Juan Alday: Updates on the development of archNEMESIS

Following the recent public release of archNEMESIS, the code has attracted increasing attention, with users applying it to the analysis of spectra from a wide range of planetary atmospheres observed with diverse facilities. As a result, the codebase is rapidly expanding, with new functionality continually being introduced to address the specific requirements of this broad range of applications. In this presentation, we summarise the architecture and capabilities of archNEMESIS, highlight recent developments and performance improvements, and outline planned future functionality. We also discuss ongoing efforts to maintain backward compatibility with NEMESIS, together with strategies to ensure this compatibility is preserved as both codes continue to evolve.

Jack Dobinson: Updates to Line Data Handling in ArchNemesis

Recent updates to the ArchNemesis program have introduced a new way of handling line data. We introduce the new HDF5 formats used to hold partition function, line, and continuum data. An overview of how to create the files from data sources. And an overview of how the line data flows through the system.

Shubham Kulkarni: Containerising NEMESIS: A Reproducible Cross-Platform Solution

In recent years, compiling NEMESIS across platforms has presented some challenges. On modern Apple M-series systems, installation is often impractical, while on Linux, builds can depend sensitively on compiler choice and linker behaviour, creating barriers for new users.

These issues are addressed by packaging NEMESIS within a fixed, reproducible Docker environment. This talk outlines the containerisation process and provides guidance for installation using Docker. By encapsulating all dependencies and configurations, this approach ensures a consistent runtime environment, improving reproducibility, accelerating onboarding, reducing platform-specific failures, and enabling easier collaboration across different operating systems.

Conor Nixon: Searching for astrobiologically important molecules on Titan

Saturn's moon Titan is known for its methane-rich atmosphere, which undergoes constant photochemical processes leading to heavier organic species. Understanding the scope and extent of this chemistry is key to understanding its astrobiological potential. In recent years, high-resolution spectroscopy with ALMA and IRTF, along with observations using other facilities, have led to a wave of new chemical discoveries in Titan's neutral atmosphere. Chemistry of species with up to three carbon atoms is now relatively well constrained, and the discovery frontier is moving upwards to species with four or more carbon atoms. This presentation will describe recent and ongoing astronomical searches to discover heavier, more complex molecule in Titan's using IR and sub-mm spectroscopy, and the role that NEMESIS atmospheric radiative transfer modeling is playing in this search. I will also mention future needs for coding updates and extensions that will enable NEMESIS to cope with expected future datasets and modeling needs.

Nick Teanby: Titan from JWST and non-LTE effects on CH3 emission

I'll give a brief update on analysis of JWST MIRI spectra. Specifically temperature, along with CH3 and C3H6 emission at 16.5 microns. CH3 emission is influenced significantly by non LTE effects, which we have attempted to include into Nemesis (FORTRAN version) in a semi-general way.

Joshua Ford: Titan's stratospheric water and far-infrared haze: Results from Cassini CIRS FP1 Observations

The water abundance in Titan's atmosphere is fairly unknown with past measurements only achieving large averages and upper-limits (Cottini et al. 2012, Bauduin et al 2018). Its weak far-infrared emission lines, low atmospheric abundances and presence of mysterious hazes make it difficult to model. Here, we present the first reported latitudinal and temporal variability of H2O in Titan's atmosphere. Using NEMESIS (Irwin et al. 2008) with temperature a priori profiles from Teanby et al. 2019 and a vertical water a priori profile from Vuitton et al.2019, we retrieve water abundance in Titan's stratosphere from 157 far-infrared high-resolution Cassini CIRS FIRNADCMP observations (Flasar et al. 2004) across the entire mission, at all latitudes. We find an enhancement of water at the north pole akin to other gas species (Teanby et al. 2007, 2010) and variability across time that could be attributed to a varying incoming external flux possibly driven changes in Saturn's environment and Enceladus' neutral torus. In fitting the spectra, we also derive cross-sections for a large aerosol known as Haze B (de Kok et al. 2008 ; Jennings et al. 2012) and use these to explore its seasonality.

Lucy Wright: Mapping Titan's N-S Atmospheric Boundary using Cassini/CIRS and archNEMESIS

Titan's atmosphere has a north-south (N-S) haze dichotomy, with an unexpectedly sharp boundary near the equator. The boundary does not sit exactly at the equator, nor does it remain stationary throughout Titan's year. This makes Titan's equator a dynamically intriguing region. We map infrared-active trace species in Titan's stratosphere (~ 5 mbar pressure) throughout 2004-2017 to probe dynamics over the equator. Using low-spectral resolution Cassini/CIRS observations (and the exciting new archNEMESIS package!), we achieve the highest latitudinal resolution mapping of HCN, C2H2, C2H6, C3H4, and C4H2 to date.

Zachary McQueen: Infrared Search for Vinyl Cyanide in Titan's South Polar Limb

Vinyl cyanide (C2H3CN) is an important astrobiological molecule that has been detected in sub-mm observations of Titan's atmosphere with ALMA. Here we utilize a newly obtained pseudo-line list of vinyl cyanide's mid-infrared spectrum to search for emission features in CIRS observations of Titan's south polar limb during southern winter.

Jaime Reyes-Guerrero: Venus atmospheric variability: Bayesian analysis and large-scale retrieval

Venus cloud structure has been studied for decades due to its significant impact on various aspects of the atmosphere such as sulfuric acid production, atmospheric dynamics and radiative energy balance. The VIRTIS instrument onboard Venus Express mission provided valuable data with a high temporal and spatial coverage of the southern hemisphere, enabling a detailed study of the variability of the thermal and cloud structure and forming the basis of our work.

Using the Bayesian inference tool MultiNest, available in archNEMESIS, we study the information content on aerosol vertical distribution that can be retrieved from these observations and define a new parameterisation to reanalyse VIRTIS-M-IR database. In this process, a clustering algorithm is applied to each observation to obtain instantaneous maps of physical properties (temperature, cloud abundance, cloud top altitude, cloud opacity), allowing us to analyse both the spatial and temporal variability of the atmosphere.

Shahid Aslam: Compact Ultraviolet to Visible Imaging Spectrometer (CUVIS) - A Tech Demo on the DAVINCI Mission to Venus

The Compact Ultraviolet to Visible Spectrometer (CUVIS) is an innovative small footprint UV to visible, with spectral range 200–570 nm, dual-band dispersion spectrometer that will complement the science obtained from the DAVINCI baseline mission instruments. The spectrometer's primary goal is to investigate radiative balance, cloud properties and chemistry of Venus's atmosphere, address the vexing scientific problem of the unknown UV absorber at the cloud tops. CUVIS key technologies are: free-form optics that enable high spatial and spectral resolution measurements in a compact design and advanced onboard data processing technologies, based on artificial intelligence (AI) hardware and software, for near real-time atmospheric parameters retrieval.

Pat Irwin: "Holistic" Cloud Model for Jupiter?

Analysing observations of Jupiter made by VLT/MUSE, Cassini/VIMS, and Juno/JIRAM, I will present early results of a new combined cloud/ammonia profile model for Jupiter's equatorial atmosphere. We find this model to be consistent with all observations considered, at a range of observation geometries, within the Equatorial Zone (EZ), the North Equatorial Belt (NEB) and a North Equatorial Dark Feature (NEDF), also known as a '5-micron-hotspot'. Preliminary results suggest the presence of three main layers: 1) a deep 'Cloud-1' at 1-2 bar; 2) an upper 'Cloud-2' in the upper troposphere based at ~0.55 bar; and 3) a layer of chromophore particles situated within the Cloud-1 layer, responsible for the blue-absorption at visible wavelengths. Our best-fit ammonia profile is closely linked with our cloud profile, with Cloud-1 coinciding with a sharp drop in ammonia abundance, perhaps associated with the formation of a H_2O-NH_3 'mushball' cloud, or an ammonium hydrosulphide (NH_4SH) cloud, or both, and Cloud-2 coinciding with the ammonia condensation level.

We find the bulk of the cloud opacity in Jupiter's atmosphere to be in the Cloud-1 layer, based at 1-2 bar and composed of relatively large particles (r ~ 10 micron), which are highly scattering at visible wavelengths to allow sunlight to penetrate and be Rayleigh-scattered from the deeper atmosphere, but more absorbing at 5 micron. The belt/zone difference at 5 micron is accounted for by changes in the opacity of Cloud-1 and also the single-scattering albedo of these particles. We find the Cloud-2 layer, based at the ammonia condensation level, to be approximately 10 times less opaque than Cloud-1 and have an absorption band near 3 micron, which is consistent with this layer having a significant opacity of large (r ~ 10 micron) ammonia ice particles.

Mikel Sanchez Arregui: Study of Jupiter's Equatorial Stratospheric Oscillation through the characterization of the temperature field, clouds and aerosols from the troposphere to the stratosphere between 2015-2026

Jupiter's Equatorial Zone exhibits a set of atmospheric phenomena that differ from what is observed in other latitudes of the planet, including a multi-year oscillation in stratospheric temperatures and winds. The vertical extent of this Jupiter's Equatorial Stratospheric Oscillation (JESO) is not well determined, although recent studies in thermal infrared observations suggest that JESO might extend down to 300 mbar, thus linking the tropospheric and stratospheric activity. The first Jupiter observations taken in June 2022 by the James Webb Space Telescope (JWST) revealed the presence of an intense narrow equatorial jet located at the lower stratosphere (50-200 mbar), that has been suggested to be a deep counterpart of JESO.

In this work, we will analyse mid-infrared TEXES observations from 5 to 20 microns obtained over multiple years to characterize the thermal state of Jupiter's equatorial atmosphere at different altitudes. After processing and calibrating the spectral data for a full Jovian year (2015-2026), we will derive the atmospheric properties of the atmosphere through retrievals of the vertical structure of the atmosphere with the NEMESIS radiative-transfer and retrievals codes. The spectroscopic inversions will provide high resolution 3D profiles of temperatures, composition and aerosols that will enable studying the differences of these properties along different altitudes of the atmosphere with greater accuracy. This characterization is essential to unveil the relation between stratospheric and tropospheric phenomena at the equator, and, therefore, the potential links between JESO, the equatorial jet and convective tropospheric activity.

Asier Anguiano Arteaga: Microphysical modelling of Jupiter's Oval BA colour changes and recent Cassini/VIMS–ISS processing

Since its formation in 2000 through the merger of two long-lived white ovals, Jupiter's Oval BA has undergone recurrent colour changes, with its annulus evolving from white to red, then towards a whiter state, and later becoming reddish again. This talk presents microphysical modelling of the upper chromophore haze, constrained by NEMESIS retrievals of HST/WFC3 observations for the red 2016 annulus and the whiter 2020 state. The model is used to investigate possible physical causes capable of reproducing the observed decrease in the optical depth of the chromophore layer on sub-annual timescales. The results favour enhanced subsidence in the annulus, with downwelling velocities of order 10^{-4}–10^{-3} m s^{-1}. A brief final update will introduce a new public catalogue of calibrated Cassini/VIMS Jupiter observations and ongoing work combining these data with Cassini/ISS UV imaging, aiming to build a dataset spanning from the UV (0.25 μm) to the thermal IR (5.12 μm). This broad spectral coverage will allow aerosol and cloud properties to be probed from small particles in the upper atmosphere down to deeper cloud layers.

Emma Dahl: Characterizing the Convective Strength of Jovian Meso-Scale Storm Systems with JunoCam

JunoCam, Jupiter's optical camera, was not photometrically calibrated before launch due to time and budget constraints, rendering the spectral information in its high-spatial resolution images unreliable. In order to probe the structure of small (~100-1000 km) meso-scale storm systems as observed by JunoCam, we utilized deep learning to generate models of calibrated JunoCam data from complementary HST datasets. Here, I'll present the results of running NEMESIS retrievals on those model-calibrated data and our first results on the properties and convective strength of meso-scale storms on Jupiter.

Shubham Kulkarni: Comparative analysis of Venera 11, 13, and 14 spectrophotometric data: implications for the near-surface particulate layer

The extreme conditions in Venus's lower atmosphere make robust calibration of in situ observations challenging. Consequently, measurements from past entry probes provided mixed evidence regarding the existence of a near-surface particulate layer (NSPL). Although the Venera 11 (1978) and Venera 13 and 14 (1982) landers performed in situ spectrophotometric observations during descent, the original datasets were later lost. However, a subset has been reconstructed by digitising graphical outputs produced during the missions' initial data-processing phase. Following careful analysis to identify and mitigate errors and other artefacts, the reconstructed dataset retains the reliable downward-looking spectra acquired by the three landers from ~62 km altitude to the surface.
Previous retrievals from the reconstructed Venera 13 indicated an NSPL centred at ~3.5–5 km, with particulate optical properties consistent with a basaltic composition. Following the methodology of, we use NEMESIS, a radiative transfer and retrieval code, to perform near-surface retrievals from the reconstructed Venera 11 and Venera 14 datasets. The results from Venera 11, 13, and 14 retrievals are compared with reported detections and non-detections from other instruments on earlier in situ missions, to explore potential formation pathways for the NSPL in light of the combined observational record.

Jo Barstow: Updates on NEMESISPY for exoplanet science including capturing 3D effects

Exoplanets present a distinct challenge to remote sensing and retrievals since they are not spatially resolved in observations. Transit spectra, that probe absorption at the limb of the planet, may be sensitive to variation in atmospheric composition and structure as a function of angle around the limb but also, for very hot objects, in the line of sight. Phase curve observations provide some explicit information on longitudinal variation to break these degeneracies. I will provide an update on the analysis of ultrahot Jupiter WASP-121b using both phase curve and transit measurements.

Another challenge which is shared with solar system applications is the appropriate representation of clouds, especially where they produce distinct spectral features. I will discuss the latest method we are using to allow Bayesian retrievals of cloud properties and the new funded project to take this further.