*, *98* (E12), 23,535-23,552, 1993.

Sprague, A.L., F. Witteborn, R. Kozlowski, D. Cruikshank, M. Bartholomew, and A. Graps, The Moon: Mid-infrared (7.5-11.4 um) spectroscopy of selected regions, *Icarus*, *100*, 73-84, 1992.

Sprague, A.L., J.P. Emery, K.L. Donaldson, R.W. Russell, D.K. Lynch, and A.L. Mazuk, Mercury: Mid-infrared (3-13.5 μm) observations show heterogeneous composition, presence of intermediate and basic soil types, and pyroxene, *Met. Planet. Sci.*, *37*, 1255-1268, 2002.

Titus, T.N., H.H. Kieffer, and P.R. Christensen, Exposed water ice discovered near the South Pole of Mars, *Science*, *299* (5609), 1048-1051, 2003.