ASTRONOMY IN FINLAND

AN OVERVIEW IS GIVEN OF ASTRONOMICAL RESEARCH IN FINLAND. THERE ARE THREE INSTITUTES DEVOTED TO ASTRONOMY IN GENERAL, AT THE UNIVERSITIES OF HELSINKI, OULU, AND TURKU, AND A RADIO ASTRONOMY OBSERVATORY AT THE HELSINKI UNIVERSITY OF TECHNOLOGY. IN ADDITION, SOLAR SYSTEM RESEARCH WITH SPACE-BORNE INSTRUMENTATION IS BEING CARRIED OUT BY THE PHYSICS DEPARTMENTS AT THE UNIVERSITIES OF HELSINKI AND TURKU, AND BY THE FINNISH METEOROLOGICAL INSTITUTE.

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FINLAND HAS A LONG TRADITION in Astronomy. The first University in Finland, the Academy of Turku (Åbo), was founded in 1640, and Astronomy was taught there from the very beginning. The first Finnish scientist to rise to world fame was the astronomer and mathematician Anders Lexell who was appointed Docent of the Academy in 1763. Lexell showed that a comet, discovered in 1770, would, after a passage close to Jupiter in 1779 be slung out of the solar system. This happened as predicted, was a great victory of celestial mechanics and Newton's theory, and made Lexell's name and the comet famous all over Europe.

In 1748 the first dedicated position in Astronomy, Observator, was established, and in 1817-19 an observatory was built, equipped with the best instruments of its time. The observator Henrik Johan Walbeck became known for his study on the size and shape of the Earth. In 1823, the Academy invited, following the advice of Wilhelm Bessel, his pupil Friedrich W. A. Argelander to the Observator position. Argelander's grandfather, a smith and a descendant of the family of Kauhanen-Argillander from Savo county in eastern Finland, had moved to Prussia where his son became a wealthy merchant. Argelander's activity at the new observatory was soon to be interrupted by the great fire of Turku. In his observing logbook of the evening of September 4th, 1827, one can read the following classical statement by a scientist living in his "ivory tower": "*These observations were interrupted by a terrible fire which put into ashes almost the whole city, but thank the Lord, left the observatory intact*."

As a consequence of the fire, the capital of Finland and the University were relocated to Helsinki. There, a new observatory, designed in close collaboration between Argelander and the state architect C. L. Engel, was established in 1834 (Fig. 1). The Observator position was upgraded to Professor's chair in 1828, and Argelander was appointed its first holder. Based on accurate proper motions from his own meridian circle observations in Turku and earlier data from others, Argelander published in 1837 a famous study on the determination of the Solar Apex. However, within the same year he moved to Bonn where he founded a new observatory and rose to become one of the leading figures of 19th century Astronomy.

After Argelander, the Observatory participated under the leadership of Adalbert Krüger, in the big international catalog work AGK1 of the Astronomische Gesellschaft. At the turn of the century the most extensive international enterprise in Astronomy so far, the photographic "*Carte du Ciel*" survey, started with the participation of Helsinki (Anders Donner) and seventeen other leading observatories around the world. The celestial mechanics tradition was continued at the beginning of the 20th century by Karl F. Sundman whose works on the three-body problem brought him international fame. Later on, research in celestial mechanics and relativity theory was carried out by Gustaf Järnefelt and Paul Kustaanheimo. Astrophysical and Radio Astronomy research were introduced at the University of Helsinki by Jaakko Tuominen after World War II.

After a hiatus of a hundred years, astron-

Figure 1: Helsinki Observatory, established in 1834, belongs to the group of neoclassical, historical buildings of the centre of the city.

Figure 2: The 13.7-metre radio telescope of the Metsähovi Radio Observatory, Helsinki University of Technology, is enclosed within a 20-metre radome that protects the telescope from rain, snow and wind. The surface accuracy of the telescope is 0.1 mm (rms). The observing frequencies available at Metsähovi range from 2 to 150 GHz, the lower end being used for geodetic VLBI and the higher end for millimetre VLBI. The primary observing frequencies, however, are in the mid-range, 22 and 37 GHz.

Institute	Senior staff	Post-docs	PhD students	Technical/ admin. staff
Observatory University of Helsinki	11	5.5	10	7
Tuorla Observatory University of Turku	16	11	13	4
Division of Astronomy University of Oulu	4	7	6	–
Metsähovi Radio Observatory Helsinki University of Technology	4.2	–	1.7	8.4
Dpt of Physical Sciences University of Helsinki and Helsinki Institute of Physics	2.6	1.8	8.6	3.3
Dpt of Physical Sciences University of Turku	4	3	4	1
Finnish Meteorological Institute Geophysical Research	5	–	3	8

Table 1. Personnel resources of Astronomy in Finland, year 2003. Included in Astronomy is all space research beyond the Earth's magnetosphere. (unit: person-years of work).

omy returned to Turku in 1924 when Yrjö Väisälä, the professor of physics at the newly founded University of Turku, also started giving lectures in Astronomy. The main interests of Väisälä were classical astronomy, celestial mechanics, and precision optics. These traditions were continued by Liisi Oterma and are still active fields in Tuorla Observatory, a separate research institute of the University of Turku, which Väisälä founded in 1951.

Astronomy teaching at the University of Oulu started in the early 1960's and a professor's chair was established in 1964 with Antero Hämeen-Anttila as its first holder. His research traditions in celestial mechanics and planetary science are being continued by his pupils both in Oulu and Helsinki.

The Metsähovi Radio Observatory, founded in 1975 by Martti Tiuri, then professor of Radio Technology, is a separate research institute of the Helsinki University of Technology (HUT). It operates a 14m diameter radome-enclosed radio telescope (Fig. 2) in Kylmälä, about 35 km west from the HUT campus in Espoo.

Present resources

The present personnel resources of Astronomy in Finland are summarized in Table 1. Besides the four astronomical institutes mentioned above, solar system research is also being carried out by Space Physics groups at the Universities of Helsinki and Turku as well as at the Finnish Meteorological Institute (FMI). Particle cosmology groups are active at the Universities of Helsinki and Turku. In total the Astronomy community in 2003 counted 47 senior researchers (including 6 professors in Astronomy and 3 in related fields of Physics), 28 Post-docs, 46 PhD students, and 32 technical/administrative staff. The number of PhD degrees awarded was 10. The personnel costs, including salaries and student grants, were 5.9 M€, half of which was covered by soft money from the Research Council for Natural Sciences and Engineering, private foundations and similar sources. The running costs were 1.2 M€, the participation fees in the Nordic Optical Telescope (NOT)(29.7% share) and Swedish-ESO Submillimetre Telescope (SEST) (5% share until 30.6.2003) were 380 K€. Finland's membership fee in ESA's space science programme was ca. 5 M€, more than half of which can be accounted for by Astronomy. Two major space instrumentation projects (Planck 70 GHz receiver; X-ray detector development) received government funding, partly via astronomy institutes, in a total of 3.4 M€ in 2003.

Thanks to Finland's membership of ESA since 1995 there has been active participation in several of its space missions, including e.g. SOHO, Cluster, ISO, INTEGRAL, Mars Express. The hardware participation

Table 2. Finnish space science instrumentation and industrial participation in ESA and bilateral Astronomy missions since 1995.

Program	Main partners	Finnish participation	Launch
SOHO	ESA	ERNE and SWAN instruments	1995
Huygens	ESA	HASI instrument, lander radar altimeter	1997
XMM-Newton	ESA	Telescope structure and satellite electronics	1999
INTEGRAL	ESA	JEM-X instrument	2002
Mars Express	ESA	ASPERA-3 instrument, participation in Beagle-2 lander, satellite power electronics	2003
SMART-1	ESA	XSM and SPEDE instruments	2003
Rosetta	ESA	In Main S/C: OSIMA, ICA, LAP and MIP instruments, satellite power electronics, satellite structure In Philae lander: PP instrument CDMS mass memory	2004
Venus Express	ESA	ASPERA-4 instrument; S/C power distribution units	2005
Herschel	ESA	Main mirror	2007
Planck	ESA	70 GHz receiver for LFI	2007
Mars-96	RUS	Central electronics units, sensors and S/W for landers	1996 failed
Cassini	USA	Hardware for IBS, CAPS and LEMS instruments	1997
Stardust	USA	CIDA instrument	1999
Odin	SE,CAN,F	119 GHz receiver and antenna measurements	2001
Radioastron	RUS	22 GHz VLBI receiver	TBD?

by institutes and industry in Space Astronomy projects since 1995 is listed in Table 2. One ongoing project with particularly wide Finnish hardware participation is the Rosetta Cornerstone Mission (Fig. 3).

In the following chapters we describe in more detail the current research fields and highlight some results of the four astronomical institutes in Finland.

Observatory, University of Helsinki

Most of the research work at the Helsinki Observatory is done in three research groups: Interstellar medium and star formation; High energy astrophysics; and Planetary-system research.

Interstellar medium and star formation

Physical and chemical conditions in star forming clouds and the star formation process itself are being studied using observations from radio to optical wavelengths, and by applying advanced radiative transfer modelling to their interpretation.

Pre-protostellar and young stellar objects, still deeply embedded in their parental molecular clouds, are being detected and physically characterized by using far-IR mappings with the Infrared Space

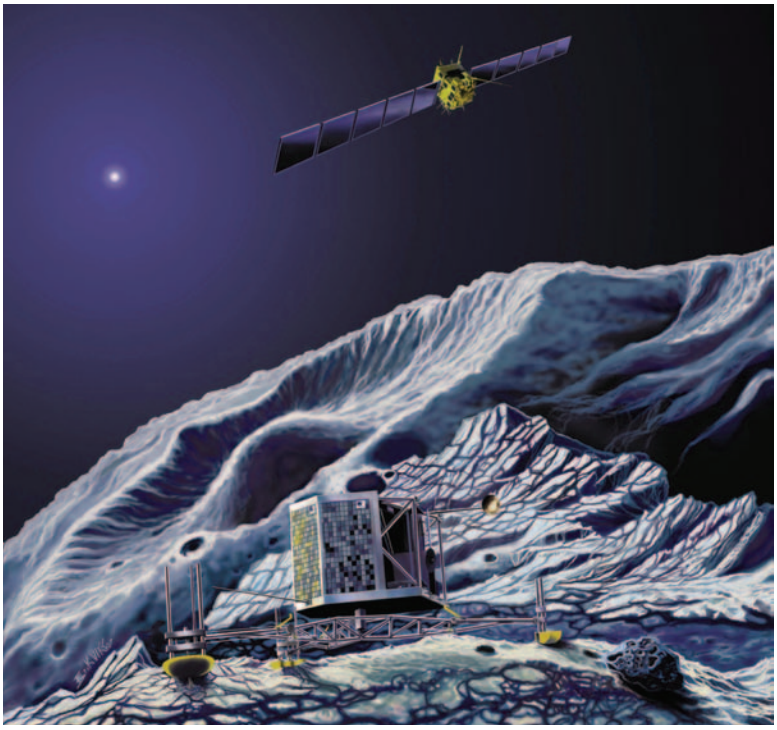


Figure 3: Rosetta Mission to comet Churyumov-Gerasimenko. The Finnish Meteorological Institute has provided subsystems to four scientific units aboard the main Rosetta spacecraft and is responsible for the permittivity probe and the solid state mass memory of the lander Philae. Finnish industry has built the mechanical structure of Rosetta and the power distribution system. (Picture ESA)

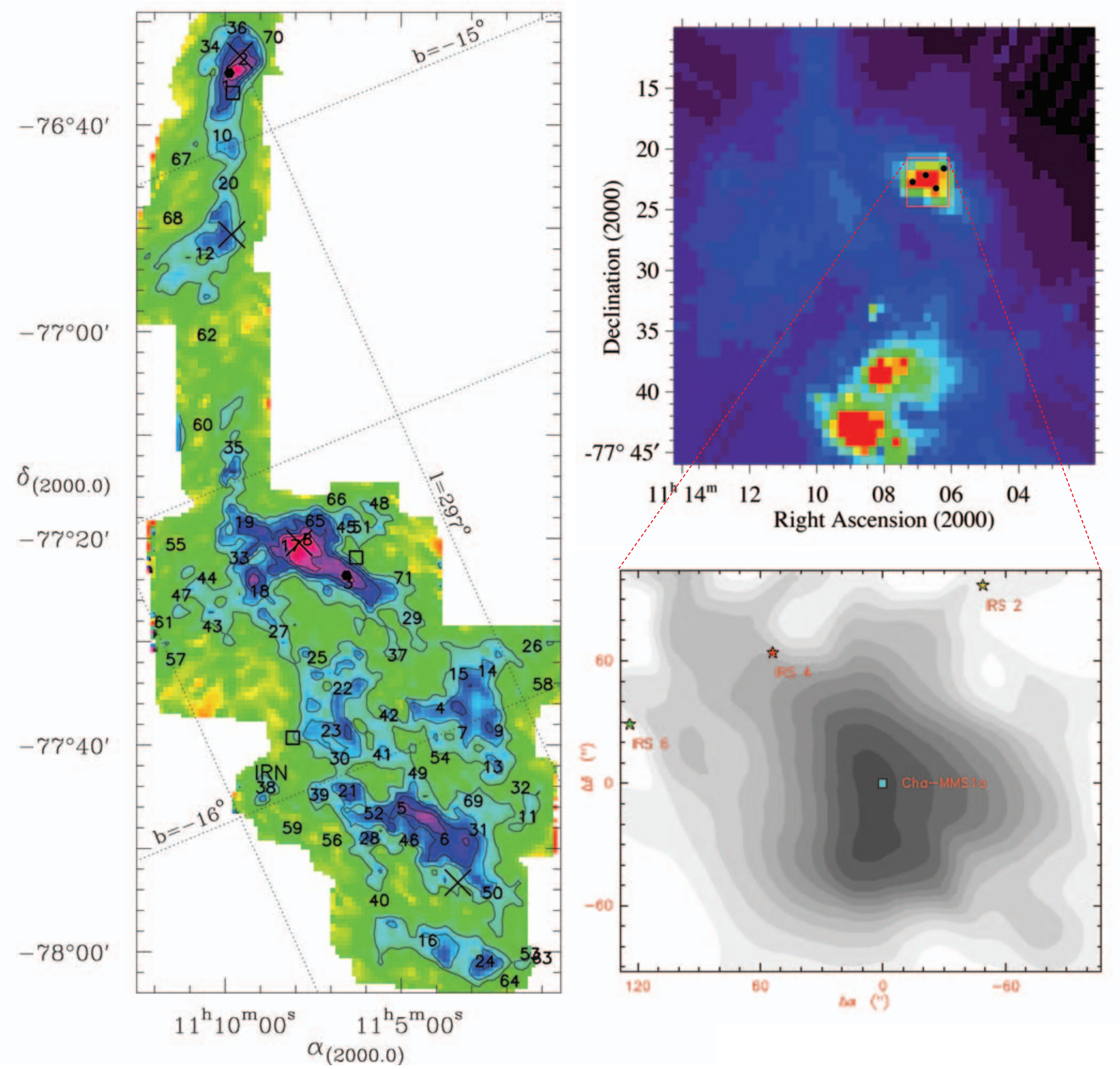


Figure 4: **a)** Clumpy filaments in the Chamaeleon I molecular cloud: the integrated $C^{18}O$ (J=1–0) intensity map measured with SEST. The locations of clumps, identified in the $C^{18}O$ spectral data cube with an automatic routine, are indicated with numbers (Haikala, Harju et al. 2004); **b)** ISOPHOT 100 µm mapping of the Ced 110 area in Chamaeleon I with four embedded infrared sources indicated as dots (Lehtinen et al. 2001); **c)** HC_3N(J = 10–9) map from SEST of the Ced 110 area with the four embedded sources. The HC_3N emission peaks at the position of the Class 0 protostar candidate Cha-MMS1 (Kontinen et al. 2000). Recent high resolution ATCA NH_3(1,1) mapping by Harju et al. reveals velocity structure, suggesting a proto-binary with precessing jets at this position.

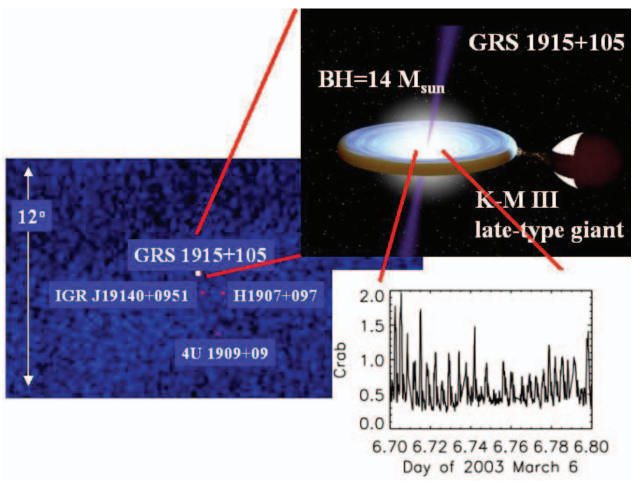


Figure 5: The left-hand side shows the INTEGRAL image of the field around the micro-quasar GRS 1915+105 (also visible is the new source discovered during the observation, IGR J19140+0951). The top-right diagram shows an artist's conception of GRS 1915+105, which consists of a 14 solar-mass black hole accreting matter from its companion. In the lower right-hand corner is the X-ray lightcurve showing the newly discovered 5-minute oscillations. (Hannikainen et al. 2003)

Observatory (ISO) and by molecular line spectroscopy with SEST of nearby molecular clouds (Fig. 4). Interaction between protostellar systems and their immediate surrounding ISM have been studied with the aid of high-resolution interferometric radio continuum observations at the Australian Compact Array ATCA.

The structure, energy balance, and dense core formation in interstellar clouds have been studied by applying three-dimensional radiative transfer codes, which have been developed for both the mm-wave molecular spectral lines and optical-infrared continuum radiation from dust.

Using ISO, the group has also studied the properties of the different populations of interstellar dust. The distribution and properties of the so-called *Unidentified Interstellar Bands*, probably due to large aromatic molecules like PAHs, have been studied over the whole inner Galaxy, and in different individual clouds.

The group is studying the *Extragalactic Background Light* (EBL) both at optical and far infrared wavelengths. Early photometric studies at La Silla with the "dark cloud method" have been described by Mattila and Schnur (1990). Spectroscopic observations are now going on at the VLT.

The group has been involved as Co-Investigator in the ISO Photometer instrument consortium. Several VLT observing programs have already been carried out. Two previous group members have recently served at ESO positions, one at SEST and another at the VLT. The group is participating in the relevant Galactic foreground science projects of ESA's Planck Mission.

High energy astrophysics

Specific fields of interest are stellar and solar coronas and flares, and the mass accretion processes in compact binary stars containing a white dwarf, a neutron star or a black hole.

Recent highlights of the group include:

- The micro-quasar GRS 1915+105, consisting of a 14 solar-mass black hole accreting matter from a red giant, is being observed with ESA's INTErnational Gamma-Ray Astrophysics Laboratory (INTEGRAL). One of the more remarkable features of GRS 1915+105 is the episodic ejection of matter at relativistic velocities in bipolar jets. The extreme X-ray variability of GRS 1915+105 has been categorized into 12 distinct classes and INTEGRAL has revealed a hitherto undiscovered class characterized by 5-minute oscillations seen in the X-ray lightcurve (Hannikainen et al. 2003). Using INTEGRAL, a new source, designated IGR J19140+0951, was discovered near GRS 1915+105. Its nature is still unclear, i.e. whether it is a binary system containing a black hole or a neutron star (see also Figure 5).
- The puzzling compact binary Cygnus X-3 is being constantly monitored using INTEGRAL and ground based infrared and radio telescopes. Observed properties of Cyg X-3 indicate that the source is closely similar to known Galactic black holes Cyg X-1 and GRS 1915+105.
- Using NOT, the group has optically monitored several X-ray emitting binaries. Recently, the candidate for the shortest period binary (RXJ0806+15) has been identified, with an orbital period of only 5 minutes (Ramsay, Hakala, Cropper, 2002). The system is spinning up, consistent with the predictions of general relativity. Double degenerate sources like this are expected to be the strongest constant sources of gravitational radiation, and are important targets for future missions like LISA.
- First results with the XSM X-ray solar monitor aboard ESA's SMART-1 mission have indicated that the XSM 1–20 keV high time resolution spectra of the full Sun provide a very powerful method for the analysis of individual flare events. Combined with simultaneous imaging data from other satellites, they will also enable semi-empirical modelling of X-ray coronas of other stars.

The group also conducts development of space science instruments. These include SMART-1/XSM, SMART-1/D-CIXS, and INTEGRAL/JEM-X. Future plans include X-ray detectors for ESA's BepiColombo and XEUS missions, and also new technology sub-mm and infrared detectors. The wide range of technical expertise needed is provided by VTT (Technical Research Centre) and industrial companies (e.g. Metorex, Patria, SSF), which work in close collaboration with the Observatory.

Planetary-system research

The group carries out both physical and dynamical studies of mainly solar-system objects. One central area of interest are the asteroids, both their physical properties such as surface structure, form and rotation, as well as their orbit determination. Other atmosphere-less bodies, like the Moon and the transneptunian objects (TNOs) are also included.

Theoretical research is focused on scattering and absorption of light by single small particles and by particulate media. Novel numerical techniques have been developed, for example, for computation of light scattering by non-spherical particles, for modelling the stochastic Gaussian shapes and cluster geometries of small particles, as well as for coherent backscattering of light by complex media of small particles. Laboratory experiments are carried out using a scatterometer device, and the group has significant responsibilities in the future ICAPS (Interactions in Cosmic and Atmospheric Particle Systems) experiment aboard the International Space Station. Significant industrial applications have been found for the scattering techniques developed.

The research on inverse problems divides into the development of mathematical methods and the interpretation of astronomical observations. The group has pioneered in the fields of statistical orbit computation for asteroids and asteroid lightcurve inversion for their spin vectors and shapes. The group is currently developing statistical techniques for exoplanet orbit computation from radial velocity data as well as for the asteroid identification problem. The dynamical stability of extra-solar planetary systems is studied numerically using a supercomputing environment.

At NOT, in an effort to accrue in-depth knowledge of near-Earth objects, the group leads an astrometric and photometric observing program. At ESO, the group has started an astrometric program at the 2.2m/WFI and is participating in polarimetric observing programs on TNOs at the VLT. It also makes use of space-borne instruments in studies of the Moon (SMART-1) and Mars (Mars Express) and is involved in the preparations of the ESA Cornerstone missions Gaia and BepiColombo.

Tuorla Observatory, University of Turku

Four themes dominate the research: the dynamics of the Universe, from the three-body problem to cosmology; active galaxies, with particular emphasis on high energies and multi-frequency connections; stars, especially interacting binaries; and finally, ground- and space-based research of our Sun. Väisälä's tradition of precision optical engineering is carried on by Opteon Company at Tuorla. The optical workshop of Tuorla Observatory remains the only place in the world with the capability of polishing large silicon carbide mirrors. Work on the Herschel Space Observatory 3.5-metre mirror has just begun.

The dynamical universe

Cosmology is currently in a golden age of discovery. Tuorla researchers are addressing such questions as the size and shape of the Universe, its age, its matter, dark matter and dark energy content, its past and present expansion rate and the growth of structures within it. Careful mapping of the (cosmologically speaking) local environment, up to a few hundred megaparsecs, can provide strong constraints on cosmology by testing structure formation via hierarchical collapse in the cold dark matter scenario.

Both dark matter and dark energy can manifest themselves in various ways on scales of a few Mpc. For example, Tuorla researchers are studying the possibility that the enigmatic smoothness of the local Hubble flow, first recognized by Allan

Sandage over thirty years ago, results from the dominance of a perfectly smooth vacuum density. On still smaller scales, studies of the dynamics of our Galaxy have already eliminated black holes and white dwarfs as significant contributions to the putative dark matter halo or galactic shroud.

Tuorla researchers are measuring accurate distances to our "local sheet" of galaxies using the tip of the red giant branch, surface brightness fluctuations, and planetary nebulae. Beyond these distances, Tuorla researchers are building the *KLUN+* galaxy sample in collaboration with the Paris and Lyon groups. On still larger scales, the distribution of clusters and super-clusters is studied with *N*-body simulations in a collaboration with Tartu Observatory. The results are compared with the Las Campanas and Sloan surveys. Light cone simulations will be developed for detailed comparisons with future observational data. This work is also a part of Tuorla's involvement in the Planck satellite project.

On the most fundamental, mathematical level, Tuorla researchers have for a long time been studying the three- to *N*-body problem and its applications from spacecraft orbits to the dynamics of our Solar System, extra-solar planets, multiple stars and galaxies. One notable achievement has been the identification, by York University and Tuorla researchers, of the asteroid (3753) Cruithne as a second "moon" of the Earth (Fig. 6).

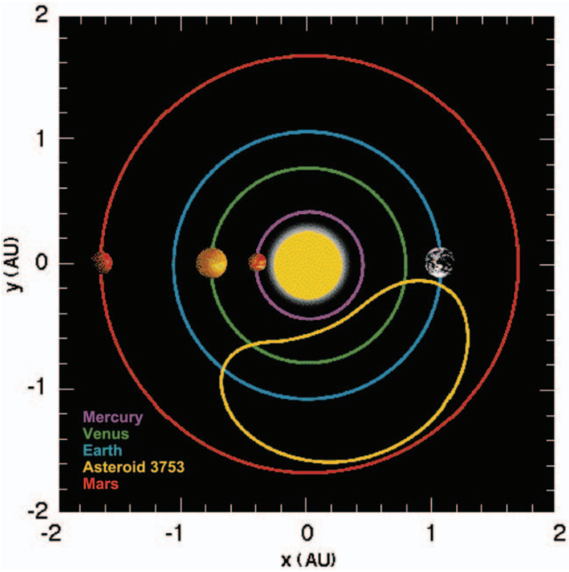
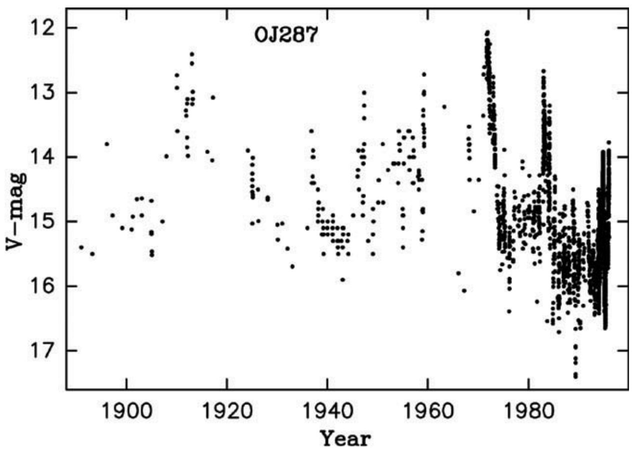


Figure 6: Earth's second "Moon": Asteroid (3753) Cruithne has been found by University of York and Tuorla researchers to be in a unique heliocentric orbit which appears geocentric when viewed from the Earth (Wiegert, Innanen and Mikkola 1997, picture: York University)

Active galaxies

Radio and optical monitoring programs of blazar-type AGN were already started in 1980, and continue to provide a unique insight into the long-term behavior of the shocked relativistic jets present in these sources. During the last decade, the focus has shifted to the highest energies, to gamma-rays detected first by the Compton and now by the INTEGRAL satellite, and to TeV radiation observed with ground-based Cerenkov detectors. Tuorla has joined the international MAGIC TeV telescope collaboration, providing multi-frequency support in addition to the normal operations. The other important AGN collaboration is the EU-funded ENIGMA, which organizes large multi-frequency campaigns. The single dish studies are supported with extensive VLBA campaigns.

Most of the work has focused on testing and developing the shocked jet paradigm. Earlier, Tuorla astronomers have found that all radio variations can be explained by growing and decaying shocks in the AGN jets; now the connections to IR and optical variations, as well as to the inverse Compton flux are being investigated using INTEGRAL and MAGIC data. Evidence has been found that the gamma-rays come from the shocks, much farther away from the core than is usually assumed.



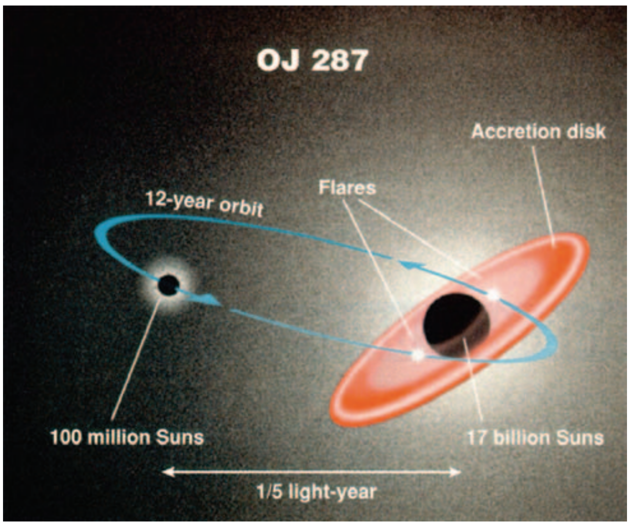


Figure 7: a) The historical light curve of the blazar OJ 287 for 1891-1998. Credit : A. Sillanpää/Takalo and the OJ Collaboration; **b)** Model for the binary black hole system in OJ 287, the first AGN with periodic behavior, discovered by Tuorla researchers. (Lehto and Valtonen 1996)

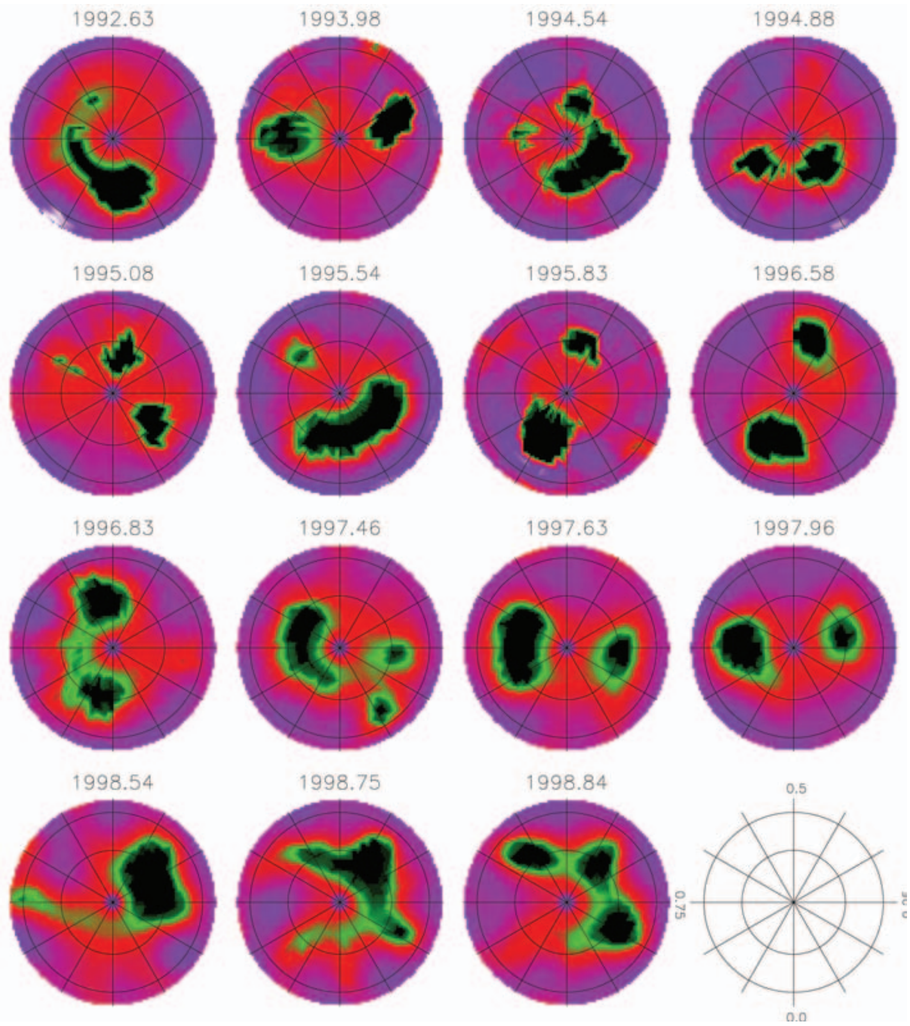


Figure 8: Pole-on views of the primary star of the RS CVn binary II Peg for different years. The spots preferably appear near two active longitudes which migrate over the stellar surface. While the total spotted area does not vary significantly, the relative activity level of the two regions changes abruptly in 1994 and 1998, indicating "flip-flop" events.

High resolution imaging with ESO telescopes, especially in the near-IR, is being used to study the cosmological evolution of AGN, their host galaxies and environments, the relationship between the different classes of AGN, as well as the star formation history of the hosts. Recent highlights include the imaging of high redshift host galaxies, the first determination of black hole masses of BL Lac objects, and near-IR spectroscopy of the nuclear regions of Seyfert galaxies. Preparations are also underway for the predicted 2006 outburst of the only known periodic AGN, OJ 287, which was identified as a binary black hole by Tuorla researchers in 1988 (Fig. 7).

Stars

The stellar research at Tuorla observatory focuses on stars with unusual properties: interacting binaries, magnetic cataclysmic variables (mCvs), intermediate polars, X-ray binaries, white dwarfs, and K dwarfs. In addition to seeking answers to many open questions about the evolution of these stars, these studies also reveal how plasma behaves in extreme circumstances, such as environments with very strong magnetic fields. The dwarf stars are essentially stellar fossils, which can be used to study the production of helium and heavy metals in our Galaxy.

The group has a unique blend of instrumental expertise, international collaboration and use of the NOT, multi-wavelength monitoring and space observations (ROSAT, XMM). Recent developments include spectropolarimetric facilities, and an extensive observational program on circular spectropolarimetry of mCVs. An ongoing monitoring campaign of 28 X-ray binaries with the Nançay radio telescope is the largest ever conducted. In the future, the VLT, as well as the 3.5m class ESO telescopes will enable phase-resolved spectroscopy and spectropolarimetry, including detailed studies of weaker features, such as polarization in intermediate polars. Ultra-high time resolution can also be achieved to map the details of accretion discs in eclipsing binaries.

The Sun

The Tuorla solar group specializes in multi-wavelength analyses of eruptive solar events. Scientific interests range from particle acceleration to shock waves and plasma emission, but solar atmospheric models have also been tested. The long-term use of solar radio data from the Metsähovi radio telescope has given the Tuorla group special expertise in data acquisition and analysis. In particular, Metsähovi observations have been used to study the activity in the polar regions of the Sun. Multi-wavelength analysis of halo-type coronal mass ejections is being carried out in collaboration with the Paris Observatory and the Space Research Laboratory of the University of Turku, the SOHO ERNE PI institute.

Astronomy Division, University of Oulu

There are four main research fields in Oulu: stellar and Solar astrophysics; high energy astrophysics; dynamics of planetary rings and disc galaxies; and planetology of terrestrial planets.

As a highlight of the research carried out in the *Astrophysics Group*, the project concentrating on solar-stellar activity is presented. It combines powerful observational techniques and computational tools. An extensive time series has been collected using the SOFIN spectrograph at the Nordic Optical Telescope. It contains more than ten years of high-resolution spectroscopic observations of active late-type stars of FK Com- and RS CVn-types, and rapidly rotating solar type stars. The major finding of these investigations has been the persistent two-spot structure in visible hemispheres, two large high latitude cool areas, spots, situated in opposite longitudes (see Fig. 8 and Tuominen, Berdyugina & Korpi 2002). Moreover, their strength varies in cyclic manner with a few years' period, the so-called *flip-flop* effect. In addition to these spectroscopic investigations which use Doppler imaging inversion methods developed by the group members, the "flip-flop" behavior is also confirmed by long-term photometric time series.

The recent dynamo models developed in the group for rapidly rotating stars predict stable non-axisymmetric magnetic fields in the form of active longitudes. The active longitudes in the same stellar hemisphere are predicted to be of opposite polarities. There are, however, no definite measurements of the magnetic field strength yet and only a preliminary proof of the polarity of the two active longitudes for such stars. Also, there is no information on polarity changes during stellar cycles. The development of the dynamo models is accompanied by detailed investigations on stellar magneto-convection using high-resolution, three-dimensional turbulence models. Such models have yielded important revisions of the turbulent transport quantities needed in the dynamo theory, especially in the rapid rotation limit relevant for the understanding of the active rapid rotators.

The main research interests of the *High Energy Astrophysics Group* are the processes in the vicinities of black holes, both stellar-mass holes found in X-ray binaries and the super-massive ones found in the nuclei of Seyfert galaxies, as well as the accreting neutron stars, and the gamma-ray bursts. X-ray and gamma-ray observations are being carried out using the Rossi X-ray Timing Explorer (RXTE), INTEGRAL, and other satellites, and theoretical models are being developed.

Large efforts are devoted to the analysis of the broad-band X-and gamma-ray spectra of black holes in our Galaxy, such as Cygnus X-1 and the micro-quasar GRS 1915+105. A hybrid thermal/non-thermal Comptonization spectral model proposed by the group members was found to describe the observed properties exceptionally well. In the field of accretion-powered X-ray sources, the group's activity is now shifting to the recently discovered accreting X-ray millisecond pulsars which constitute a link between low-mass X-ray binaries and radio millisecond pulsars. Detailed analysis of the energy-dependent pulse profiles of SAX J1808.4-3658 have provided very strong constraints on the equation of state of the extremely dense matter of neutron stars (Poutanen & Gierliski 2003).

Spectra of the prompt soft gamma-ray emission of gamma-ray bursts are still not explained and seem mysterious despite strong theoretical efforts devoted to this problem. The Oulu group in collaboration with the Lebedev Physical Institute in Moscow is now actively involved in a project to develop the necessary tools to model the emission mechanisms. Synchrotron self-Compton emission of nearly mono-energetic electron-positron pairs seems to explain most of the observed properties.

The *Dynamics Group* studies planetary rings and disc galaxies, combining analytical and *N*-body modelling with observations. An important result has been the prediction of local trailing wake structures in Saturn's rings (Salo 1992), forming spontaneously due to mutual gravity between colliding ring particles. The existence of such non-resolved wakes with radial scale of ~100 metres is indirectly supported by photometric modelling of global azimuthal brightness asymmetries seen in Voyager, HST and Arecibo radar data. An intriguing new prospect is the direct detection of wakes in high resolution Cassini data: like density waves driven by external satellite resonances, intrinsic wakes provide constraints for ring velocity dispersion and viscosity.

The group's galactic research concentrates on numerical modelling of prototypical interacting and barred galaxies, and on the role of bars on the nuclear activity and secular evolution of disc galaxies. In particular, methods for estimating the bar gravitational field from near-IR images are developed and applied to recent galaxy surveys (2MASS, Ohio State University Bright Galaxy Survey). A new observational survey is also in progress, addressing the bar strength distribution in S0 galaxies as a clue of their origin. Planetary ring studies are performed in collaboration with U. Potsdam, Wellesley C. and U. Cornell, and galaxy studies mainly with U. Alabama.

The *Planetology Group* of the University of Oulu studies the surface structures of terrestrial planets. The strategy of the group is to combine data from planetary missions and tools from space science, geosciences and remote sensing with the group's own expertise in planetology. The goal is to gain a detailed view of the evolutionary processes which are forming the surface structures of terrestrial planets.

The group is currently involved in a long-term study of Mars. Based on its previous research experience the group is participating as a Co-Investigator in the HRSC-camera team of ESA's Mars Express mission. The HRSC data analyses have already begun and will enable, as the data accumulates, very detailed investigations of Martian surface structures.

The group also contributes to the new mission initiatives and participates in other European space activities within ESA's planetary science program, such as the Venus Express mission in 2005.

Metsähovi Radio Observatory, Helsinki University of Technology

The main research topics are the multi-frequency behavior of active galactic nuclei (AGNs) and the solar microwave radiation. The Metsähovi group is also active in developing radio astronomical instrumentation and measurement methods. Both solar and AGN research is being done in very close collaboration with the Tuorla Observatory (see also the section on Tuorla Observatory for information on the Metsähovi Solar research).

Active galactic nuclei

The main research project at Metsähovi is the study of active galactic nuclei. Data across the whole electromagnetic spectrum are being used. However, the backbone of the research has always been the long-term monitoring of the AGN radio variability that has been going on in Metsähovi since the late 1970's. The group has also been very active in using the SEST for studying AGNs between 1988 and 2003.

The details of the flux density evolution at various radio frequencies help in modelling the radio shock formation and development, and determination of the physical parameters related to the shock-in-jet structure. Studying the relationships between outbursts observed in the radio domain and other frequency domains helps to constrain the models for the high-energy emission in AGNs.

Quick Detection System for the Planck satellite. The knowledge of the nature, number and behavior of foreground sources is essential for the success of the Planck satellite's primary mission, the measurement of the CMB. The group is involved in the study of the extragalactic foreground sources and is also developing a special software that will be used for detecting strong, possibly flaring, radio sources in the time ordered data stream of the Planck satellite within 1–2 weeks of the time of the observation. The supporting theoretical studies in connection to the software include radio variability modelling of various source types, needed for defining the triggering criteria for follow-up observations.

Inverted-spectrum radio sources. Gigahertzpeaked spectrum (GPS) radio sources are extragalactic radio sources characterized by convex spectra peaking in the GHz range and steep at high radio frequencies. Only very few sources with extremely high (> 10 GHz) peak frequencies have been reported earlier. Recently, the group has identified several new extreme-peaking sources. Identifying high-peaked sources is related to the work on the Planck satellite's extragalactic foreground.

Work is currently going on with new data sets from the Metsähovi and RATAN-600 telescopes to search for new high-peaked sources, to study the variability behavior of *bona fide* GPS sources, to work on the models for inverted-spectrum sources and to study the contribution of the high frequency tail of the radio spectrum to the extragalactic foreground. Also, VLBI observations have been made of the extreme-peaking sources newly identified by the group.

Radio properties of BL Lacertae Objects. The two main BL Lacertae Object (BLO) subclasses, radio-selected BLOs and X-ray-selected BLOs are a product of different discovery techniques. It is not currently known whether these two classes of objects are two extremes of one class, or whether they have intrinsically different properties. A complete set of BLOs has been observed in Metsähovi, and additional observations using other facilities have also been made.

The study of the BLOs is also related to the Planck foreground science: if some of the X-ray selected BLOs turn out to be brighter than previously assumed, or if the number of Intermediate BLOs turns out to be large, then this information is also essential for the Planck mission.

Correlations between the radio and high-energy behavior in AGNs. The Metsähovi radio monitoring data are also used for studying the correlation between radio and high-energy domains: activity states and flares, differences in various source populations, etc. Multifrequency radio-to-submm data and VLBI images are used to study the radio-to-gamma connections. According to the studies of the group, the strong gamma-ray emission in AGNs clearly occurs after the formation of the radio shock in the relativistic jet, i.e. the site of the gamma-ray emission must be at a distance well outside the accretion disc or even the broad line region usually considered to be responsible for the gamma-ray emission.

Instrumentation

As part of its VLBI instrumentation project the group has recently designed and manufactured next generation VLBI recording systems that enable world record data acquisition rates: on March 12, 2003, the first European 1 Gbit/s VLBI experiment and on June 17, 2003, the first international 2 Gbit/s experiment.

Along with developing high-speed data recording systems for VLBI the Metsähovi team is also developing e-VLBI technologies. The team has been evaluating high-speed Internet protocols for e-VLBI and in the preliminary data transfer tests, the team has achieved an order of magnitude improvement to the normal TCP/IP transfer speed.

The Metsähovi group is also involved in the Alpha Magnetic Spectrometer (AMS) project. This instrument will be placed aboard the International Space Station. The project is a very large international collaboration project, in which Metsähovi's responsibility is the hardware and software for the ground-based high-rate data link, receiving science data from the instrument.

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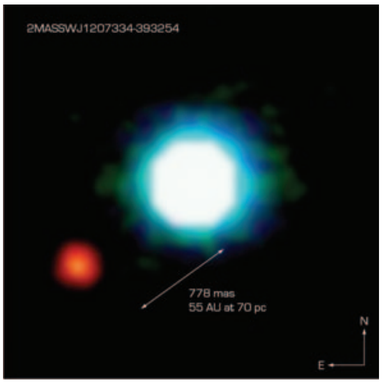
Is this Speck of Light an Exoplanet?



Is this newly discovered feeble point of light the long-sought bona-fide image of an exoplanet?

A research paper [1] by an international team of astronomers [2] provides sound arguments in favour, but the definitive answer is now awaiting further observations.

On several occasions during the past years, astronomical images revealed faint objects, seen near much brighter stars. Some of these have been thought to be those of orbiting exoplanets, but after further study, none of them could stand up to the real test. Some turned out to be faint stellar companions, others were entirely unrelated background stars. This one may well be different.

In April of this year, the team of European and American astronomers detected a faint and very red point of light very near (at 0.8 arcsec angular distance) a brown-dwarf object, designated 2MASSWJ1207334-393254. Also known as "2M1207", it is a member of the TW Hydrae stellar association located at a distance of about 230 light-years. The discovery was made with the adaptive-optics supported NACO facility at the 8.2-m VLT Yepun telescope at the ESO Paranal Observatory (Chile).

The feeble object is more than 100 times fainter than 2M1207 and its near-infrared spectrum was obtained with great efforts in June 2004 by NACO, at the technical limit of the powerful facility. The spectrum shows the signatures of water molecules and confirms that the object must be comparatively small and light.

None of the available observations contradict that it may be an exoplanet in orbit around 2M1207. Taking into account the infrared colours and the spectral data, evolutionary model calculations point to a 5 jupiter-mass planet in orbit around 2M1207. Still, they do not yet allow a clear-cut decision about the real nature of this intriguing object. Thus, the astronomers refer to it as a "Giant Planet Candidate Companion (GPCC)".

Observations will now be made to ascertain whether the motion in the sky of GPCC is compatible with that of a planet orbiting 2M1207. This should become evident within 1-2 years at the most.

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[1] The research paper (A Giant Planet Candidate near a Young Brown Dwarf by G. Chauvin et al.) will appear in Astronomy and Astrophysics on September 23, 2004 (Vol. 425, Issue 2, page L29). A preprint is available as astro-ph/0409323.

[2] The team consists of Gael Chauvin and Christophe Dumas (ESO-Chile), Anne-Marie Lagrange and Jean-Luc Beuzit (LAOG, Grenoble, France), Benjamin Zuckerman and Inseok Song (UCLA, Los Angeles, USA), David Mouillet (LAOMP, Tarbes, France) and Patrick Lowrance (IPAC, Pasadena, USA).