27th International School for Young Astronomers

Al Akhawayn University in Ifrane, Morocco

July 2-23, 2004

Organized by

Al Akhawayn University in Ifrane (AUI) & the International Astronomical Union (IAU)

Sponsored by

International Astronomical Union (IAU)
The Abdus salam International Centre of Theoretical Physics (ICTP)
Le Centre National pour la Recherche Scientifique et Technique (CNRST)*
Al Akhawayn University in Ifrane (AUI)

the abdus salam international centre for theoretical physics

* Event supported by the Moroccan Ministry of Education and Research "Ministère de l'Enseignement Supérieur, de la Formation des Cadres et de la Recherche » by funds managed by the C.N.R.S.T.

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PREFACE

The International School for Young Astronomers (ISYA) is one of the essential educational activities of the International Astronomical Union (IAU). It seeks the participation of young astronomers mainly, but not exclusively, from astronomically developing countries. It is also aimed at developing local and regional collaborations between institutions involved in teaching and research in astronomy. This school is the beginning of a series of activities housed by Al Akhawayn University and sponsored by the IAU. Our objective is to implement in our AUI and other Moroccan Universities several areas of Astronomy, encouraging young people to get involved in them by discussing current research topics with experienced professionals from Morocco and abroad.

The main subjects that will be covered in the 27th ISYA are: Cosmology, High Energy Astrophysics, Stellar Evolution and Dynamics of the Solar system and Spectroscopy.

ISYA students will have the opportunity of getting familiar with the use of several powerful astronomical facilities, from small telescopes and software to the large archives of public data produced for by space experiments such as HIPPARCOS, WMAP and HST or ground based observatories such as VLT. Practical exercises will be organized with data handling and reductions, using some of the usual packages (IRAF, AIPS, MIDAS).

As some observing with a 20 cm telescope is also planned, ISYA students will have the opportunity of reducing their own data. Students will also do short presentations about their current research and interests.

ISYA Chairperson:

Michèle Gerbaldi, Institut d'Astrophysique, Paris, France.

Programme Committee

Michèle Gerbaldi, Institut d'Astrophysique, Paris, France.
Hassane Darhmaoui, School of Science & Engineering (SSE), AUI, Morocco
Khalil Chamcham, Oxford University, UK

Organizing Committee

Amine Benaid, Dean, SSE, AUI, Morocco
Khalil Chamcham , Oxford University, UK
Hassane. Darhmaoui, SSE, AUI, Morocco
Ahmed Legrouri, SSE, AUI, Morocco
Khalid Loudiyi, SSE, AUI, Morocco
Tajje-Eddine Rachidi, SSE, AUI, Morocco
Zouheir Sekkat, SSE, AUI, Morocco
Izeddine Zorkani, Faculté des sciences Dhar Mehraz, Fes, Morocco
Astronomic Club, AUI, Morocco

PROGRAM

27th International School for Young Astronomers

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Friday, July 2 (Building 1, board room)

- 10:00 - 11:00 Registration
- 11:00 - 11:45 Opening Ceremony of the ISYA
- 11:45 - 13:00 Campus Tour & Orientation
- 13:00 - 14:30 Lunch
- 15:30 - 16:45 Plenary Lecture "**Astrophysics: … physics at work**" by Professor Michèle Gerbaldi, ISYA chairperson, Institut d' Astrophysique de Paris, France
- 16:45 - 17: 00 Coffee Break
- 17:00 - 17:45 Agreement signing ceremony: International Astronomical Union & Al Akhawayn University in Ifrane
- 17:45 - 18:30 ISYA practical information/ technical presentation on computers, accounts, e-mail, printers etc.

ISYA program from July 3 to July 23

July 3 - 9	**Saturday 3**	**Sunday 4**	**Monday 5**	**Tuesday 6**	**Wednesday 7**	**Thursday 8**	**Friday 9**
9:00 - 10:30	De Greve	Excursion to Fes	De Greve	De Greve	Ribas	Chamcham	Gerbaldi
10:30 - 11:00	Break		Break	Break	Break	Break	Break
11:00 - 12:30	Guinan		Chamcham	Guinan	Hendry	Hendry	Students' talks
12:30 - 15:00	Lunch		Lunch	Lunch	Lunch	Lunch	Lunch
15:00 - 16:30	Ribas		Hendry	Hendry	TBA	Guinan	Badaoui
16:30- 16:45	Break		Break	Break		Break	Break
16:45 - 19:00	Lab computers Ribas		Lab computers Ribas	Lab computers Chamcham		Lab computers Chamcham	Lab computers Elmhamdi

July 10 - 16	**Saturday10**	**Sunday 11**	**Monday 12**	**Tuesday 13**	**Wednesday 14**	**Thursday 15**	**Friday 16**
9:00 - 10:30	Badaoui	Excursion to Meknes	Chamcham	Partridge	Guiderdoni	Mendez	Partridge
10:30 - 11:00	Break		Break	Break	Break	Break	Break
11:00 - 12:30	Guiderdoni		Moodley	Guiderdoni	Moodley	Partridge	Students' talks
12:30 - 15:00	Lunch		Lunch	Lunch	Lunch	Lunch	Lunch
15:00 - 16:30	Free		Mendez	Mendez	TBA	Students' talks	Mendez
16:30- 16:45			Break	Break		Break	Break
16:45 - 19:00			Lab computers Moodley	Lab computers Mendez		Lab computers Elmhamdi	Lab computers Mendez

July 17 - 22	**Saturday 17**	**Sunday 18**	**Monday 19**	**Tuesday 20**	**Wednesday 21**	**Thursday 22**	**Friday 23**
9:00 - 10:30	Partridge	Excursion to Volubulis & Moulay Driss Zerhoun	Ferreira	Ferreira	Ferreira	Students' talks	Departure
10:30 - 11:00	Break		Break	Break	Break	Break	
11:00 - 12:30	Moodley		De Greve	Silk	Silk	Closing ISYA	
12:30 - 15:00	Lunch		Lunch	Lunch	Lunch	Lunch	
15:00 - 16:30	Free		Elmhamdi	Silk	Elmhamdi		
16:30- 16:45			Break	Break	Break	Lab computers	
16:45 - 19:00			Lab computers Elmhamdi	Students' talks	Lab computers Elmhamdi		

Note: lectures will be held in Building 5/Room 106 and computer labs in Building 8/Room 102

LECTURES OUTLINE

Physics and Observational Properties of Supernovae

Abouazza Elmhamdi
SISSA / ISAS, Trieste - Italy.

The main physics and observational properties of Supernovae (SNe) will be presented and analyzed during the lectures. Some tutorials and practical exercises with participants at the ISYA on SNe data, spectra and light curves, will be provided in order to reach more understanding.

Main Topics:

1. SNe Taxonomy and Classification

I will show the present understanding of the SNe classification. The observational properties of the two great classes, namely Thermonuclear and Core collapse, and the nature of their Host Galaxies will be presented.

2. Physics of the explosion: Energy budget and SNe Progenitors

A general view on the physics behind the explosion will be discussed. I will talk about the progenitor stars (Mass, Radius & Evolution) that may lead to one class or other of SNe explosions. This will be obviously accompanied with the analysis of the progenitor characteristics and features imprinted on spectra and light curves (e.g. Identifications of elements, Expansion velocities, Peak light curve duration,
Radioactive decay slopes). Discussing the remnant nature is of high importance as well (i.e. Neutron stars or Black holes).

3. Abundance and Yields

This is a point of high importance, especially for people dealing with Chemical Evolution of Galaxies. Here I will basically focus on elements like Oxygen and Iron. Some methodologies in estimating the Iron masses from late-phases light curves will be illustrated. Important results and conclusions will be drawn.

4. Doing cosmology with SNe

The basic idea behind the use of type Ia events, the "most homogeneous class" among SNe types, as standard candles will be discussed. Results concerning the nature of our universe and the cosmological parameters will be shown. The homogeneity of other classes and their possible use in cosmology will be questioned.

Physics and Observational Properties of Supernovae

(Tutorials and Practical Aspects)

Abouazza Elmhamdi
SISSA / ISAS, Trieste - Italy.

The practical exercises will be essentially related to analyzing Spectra and Light curves of the main subclasses of SNe. For this purpose I am collecting a rich sample of SNe data covering different bands and all phases of evolution.

Radio Astronomy and Cosmology

Bruce Partridge
Haverford College, Haverford PA 19041, USA

I plan to start with fairly basic physics, to provide some worked examples in lecture, and to ask the students to do some small problems in the evenings beyween lectures. My current plans for my lectures, which would come late in the school, are as follows:

1. The physics of radio astronomy (1), starting with antenna theory and diffraction through a circular aperture, then continuing on to interference and the combining of signals from two or more apertures. This would provide a brief review of the wave theory of light, including diffraction and interference for the students.

2. The physics of radio astronomy (2), the size of astronomical signals, stochastic noise, radio receivers and the technique of beam switching and phase sensitive detection.

3. Radio sources and the unified model for active galactic nuclei: thermal emission, bremstrahlung and synchrotron emission, orientation effects, etc

4. Basic techniques for the detection of the cosmic microwave background (CMB) with emphasis on absolute measurements of intensity and calibration.

5. (If desired) a "cartoon version" of the derivation of the CMB power spectrum. This would be a very low level approach for the less sophisticated students running parallel to Pedro Ferreira's more mathematical coverage.

Galaxy Formation

Bruno Guiderdoni
Institut d'Astrophysique de Paris, IAP, Paris, France

I will give a series of lectures on Galaxy Formation. The talks will review recent observational data on high redshift galaxies, the basic concepts involved in hierarchical galaxy formation, the techniques of numerical simulations and the state-of-the-art models.

Lecture 1:

A brief introduction to the Friedman-Lemaitre model

Lecture 2:

Galaxy formation in the Friedman-Lemaitre model

Lecture 3:

Observational properties of high-redshift galaxies

Magnetic Activity of the Sun and Solar type Stars

Edward Guinan
Villanova University, USA

- Introduction to the solar and stellar magnetic dynamos
- Possible effects of Solar Magnetic Activity on the Earth's Climate
- Nuclear Evolution of the Sun and the Effects on Earth's Climate
- The Study of Solar Analogs ---The Sun in Time Program
- Learning about the young Sun's X-UV Fluxes from young dG stars
- The active young Sun and the effects of the young Sun's Strong X-UV emissions and solar winds fluxes on the planets.
- How the Young Sun's Strong Magnetic Activity produced major changes in the atmospheres of the terrestrial planets (for example- Loss of water on Mars and the evolution of Life on Earth)
- Effect of Stellar magnetic activity on Extrasolar Planets
- Ideas for research programs for ISYA participants

Variable and Eclipsing Stars as Astrophysical Laboratories

Edward Guinan
Villanova University, USA

Fundamental stellar quantities from the study of eclipsing binaries, examples include:

- Stellar masses and diameters,
- Internal structure of stars from apsidal motion studies,
- Testing general relativity,
- Detecting low mass companions and planets from the light travel time effect,
- Calibration of the extragalactic distance scale using extragalacric eclipsing binaries,

Transit eclipses from exosolar planets (illustrated with examples)

Other planned activities

- Possible research ideas for ISYA participants
- Neat programs that can be done with small telescopes or with no telescopes (using photometry archives);
- Collaborative programs for ISYA partipants.
- Taking advantage of NASA's and ESA's rich archival data bases with examples.
- Informal Discussions and Advising on Writing Effective Resumes and Strong Research Proposals; and Employment Opportunties in Astronomy and Astrophysics.

Astronomical Techniques

Ignasi Ribas
Barcelona University, Spain

The main theme of my lectures will be the analysis of astronomical data and the use of databases. More precisely, I plan to discuss general concepts on astronomical techniques (astrometry, photometry and spectroscopy), including the effects of the interstellar medium and Earth's atmosphere. Modern optical/near-IR detectors, such as CCD cameras, will be covered with detail. Here I will explain the basic operation of a CCD device and discuss their advantages and shortcomings. To complete this instrumental part, I will briefly describe how astronomical data reductions proceed, with focus on each of the steps involved in the preliminary processing and the extraction of scientifically useful data.

Along this same lines, I plan to devote some time to discuss the importance of astronomical databases, their exponential growth, and the crucial role they will play in the near future. The flourishing wealth of public astronomical data constitutes a great resource for scientists in countries that have no direct access to world-class observatories. Examples of currently existing (MAST, VLT, HEASARC, 2MASS) and future databases (SDSS, GAIA, Planck, etc) will be given.

Practical sessions are planned to illustrate the concepts discussed. In one case, raw CCD observations of the open cluster M67 will be provided, together with the necessary calibration data. The students are expected to carry out all the steps of the reduction and analysis with the aid of IRAF, a suite of custom programs and the help of public databases. The goal of this session is the construction of a color-magnitude diagram and the determination of cluster parameters such as its age, reddening, distance and metallicity.

The other practical session will focus on spectroscopy of binary stars. In this case, the students will be provided with several high-quality double-lined spectra to measure line positions with IRAF. Then, by using a catalog of spectral lines they will calculate the radial velocity shifts of the components. The star's fundamental properties follow from the fit of the radial velocity curve. Finally, to illustrate the use of ultraviolet data, the students will request and download public spectra from HST and measure radial velocities. This will also illustrate the complications added by low signal-to-noise data.

Evolution of Close Binary Stars

Jean-Pierre de Grève
Vesalius College V.U.B, Brussels, Belgium

The foundation: Evolution of single stars.

- Basic equations of stellar structure and recipes to solve them.
- Ingredients for a good solution (equation of state, nuclear reactions, convection, absorption coefficients, …)
- Complicating ingredients: Overshooting, stellar wind, …
- Stellar evolution (Phases, differentiations, internal changes, …)

The ground floor: Binaries and their evolutionary parameters.

- The problem: Additional parameters (P, q, e, Roche lobe approximation)
- Accretion and mixing.

The first floor: Evolution of close binaries.

- Close binary evolution: Phases (results of calculations)
- Different types of evolution, internal changes, ….
- At last: Comparison with observations (observable counterparts, though theorists care little about them)

The roof: Close binary evolution and all the rest.

Evolution of Stars and Close Binaries

(Tutorial)

Jean-Pierre de Grève
Vesalius College V.U.B, Brussels, Belgium

- You will find in the folowing link a table representing the evolution of a close binary system. In the calculation, the structure and evolution of the two components was simultaneously followed
  (Data files are located in: http://mail.alakhawayn.ma/~H.Darhmaoui/ISYA/material/JP-Tutorial.html).
- To get an insight in the evolution of the system, make a diagram of the time evolution of the period and the mass ratio evolution (one diagram, double vertical axes), and write a clear, concise and coherent figure caption.
- The evolution of log T_{eff} and Log L/L_o could well be represented in an HR diagram. However, it is more interesting to answer the question "**In a close binary, when will one of the components be visible – and which one – and when will we observe two components simultaneously?"** This relates to the probability of observing the system as a single-lined spectroscopic binary or a double-lined one. Assume that the inclination of the system's orbital plane is 90°. To answer the above question, the theoretical HR-diagram (or better, the corresponding data) need to be transformed into observable data.
- Which are the observable quantities corresponding to log L/ L_o and log T_{eff}? What conversion tables are needed for the transformation? What is the algorithm of the transformation? Make the "observed" HR diagram.
- Draw the observed light behaviour of the two components as a function of time. Use different timescales on the horizontal axis to map the complete history.

Evolution of Stars and Close Binaries

(Tutorial … continued)

Jean-Pierre de Grève
Vesalius College V.U.B, Brussels, Belgium

- Construct the periodical light curve(s) near the end of the first mass transfer, taking into account the observability of the two components.
- Calculate V_1 and V_2 and construct the radial velocity diagram near the end of the first mass transfer, again taking into account the observability of the components (and assuming circular orbits).
- What are your conclusions?

Relevant equations, conversion tables and close binary data can be found in *Allen's Astrophysical Quantities (1972)*, or *Astrophysical Formulae from Kenneth Lang (1980).*

In addition to that, you'll find two catalogues on line: http://cdsweb.u-strasbg.fr/cats/Cats.htx where you find the newest catalog of *Budding on Algols, Budding E., Erdem A., Cicek C., Bulut I., Soydugan F., Soydugan E., Bakis V., Demircan O.* Astron. Astrophys., 417, 263-268 (2004)

and *Batten's catalog of spectroscopic binaries, Batten A.H., Fletcher J.M., McCarthy D.G.* Publ. *Dominion Astrophys. Obs. 17 (1989)*

However, it being 15 year old, an update of the latter can be found on http://SB9.ASTRO.ULB.AC.BE/

(*9th catalogue of Spectroscopic Binary systems*)

Galaxy Formation

Joseph Silk
Oxford University, UK

1. From density fluctuations to galaxy halos

- Introduction to dark matter.
- Matter power spectrum, linear growth, nonlinear growth, epoch of galaxy formation, number density of halos.

2. The role of baryonic dissipation and the first stars

- Introduction to baryonic matter.
- Dissipation, smallest galaxies, most massive galaxies, clusters, intertgalctic matter.
- First stars, reionisation, chemical evolution.

3. Formation of disk galaxies and ellipticals

- Introduction to normal galaxies.
- Disk instability and star formation. Mergers and starbursts. Galactic outflows and active galactic nuclei

Cosmological Models

Kavilan Moodley
University of KwaZulu-Natal, South Africa

My tutorials would develop on computational and statistical techniques, not the processing of raw data, but using processed data to tie up with cosmological models. Examples of this include using the Hubble data to derive the value of the Hubble parameter (with an analysis of systematic and statistical errors) and using the Type 1a supernovae data to determine the acceleration rate of the universe. A more computational-type tutorial on the physics of the CMB can be done using CMBfast. The basic idea of these tutorials would be to tie the observations to theory.

Galaxy Formation and Evolution

Khalil Chamcham
University of Oxford, UK

I will be lecturing on some aspects of galaxy formation and evolution, namely chemical evolution of galaxies. I will describe how galaxies form from primordial gas -left from the Big Bang- that has condensed due to density fluctuations which isolate 'islands' of dark matter that will act as the well within which gas (baryonic matter) will collapse to form a protogalactic system. Then I will follow the evolution of this protogalaxy until stars start forming due to gravo-thermal instabilities. With this I will explain how chemical elements are synthesized, ejected in a form of 'rich' gas (due to supernova explosions) and recycled to form a new generation of stars.

I will provide as a tutorial a computing program, based on one of the models I have developed and written in Fortran, which predicts the number of stars formed at each epoch at a given position within the galaxy, the gas left, the contribution of dark matter and the abundance of chemical elements like Oxygen, Iron etc... Participants at the ISYA will run the program and plot the data and compare them to observations. I will help them to finish the project in half a day if necessary.

High-Energy Astrophysics

Mariano Méndez
SRON - National Institute for Space Research, The Netherlands

I will briefly review the emission mechanisms that are relevant in producing the continuum X-ray/Gamma-ray part of the electromagnetic spectrum: Bremsstrahlung, Synchrotron, and Inverse Compton. I will then discuss the most salient aspects of the X-ray emission from collisionally ionized and photoionized plasmas. All these concepts will be used to understand the spectra of X-ray emitting sources, like X-ray binaries, active galactic nuclei, and clusters of galaxies. I will show how to use current software to analyze X-ray spectra; the students themselves will use this software to fit the X-ray spectrum of a cluster of galaxies observed with XMM-Newton. They will be able to extract temperature and chemical abundance gradients. Finally, I will review the importance of variability in the X-ray domain in studying neutron stars and black holes.

Statistical Astronomy

Martin Hendry
University of Glasgow, UK

In many areas of astrophysics the application of advanced statistical methods to analyse very large data sets is playing an increasingly important role. Recent observational developments in cosmology, for example, supply a wealth of new data (from e.g. galaxy redshift surveys, distant supernovae and the cosmic microwave background radiation) of unprecedented quality and quantity. These data sets can in principle place powerful constraints on the parameters of cosmological models, but their analysis presents an enormous computational challenge. Sophisticated new statistical tools are, therefore, being applied to compress and characterise very large data sets, and compare them to theoretical models via quick and efficient searches of multidimensional parameter spaces.

The aim of these lectures will be to summarise recent developments in the analysis of very large astrophysical data sets, highlighting the powerful statistical tools which are now available and providing a series of concrete examples of their application. The main topics to be covered are as follows:

1) Setting the context: why does astrophysics need advanced statistics?
2) Mathematical building blocks: an introduction to probability theory
3) Statistical building blocks: sampling theory, parameter estimation and the principle of maximum likelihood
4) An introduction to Bayesian inference: prior and posterior probability, Bayesian evidence and model election
5) Bayesian and non-Bayesian hypothesis testing
6) Dealing with observational selection biases
7) Data compression methods, including principal component analysis
8) Searching multidimensional parameter spaces: Markov Chain Monte Carlo sampling
9) Robust methods: inference with minimal model assumptions
10) Current and future applications: from accelerating universes to measuring gravitational waves

Stellar Atmospheres and Data Analysis

Michèle Gerbaldi
Université de Paris XI - Orsay, Institut d'Astrophysique de Paris, CNRS, France

The guidelines of these lectures are:

- Why stellar observations ?
- Tools to interpret the observations,
- Interplay between observations and theories.

These lectures will insist upon some facts concerning the stellar astrophysics, not only how the parameters which describe the stars can be measured but also what really are we measuring due to the fact that between the detector and the star there are: the interstellar medium, the earth atmosphere and finally the telescope.

The emphasis will be put on the use of the archives of the observational data available from most of the observatories, whatever their localization is, and from the space experiments.

The physics of stellar atmospheres will be described as well as the methods used to compute a "synthetic" stellar spectra which in turn allows the determination of the photospheric chemical composition.

Examples of the methods currently used to analyze the structure of a stellar atmosphere will be developed in the framework of the determination of the abundances of some key elements for stars of various ages, in order to frame the metallicity of our Galaxie.

Astrophysics: ..... physics at work

(Plenary lecture)

Michèle Gerbaldi
Université de Paris XI - Orsay, Institut d'Astrophysique de Paris, CNRS, France

How do we organize our thinking in Astrophysics: around individual objects (planets, stars, nebulae, galaxies ...) or whether are we dividing the subject according to the physical laws in common?

An emphasize on physical concepts will make the second approach more appropriate when astrophysics is included in courses of physics and not treated as a separated subject, but rise some problems: no complete knowledge about individual types of objects can be given in a reasonable amount of time and this lead to an unevenness of the knowledge. Whatever the attitude adopted, our final understanding of the universe: its formation, its evolution, relies entirely upon the analysis of the observations with the physical concepts developed on Earth.

Due to the evolution of our observational capacity - very fast those past ten years - we have discarded what has appeared to be our most reliable theories, replaced them and frequently found even the replacement lacking.

Astrophysics is an interplay between observations and theories developed from physical concepts and we must continually revise them and create new observing tools.

Through examples taken among various astrophysical objects: stars, nebula, galaxies, I will present some of the development of astrophysics through the past years, and the future expectations with an emphasis on the topics taught during the ISYA (International School for Young Astronomers) at Al Akhawayn university.

Molecular Spectroscopy

Mohammed Badaoui
APESA- Agronomic and Veterinary Institute Hassan II., Rabat - Morocco

Lecture 1: An Introduction to Infrared High Resolution Molecular Spectroscopy

1. Classical Mechanic Energy of Rotation-Vibration of Molecules, Group Theory, and Molecular Symmetry.

2. Quantification of Rotation-Vibration Energy of Molecules, Quantum Hamiltonian and Infrared Spectra.

3. Resonances: Interaction between rotation-vibration energy levels.

4. Nomenclatures, Blass' relations and assignment of experimental spectra

5. Programming of matrix elements in wave functions standard base for C_{3V} symmetrical type molecules as CH3X (X = Cl , Br, F)…etc.

6. Least Squares method to determine parameters of the Hamiltonian. The finger prints of molecules. Applications.

7. An example of Calculation: Determination of parameters of $2n_3$ parallel band of $CH_3{}^{79}Br$ around 1214.7 cm^{-1} using a Fortran source code.

Molecular Spectroscopy

Mohammed Badaoui
APESA- Agronomic and Veterinary Institute Hassan II., Rabat - Morocco

Lecture 2: Lines Parameters Measurement in Infrared Spectra recorded by Fourier Transform Spectroscopy

This lecture presents Michelson's Interferometer or what we call Fourier Transform Spectrometer (FTS) that produces signatures of molecules in the infrared range for many purposes and especially atmospheric and astrophysics ones. We show that raw data obtained by the FTS are convoluted with the apparatus function of the instrument. Afterwards, we discuss about a method devoted to the measurement of line parameters: position, intensity, collisional width and position's shifting. More specifically, the method takes into account the influence of the throughput, of the phase error and of the channeling caused by internal multiples reflections.

- The method has been applied to the treatment of HNO_3 gas allowing one to generate improved line parameters which should be useful to produce its synthetic spectra or its infrared finger print. The unstable gas HNO_3 is harmful for the terrestrial environment for it causes acid rains. The HNO_3' rotation-vibration bands considered in this lecture are ν_5 and $2\nu_9$ (896 cm^{-1}), ν_3 and ν_4 (1334 cm^{-1}).
- Voyager 1 infrared (IRIS) spectra of Titan in 200-1400 cm^{-1} spectral region will be displayed and discussed.

Cosmology with the Cosmic Microwave Background

Pedro Gil Ferreira
University of Oxford, UK

Cosmology is the focal point of modern physics, with the interplay of mathematics, physics and astronomy. It allows for extreme speculation but also requires stringent predictions to be compared to precise experimental facts. The cosmic microwave background, the relic radiation left over from the early universe supplies us with a clean observable, which can link physical processes when the universe was a fraction of its age, to high precision, high resolution observations. In these lectures I will develop the physics of the cosmic microwave background, describe the mathematical tools one must use to make accurate predictions and the statistical tools necessary to compare it to data. I will discuss what we currently know about the state of the universe from the existing data.

PARTICIPANTS

ISYA2004 - Lecturers		
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