Activity reports from research teams

Centre de Données astronomiques de Strasbourg (CDS)

One key of the success and sustainability of CDS has been that it has from the beginning been fully included in a scientific structure, the Observatoire Astronomique de Strasbourg, and that the team includes active scientists. Their expertise is mandatory to ensure the quality of content and the relevance of the services on the long term, taking into account the constant evolution of astronomy and of users' needs. The founding fathers of CDS, when it was the Centre de Données Stellaires, were stellar astronomers. Taking into account the extension of SIMBAD to other objects and the development of multi-wavelength astronomy, the expertise of CDS astronomers now covers a palette of domains which will be described in the following: stellar astronomy - circumstellar matter, AGB/Post AGB stars (C. Loup); galactic astronomy - ISM, formation of stars (L. Cambrésy), formation of the galactic disk, large surveys, simulations (A. Siebert); extragalactic astronomy – ISM in nearby galaxies (C. Bot), cluster galaxies, galactic centres, galactic evolution (B. Vollmer), AGNs (M. Allen), "VO science" (M. Allen, I. Chilingarian). Several scientific topics are also linked to the CDS activities, in the domain of ontologies, semantics, information discovery (S. Derriere); cross-identification methods (S. Derriere, T. Boch, F.-X. Pineau, B. Vollmer); image processing (F. Bonnarel, M. Louys, B. Vollmer).

For the CDS, the requirement is the diversity of scientific topics, and not as usual building a critical mass on the subjects. CDS scientists have many collaborations with colleagues working in their fields in other laboratories, and there are also very good interactions with the other teams of the Observatory, with common scientific projects and publications, a common seminar with the Team "Galaxies", and exchange of expertise with the SSC-XMM (for instance common supervision of F.-X. Pineau's PhD). Some of the activities of the CDS researchers are put in a more general context in the reports of the other teams. CDS astronomers participate in large surveys such as RAVE, but also e.g. to Spitzer surveys such as SINGS, SAGE-SMC, or S3MC. They are using many ground and space-based telescopes, including AAOmega on the AAT, VLT/FLAMES, Herschel (HERITAGE), Planck, and LABOCA on APEX.

The research activities of the team will be briefly summarised in the following sections, plus a few words on the prospective on some of the topics, since it has been chosen to gather the description of the Observatory scientific strategy under the main themes of the two other teams and there is no specific prospective section for the CDS scientific activities.

Stellar astronomy

Loup

The activity of Cécile Loup is concentrated on the study of the Asymptotic Giant Branch stars of the Large Magellanic Cloud (LMC). The AGB is a short (100 000 years) evolution stage of stars below 6 $M_{\odot}$ at the end of their lives, which follows the red giant phase: these stars lose a large part of their mass and build an expanding circumstellar envelope, which is finally ejected into the interstellar medium. These cold and luminous stars are pulsating. Depending on their evolution phase and metallicities they belong to 4 different period-luminosity relations, and depending on the envelope density the emission maximum goes from optical RI bands to mean infrared.

These stars have been first catalogued in the LMC from objective prism observations or from optical photometry surveys detecting long period variables. About thirty catalogues of the whole or part of LMC are available, but they are not directly usable because, except one, the authors did not perform cross-identification between the different types of surveys. Also, the modern large photometric surveys such as

2MASS, DENIS and Spitzer SAGE, plus OGLE, EROS and MACHO for the Long Period Variables, should allow one to detect most of the AGB stars, but they do not give access to spectral information. A long term project is on-going, to cross-identify the whole information available since 1960 into a reference catalogue of LMC AGB stars. This has been a difficult task for many reasons, including problems with the astrometry in early catalogues, which requires verification by eye. The catalogue is being finalised, and will be made easily accessible to the community. It will be used to revisit the period-luminosity relations, and to establish the luminosity function of AGBs in the LMC, which is an important parameter in galaxy modelling.

Galactic astronomy

Cambresy, Siebert

ISM and star formation. Laurent Cambrésy is interested in the interstellar medium of our galaxy, with the main objectives to understand the structure of dense regions, to measure dust grain properties and to study the variations of the gas-to-dust ratio. The aim is in particular to study molecular clouds by comparing extinction in the near and mid-IR, dust thermal emission, or gas emission. He also addresses the history of star formation in the clouds.

Among the results, the study of the molecular cloud of the Trifid nebula (ACL11-34) has led to an unexpected result on the extinction law: the flattening of extinction beyond 3μm when visual extinction is larger than 20 magnitudes. This had never been observed before. In addition, the emissivity of the Trifid Cores is twice the one observed in other dense regions, and the Trifid distance has been re-evaluated to 2.7 kpc, instead of the current value 1.7 kpc. On the other hand, the gas-dust relation has been studied in details in the Taurus Cloud, and the value of $X=[CO]/[H_2]$ in this cloud is similar to the galactic value.

The next step will be to use data from Planck, Herschel and WISE to determine more precisely dust temperatures, and then their emissivity, to understand better the process responsible for their variation. A 3D study of ISM distribution, using submillimetre data and inversion techniques requiring the knowledge of extinction, has begun using Herschel HI-Gal data in collaboration with IPAC/CalTech. WISE data will be also used to develop studies of young stars and stellar formation, in particular in the Rosette Nebula for which lots of X-ray data is also available.

Galactic dynamics and kinematics. Arnaud Siebert's research is focused on the Milky Way, trying to understand the mass distribution and history of our galaxy using large scale surveys, in particular spectroscopic surveys. He has been in particular deeply involved in the RAVE survey (pipeline computing the radial velocity and the atmospheric parameters, data validation, input catalogue construction − ACL11-8; ACL08-23; 19 papers since 2007 based on the RAVE catalogue). A PhD under his supervision at the AIP has built a pipeline to measure the abundances of 14 elements from the RAVE spectra (Boeche, Siebert et al, 2011, submitted). The RAVE pipeline has been adapted to handle AAOmega and VLT/FLAMES, with applications to study respectively the dynamics of globular clusters of the Milky Way (ACL09-2, ACL10-76, ACL10-33, ACL10-72, ACL11-13) and the Palomar 5 and Sagittarius streams, in close collaboration with the Galaxy team. Work is on-going to release a stable version of the pipeline for community usage.

Using the RAVE catalogue, the inclination of the velocity ellipsoid at 1 kpc below the galactic plane was measured for the first time (ACL08-1). The knowledge of the amplitude of the tilt at various heights above/below the plane provides a unique tool to test the mass distribution of the Milky Way, and we showed that the measured value further confirms that the dark halo cannot be significantly flattened. Analysing the global motion of the stars in the RAVE survey, we also detected significant non-circular motion in the extended Solar neighbourhood (ACL11-20), likely associated to non-axisymmetric

perturbations in the Galactic disc, the influence of local spiral arms being so far the most likely explanation. The importance of the spiral arms and of the Galactic bar on the local dynamics is now well established and can be observed via the clumping in velocity space (ACL08-29, ACL09-29, ACL10-21). Comparing the two effects should help constrain the amplitude of the spiral arms in the near future.

For the future, theoretical work on the perturbations of the galactic disc are planned in collaboration with the Galaxy team, as well as participation in the Gaia/ESO survey and in 4MOST on the VLT, HERMES on the AAT and Gaia.

Extragalactic astronomy

Allen, Bot, Chilingarian, Vollmer

Interstellar medium in nearby galaxies. Caroline Bot studies infrared to millimetre dust emission in galaxies, especially in the Small Magellanic Cloud (SMC). The Magellanic Clouds are excellent candidates to study interstellar dust in an environment different from our Galaxy, because of their proximity and low metallicity, and to make the link with more distant galaxies.

The mass of dust can be used to trace the gas which is not observed by other tracers such as HI or CO. This "dark" gas has been observed in our galaxy and in nearby galaxies, and could correspond to molecular cloud envelopes. If so, the "dark" gas quantity should increase at low metallicities. C. Bot has observed that this is the case in the giant molecular clouds of the SMC, by showing that the quantity of molecular gas traced by dust emission is higher than the virial masses computed from CO observations (ACL07-40, ACL10-3). Another aspect is the excess in dust emission observed in far infrared and millimetre wavelengths at low metallicities. By extending the spectral energy distribution of the Magellanic Clouds with WMAP and TopHat, it was shown that the excess observed in far infrared and submillimetre extends to the centimetre domain (ACL10-31, ACL10-14). This cannot be explained by the reasons usually put forward, in particular it cannot be very cold dust since it should be as cold as the CMB. Using Planck observations it has been shown that CMB fluctuations can explain the excess observed in the LMC, but not in the SMC where a significant excess remains (Planck collaboration, 2011, arXiv: 1101.2046).

Among other studies, the search for dust emission in intergalactic clouds, e.g., the Leo intergalactic Cloud (ACL09-19). Projects involve the analysis of data obtained by Planck and Herschel on the Small Magellanic Cloud and foreground cirrus, which can significantly bias extragalactic observations, and participation in an international team to inter-calibrate dust models.

Cluster galaxies, galactic centres and galaxy evolution. Bernd Vollmer develops different studies in these domains, with a wide set of collaborations. One is linked to the evolution of cluster galaxies, with the development of a code simulating the interactions of a spiral galaxy with its environment, and observations of a significant number in CO, HII and continuum. The comparison between observations and simulations has led to the first model-based ram pressure stripping time sequence for spiral galaxies of the Virgo cluster (ACL07-28, ACL08-8, ACL08-30, ACL09-22, ACL09-45, ACL10-73, ACL10-69, ACL11-19). He also studies the physics and dynamics of gas in the Galactic centre and in AGNs. An analytical and dynamical model of gas in the central 20pc of the Milky Way has been developed, which has then been generalized to active galactic nuclei (ACL08-9). In addition, he is studying the theory of clumpy turbulent accretion disks, by extending it to describe galactic disks, with application to nearby galaxies (ACL11-45).

The cross-identification of radio catalogues, realised as a service task for CDS (ACL10-79), has also allowed the discovery of new sources with peculiar spectra. Follow-up radio observations have confirmed 65 new Gigahertz-Peaked Spectrum (GPS) and High Frequency Peaker (HFP) sources to add to the known <200 sources from existing samples (ACL08-15). These are young AGN sources with peculiar properties, which are not so well studied for the moment.

Physics of ionized gas in galaxies. Mark Allen's research work in the field of Active Galaxies is focused on understanding the physical processes in galaxies in order to study the effect of Active Galactic Nuclei (AGN) on their host galaxies, and to establish the role of AGN in the formation and evolution of galaxies.

A major theoretical modelling effort to compute the MAPPINGS III Library of Fast Shock Models was completed in 2008 (ACL08-16). Combined with AGN photoionization and starburst ionizing models, the shock models have been made accessible in a uniform way via a program called ITERA, the IDL Tool for Emission-line Ratio Analysis (ACL10-17). These models are being applied to a range of astrophysical phenomena (66 refereed citations since 2008). Recent low velocity shock models (v<200 km/s), along with all the ITERA models, have been developed to support analysis of ionized gas in nearby interacting galaxies with HST. One can also cite two studies performed with PhD students: an extensive study of the environments of High Redshift Radio Galaxies, and AGN in galaxy clusters (ACL09-8); the X-ray properties of LINER galaxies (ACL10-62, with the High Energy astrophysics team).

VO science. One can cite here the results obtained from one of the projects selected in the framework of the 2008 Announcement of Opportunities of the EuroVO-AIDA project for advanced exploitation of astronomical digital archives through VO tools. This project, *Is a galaxy's disk scale-length universal?*, was supported by CDS. The project has derived key parameters for the largest ever sample of galaxies in a robust and homogeneous way, using Virtual Observatory methods and tools (ACL10-35). These parameters have subsequently been used by Fathi to show that the stars populating the discs of galaxies are distributed in the same fashion throughout the entire Hubble sequence.

Another example is the series of studies of compact elliptical and ultracompact dwarf galaxies by I. Chilingarian, which combine data mining using the Virtual Observatory, optical spectroscopy, stellar population synthesis and the usage of workflows.

Information research and processing

Boch, Bonnarel, Derrière, Louys, Pineau, Vollmer

This domain is in particular the domain of research of the CDS staff with 'instrumentalist' profile, but other researchers with a more classical profile are also involved. In the previous period (2001-2006), several projects in the *Action Concertées Incitatives* framework were performed in collaboration with IT laboratories, in the domain of semantics and ontologies, of image processing, and of 'system architecture'. The period of the present report has rather been for exploitation of the knowledge gained from these collaborations, in particular in R&D programmes linked to European projects (VO-TECH and EuroVO-AIDA), and in the definition of IVOA standards. The International Virtual Observatory Alliance (IVOA, www.ivoa.net) is a worldwide alliance of the VO projects which coordinates the development of the VO and the definition of the interoperability standards which constitute the VO framework. It is important to note here that IVOA standards follow a tough review process in successive steps by the whole community of IVOA developers, which is much harder than the one of refereed publications. These standards should be considered as the equivalent of refereed publications for 'instrumental' research. In addition, papers presented at the ADASS conferences are similar to the SPIE papers for more classical 'instrumental' research. The details of these publications can be found in Sections PT, C-ACTI and C-AFF of the publication list.

Ontologies. The aim was to experiment on 'real' usage of ontologies, and for this a full ontology of astronomical object types was built, which contains concepts and the relations between them. This domain

was chosen because of CDS knowledge about astronomical objects, gathered in particular when building SIMBAD content, and because the number of concepts remains manageable. An IVOA standard for Vocabularies in the Virtual Observatory was also worked out,. It specifies a standard format based of the W3C's Resource Description Framework (RDF) and Simple Knowledge Organisation System (SKOS), which permit different groups to create and maintain their own specialised vocabularies while letting the rest of the astronomical community access, use, and combine them. The use of current, open standards ensures that VO applications will be able to tap into resources of the growing semantic web.

Cross-identification. CDS collaborated with the High Energy Astrophysics Team in the development of a cross-match algorithm to cross-match the XMMi catalogue with the 7th release of the SDSS (PhD of F.-X. Pineau, ACL11-35). One also has to recall here the cross-identification of radio catalogues for SIMBAD, taking into account the physical characteristics of sources and observations, which produced a new catalogue, SPECFIND, and a set of VO tools (ACL10-79). Since then, a more general algorithm is being built for the CDS cross-match service, with the aim to be able to cross-match efficiently very large catalogues, taking into account positional errors (ACTI11-20). This has led to the development of methods relying on multi-threaded modified kd-trees and HEALPix tessellation to manipulate and allow fast query by position for tables up to several billion rows. We also developed a method to compute fast likelihood ratios on a cross-match result.

Image processing. The collaboration with the LSIIT[1] continued, on object detection using a Markovian approach based on hierarchical neighbourhood relations and Bayesian inference. Images pixels are sorted into different classes according to their surface brightness and spatial continuity. This method has been successfully applied to the detection of Low Surface Brightness Galaxies, and its usage in the CFHT Large Program called "Next-Generation Virgo Survey" (NVGS, see Page 17Galaxies residing in Clusters) is being assessed.

[1] LSIIT is the *Laboratoire des Sciences de l'Image, de l'Informatique et de la Télédection* (UMR 7005, Illkirch)