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Commission 36: Theory of Stellar Atmospheres

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1. Introduction

Commission 36 covers all the physics of stellar atmospheres. The scientific activity in this large field has been very intense during the last triennium and led to the publication of a large number of papers which makes an exhaustive report practically not feasible. As a consequence we decided to keep the format of the preceding report: first a list of areas of current research, then web links for obtaining further information.

Many conferences and workshops were held during this report period on topics within the scope of commission 36. Some of them were sponsored by IAU: "Young Neutron Stars and their Environment" (IAU Symp 218), "Stars as Suns: Activity, Evolution and Planets" (IAU Symp 219), "The A-Star Puzzle" (IAU Symp 224), "Massive Star Birth: A Crossroads of Astrophysics" (IAU Symp 227), "From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution" (IAU Symp 228), "The Environment and Evolution of Binary Stars" (IAU Coll 191), and "Variable Stars in the Local Group" (IAU Coll 193).

2. Primary research areas 2002–2005

2.1. *Physical processes*

General properties Improved models available to the community. Grids of synthetic fluxes and spectra. Calibrating parameterized models through physical modeling. Calibrating abundance determinations by filter photometry or low-resolution spectroscopy.

Stationary processes within stellar atmospheres Convection (granulation) in surface layers, and its effects upon emergent spectra. Interplay between convection and non-radial pulsation. Scales of surface convection in stars in different stages of evolution. Hydrodynamic simulations of entire stellar volumes.

Transient processes Shocks in pulsating stars. Radiative cooling of shocked gas. Emission lines as shock-wave diagnostics. Particle acceleration during flares. Interaction of jets with interstellar medium. Episodic outflows and star-disk interaction.

Magnetic phenomena Magnetic structures in single and binary stars. Dynamo generation of magnetic fields by convection. Effects by magnetic fields on convective structures. Magnetic cycles at varying activity levels. Polarized radiation, gyrosynchrotron and X-ray emission. Interpreting Zeeman-Doppler images of stellar surfaces. Hanle effect diagnostics in stellar environments.

Radiative transfer and emergent stellar spectra Effects on atmospheric structure by deviations from local thermodynamic equilibrium (non-LTE). Multidimensional radiative transfer. Radiative hydrodynamics. Origin and transfer of polarized light. Numerical methods in radiative transfer.

Spectral lines, and their formation Line formation in convective atmospheres. Wavelength shifts as signatures of convection. Spectra of rotating stars viewed pole-on and equator-on. Non-LTE effects in permitted and forbidden lines. Atomic and quantum processes affecting spectral lines. Databases for spectral lines. Atlases of synthetic spectra.

Forbidden lines and maser emission Molecules in atmospheres of cool giant stars. Effects of fluorescence. Permitted and forbidden lines from shocked atmospheres of pulsating giants. Maser and laser emission from stellar envelopes.

Chemical abundances Abundance anomalies. Hydrodynamical models of metal-poor stars. Depletion of light elements through atmospheric motions. Pollution of atmospheres by interstellar dust. r- and s-process elements. Chemical stratification in stable atmospheres. Coronal versus photospheric abundances. Chemical inhomogeneities and pulsation.

Molecules Chromospheric structures and temperature inhomogeneities. Cool molecular constituents in warm stars. Molecular spheres around red giants. Molecular opacities, and non-LTE effects. Role of molecular hydrogen.

2.2. *Stellar structure*

Structures across stellar disks Doppler mapping of starspots. Radii and oblateness at different wavelengths for giant stars. Gravitational microlensing to test model atmospheres. Interaction between rotation and pulsation. Doppler tomography of stellar envelopes.

Stellar coronae Coronal heating mechanisms (quiescent and flaring). Effects of age and chemical abundance. Multicomponent structure. Coronae in also low-mass stars and brown dwarfs. Diagnostics through X-ray spectroscopy and radio emission.

Stellar winds and mass loss Dynamic outer atmospheres. Multi-component radiation- and dust-driven winds. Mass loss from pulsating giants. Effects of mass flows on the ionization structure. Coronal mass ejections. Instabilities in hot-star winds. X-ray emission.

Dust, grains, and shells Formation of stellar dust shells. Grains in the atmospheres of red giants, and in T Tauri stars.

2.3. *Different classes of objects*

Pulsating stars and asteroseismology Classically variable stars, and 'ordinary' solar-type ones. Inverting observed pressure-mode frequencies into atmospheric structure. Mass-loss mechanisms in pulsating stars. Effects of rapid rotation on pulsation.

Binary stars Atmospheric structure and magnetic dynamos in common-envelope binaries. Role of binarity on mass loss. Tidal effects. Non-LTE effects by illumination from the component. Reflection effects in close binaries. Colliding stellar winds.

New classes of very cool stars Dust, clouds, weather, and chemistry in brown dwarfs. Cloud clearings and hot-spots. Magnetic activity. The effective temperature scale. Molecular line and continuum opacities. Transition between extra-solar giant planets and ultra-cool brown dwarfs.

White dwarfs and neutron stars Radiative transfer in magnetized white-dwarf atmospheres. Stokes-parameter imaging of white dwarfs. Molecular opacities in white dwarfs. Atmospheres and spectra of neutron stars. Effects of vacuum polarization and accretion around magnetized neutron stars.

Special objects Central stars of planetary nebulae. Population III stars of extremely low metallicity. Protostars. Accretion disks and coronal activity in young stars.

Interaction with exoplanets Effects of planets on the atmospheres of evolved red giants. Characteristics of stars hosting exoplanets.

2.4. *Development of techniques*

Computational techniques Parallel (super)computing to simulate convective surface regions, and throughout complete stars. Neural networks and machine-learning algorithms. Preparing for the widely distributed network of computational tools and shared databases being developed for the forthcoming computing infrastructure GRID.

2.5. *Applications of stellar atmospheres*

Besides their study per se, stars are being used as probes for other astrophysical problems:

Exoplanets Variable wavelength shifts in stellar spectra serve as diagnostics for radial velocity variations induced by orbiting exoplanets. Atmospheric modeling can indicate which spectral features are suitable as such probes, and which should be avoided due to their sensitivity to intrinsic stellar activity.

Chemical evolution in the Galaxy How accurately observations of stellar spectral features can be transformed into actual chemical abundances depends sensitively on the sophistication of the stellar model atmospheres.

Kinematics of the Galaxy Planned space missions intend to measure radial velocities for huge numbers of stars. Model atmospheres are used to identify suitable spectral features for such measurements in different classes of stars.

Galaxies and cosmology Stars are the main observable component of galaxies, and population synthesis for galaxies utilize model atmospheres to interpret observations. Cosmological origin of the lowest-metallicity stars.

3. Web links for further information

The following collection of links provides introductions and overviews of several significant subfields of the physics of stellar atmospheres.

3.1. *Calculating atmospheric models and spectra*

ATLAS, SYNTHE, and other model grids
`http://kurucz.harvard.edu`
MARCS, model grids
`http://www.marcs.astro.uu.se`
Tuebingen: Stellar atmospheres – grid of models
`http://astro.uni-tuebingen.de/groups/stellar`
`http://astro.uni-tuebingen.de/~rauch/`
CCP7 – Collaborative Computational Project
`http://ccp7.dur.ac.uk`
CLOUDY – photo-ionization simulations
`http://www.nublado.org/`
MULTI – non-LTE radiative transfer
`http://www.astro.uio.no/~matsc/mul22/mul22.html`
PANDORA – atmospheric models and spectra
`http://cfa-www.harvard.edu/~rloeser/pandora.html`
PHOENIX – stellar and planetary atmosphere code
`http://www.hs.uni-hamburg.de/EN/For/ThA/phoenix/index.html`
STARLINK – theory and modeling resources
`http://www.astro.gla.ac.uk/users/norman/star/sc13/sc13.htx`
Synthetic spectra overview
`http://www.am.ub.es/~carrasco/models/synthetic.html`
TLUSTY – model atmospheres
`http://tlusty.gsfc.nasa.gov`

3.2. *Useful links from Research groups or Individual researchers*

Vienna: Stellar atmospheres and pulsating stars
`http://ams.astro.univie.ac.at/main.php`

Potsdam: Stellar convection
`http://www.aip.de/groups/sternphysik/stp/convect_neu.html`
M.Asplund: Stellar convection and line formation
`http://www.mso.anu.edu.au/~martin`
R.F.Stein: Convection simulations & radiation hydrodynamics
`http://www.pa.msu.edu/~steinr/research.html#research`
D.Dravins: Stellar surface structure
`http://www.astro.lu.se/~dainis/HTML/GRANUL.html`

A.Collier Cameron: Starspots and magnetic fields on cool stars
`http://star-www.st-and.ac.uk/~acc4/coolpages/imaging.html`
D.F.Gray: Stellar rotation, magnetic cycles, velocity fields
`http://www.astro.uwo.ca/~dfgray/`
J.F.Donati: Magnetic fields of non degenerate stars
`http://webast.ast.obs-mip.fr/people/donati/field.html`

M.Jardine: Stellar coronal structure
`http://star-www.st-and.ac.uk/~mmj/Welcome_research.html`

Munich: Programs, Models, Fluxes and synthetic Spectra of the atmospheres of hot stars
`http://www.usm.uni-muenchen.de/people/adi/adi.html`
S.Jeffery: Stellar model grids, hot stars
`http://star.arm.ac.uk/~csj/`
P.Stee: Be-star atmospheres and circumstellar envelopes
`http://www.obs-nice.fr/stee/Bemodel.html`
`http://www.obs-nice.fr/stee/simugb.html`

J.L.Linsky: Cool stars, stellar chromospheres and coronae
`http://jilawww.colorado.edu/~jlinsky/`
G.Basri: Brown dwarfs
`http://astro.berkeley.edu/~basri/bdwarfs/`
Adam Burrows: M dwarfs, brown dwarfs etc model atmospheres
`http://zenith.as.arizona.edu/~burrows/`

Vienna: Atomic Line Database (VALD)
`http://ams.astro.univie.ac.at/vald/`
D.Montes *et al.*: Libraries of stellar spectra
`http://www.ucm.es/info/Astrof/spectra.html`
R.J.Rutten: Lecture notes: Radiative transfer in stellar atmospheres
`http://www.fys.ruu.nl/~rutten/node20.html`

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