Finnish Centre for Astronomy with ESO

Annual Report

2017

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FINNISH CENTRE FOR ASTRONOMY WITH ESO, ANNUAL REPORT 2017

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Based on a template by Andrea Hidalgo

COVER IMAGE: THE FINAL IMAGE OF ABELL 370 PRODUCED IN THE FRONTIER FIELDS LEGACY SURVEY, SHOWING THE TRACKS OF ASTEROIDS
May 2018

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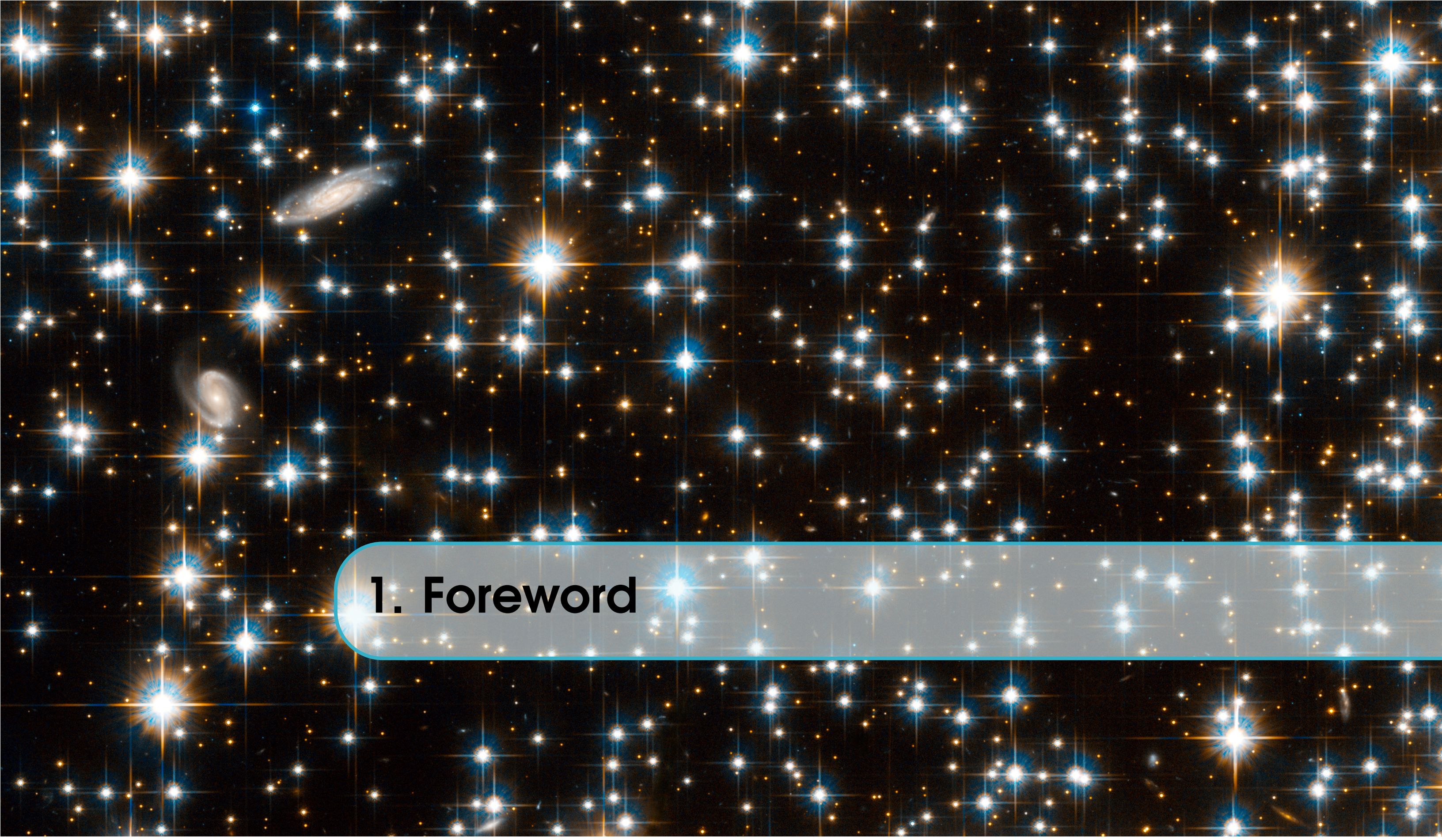

1. Foreword

Finland is a member of the European Southern Observatory (ESO) since 2004. ESO is a world leading astronomical research and technology organization, with 15 member states, headquarters in Garching, Germany, and three world-class observatories in Chile.

Finnish Centre for Astronomy with ESO (FINCA) is a national research institute for astronomical and astrophysical research in Finland. FINCA coordinates Finnish co-operation with ESO by networking into the ESO infrastructure and projects; practices and promotes high quality research in all fields of astronomy, and ESO-related technological development work; participates in researcher training in astronomy; and fosters and implements ESO-related co-operation of all the Finnish universities engaged in astronomical research. The ultimate goal of FINCA is to improve the scientific and industrial benefit of Finland's membership in ESO, and Finland's international competitiveness in astronomical research.

The year 2017 marked the 8th year of operation for FINCA, administratively a Special Unit of the University of Turku, and funded by the Ministry of Education and Culture, and by the participating universities (Aalto, Helsinki, Oulu and Turku). The highest decision-making body is the Board, chaired by Vice-Rector Kalle-Antti Suominen of the University of Turku, and comprising of two members from each participating university and one member from FINCA staff. The scientific activities of FINCA are overseen by an international Scientific Advisory Board (SAB), chaired by Prof. Susanne Aalto (Chalmers University of Technology, Sweden),

The research at FINCA covers a large range in contemporary astronomy, from cosmology, active galaxies, and galaxy formation and evolution, through properties of nearby galaxies, to supernovae and their progenitor stars, stellar activity and star formation in our own Galaxy. In our research, we use radio to gamma-rays multi-wavelength observational data from large ground-based and space telescopes, especially from the four 8m ESO Very Large Telescopes (VLT), and the Nordic Optical Telescope (NOT) on La Palma, Spain, in the optical and near-infrared. Observational research is supplemented by modelling, simulations and theoretical work, that are essential in understanding the physics behind the observations. Our research were reported in 45 refereed scientific articles, and some of them are highlighted in this Report.

Our researcher training activities in 2017 focused on one hand in supervision of PhD and MSc students in the participating universities, and on the other hand in hands-on teaching of advanced observing, data reduction and analysis methods in observational astronomy as national collaboration. There was one such course held in 2017, the annual course on remote optical/infrared observing with the NOT. In addition, FINCA co-organized a practical course for Finnish high school students, also on remote observations with the NOT.

The construction of the ESO Extremely Large Telescope (ELT), a 39 m diameter giant for infrared and optical astronomy, is well underway, with Phase 1 instruments being constructed, Phase 2 instruments being in final design phase, all major contracts for the construction of the ELT been awarded, and construction started at Cerro Amazons. This keeps ESO on-track to remain in a world-leading position, when the E-ELT starts operations in 6 years time, bringing an enormous leap forward in sensitivity and resolution.

FINCA continues in an active role to facilitate Finnish industry to participate as sub-contractors in building the ELT and its instrumentation. FINCA is participating on behalf of the Finnish community in two of the ELT instrument consortia, MOSAIC (optical and near-infrared multi-object spectrograph), and MICADO (near-infrared adaptive optics imager). FINCA is also participating in the NOT Transient Explorer (NTE), a new instrument for the NOT capable of simultaneous optical and near-infrared spectroscopy and imaging, with first light expected in late 2019. As a followup to NTE participation, and to build a bridge toward involvement in ESO instrumentation, FINCA is also participating in a new instrument to the ESO 3.5-m New Technology Telescope (NTT), the Son Of X-Shooters (SOXS), a very similar instrument to the NTE. FINCA received in 2017 a five-year research infrastructure grant from the Academy of Finland to enable participation in these instrument projects.

Jari Kotilainen,
FINCA Director

2. Staff and Organisation

FINCA Staff (Turku, unless marked)

Director	Jari Kotilainen
Emeritus Professor	Mauri Valtonen
University Researchers	Roberto De Propris Pasi Hakala Vitaly Neustroev (Oulu) Kari Nilsson
Postdoctoral Researchers	Ghassem Gozaliasl (Helsinki) Joachim Janz (Oulu: from 1.9.2017) Jari Kajava (from 1.2.2017) Karri Koljonen (Aalto) Hanindyo Kuncarayakti Ronald Läsker Pasi Nurmi Laura Zschaechner (Helsinki:from 1.12.2017)

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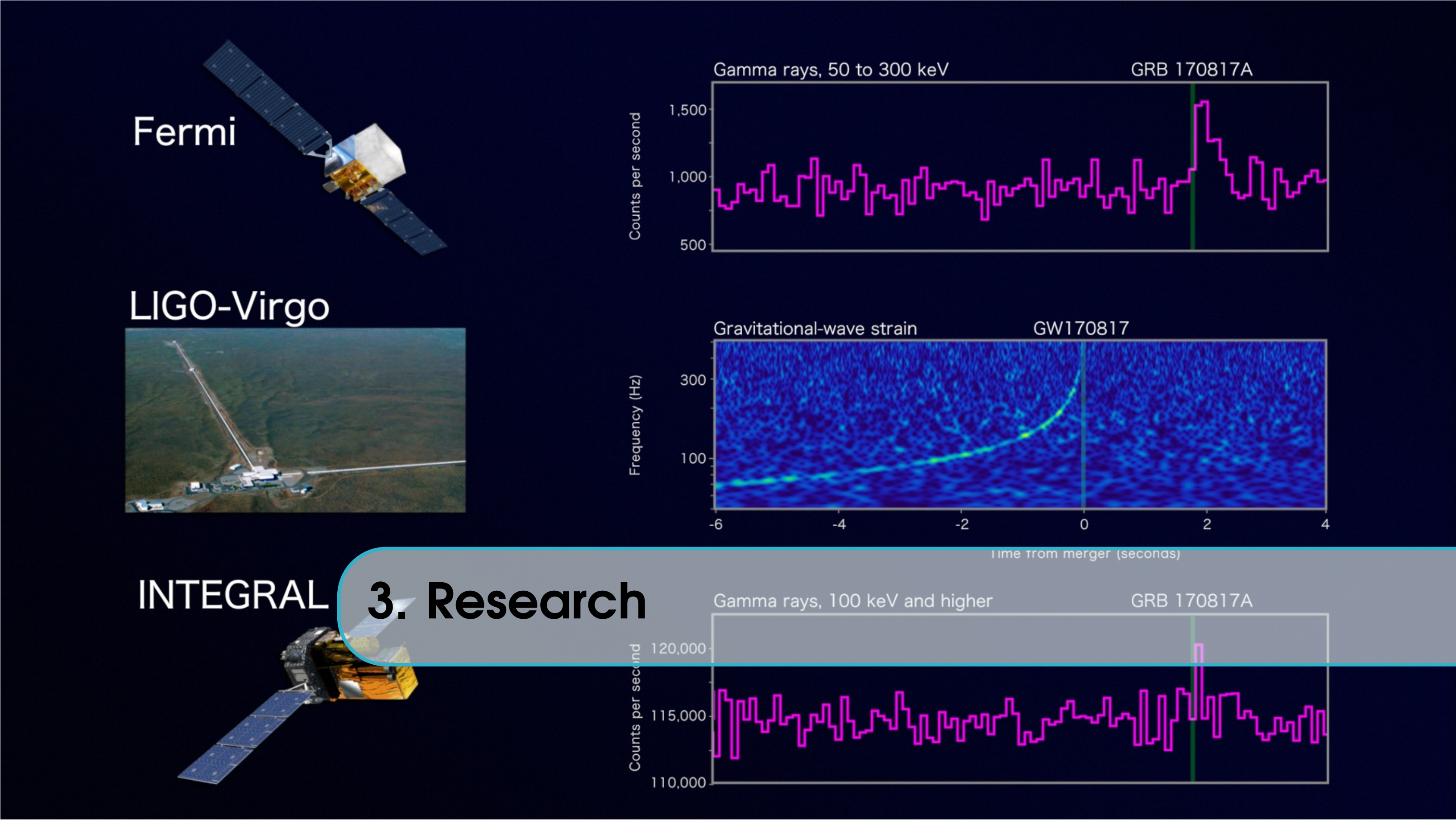


3. Research

3.1 Main Research Areas

The research at FINCA concentrates on observational astronomy carried out using radio to gamma-rays multi-wavelength data from large ground-based and space telescopes. Especially, we make use of ESO's large ground-based facilities in the optical and infrared (the four 8m ESO Very Large Telescopes; VLT) and in (sub)millimetre (Atacama Large Millimeter Array; ALMA), together with the Nordic Optical Telescope (NOT) on La Palma, in the northern hemisphere. Our observational research is supplemented by modelling, computer simulations and theoretical work, that are essential in understanding the physics behind the observations. The present science topics at FINCA cover a large range in contemporary astronomy from observational cosmology, distant active galaxies, and galaxy formation and evolution, through properties of nearby galaxies, to supernovae and their progenitor stars, stellar activity and star formation in our own Galaxy. In 2017, our research were reported in 45 refereed scientific articles, and some of them are highlighted below.

3.2 Research highlights

3.2.1 Galaxy evolution and cosmology

Galaxy clusters: falling in line

Brightest cluster galaxies (BCGs) are special in many ways. A particularly intriguing property of BCGs is that their major axis is aligned with the major axis of their parent cluster and that this idealised line on the sky points in the direction of nearby clusters as well. This "alignment effect" implies that the formation of BCGs is connected to the development of the surrounding large scale structure, on scales of 10s of Mpcs. This may be due to formation of BCGs via collimated infall, early in the history of cluster assembly, where only a single or a few filaments feed the growing

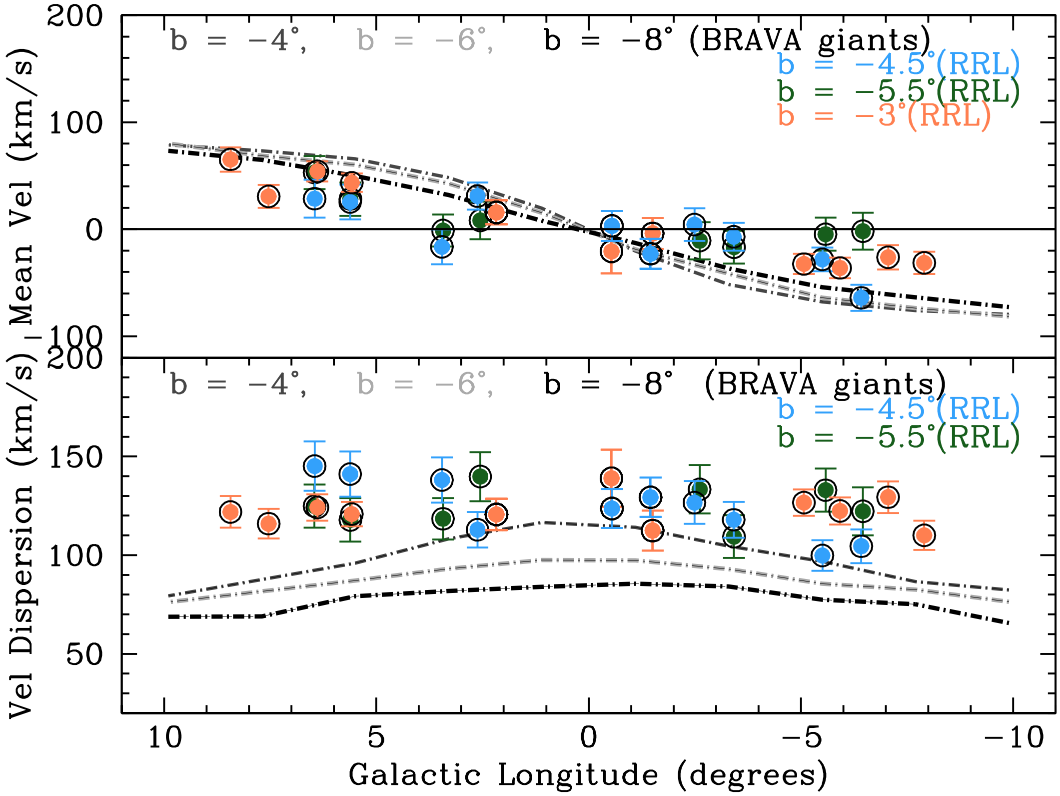


Figure 3.1: The rotation curve of RR Lyrae in the Milky Way bulge, showing the presence of a pressure supported component

clusters. We (West, **De Propris**, Bremer, Phillipps) have for the first time studied the evolution of the alignment effect to $z \sim 2$ using archival HST data. We find that BCGs are still significantly aligned with their parent cluster even at these lookback times. This suggests that BCGs are the "seed" around which clusters grow. Together with a group in Trieste we are studying the evolution of the alignment effect in simulations, to see if we can reproduce the observations and predict whether the effect will be visible in higher redshift samples that will be uncovered by JWST and EUCLID.

The Hidden Bulge of the Milky Way

We are continuing our survey of stars in the Galactic bulge to uncover the oldest stellar populations in the Galaxy and therefore the fossil remnants of the earliest epochs of star formation and Galaxy assembly. Theoretical predictions place these objects in the centre of the Milky Way, but having distinctive abundances and kinematics. One such object may be Terzan 5. We have been targeting RR Lyrae, as these are definitely old and metal poor systems whose membership in the bulge can be securely established as they are also excellent distance indicators. Our preliminary results (Fig 3.1) indicate that RR Lyrae follow a more spheroidal and non-rotating distribution (although the inner regions may be spun up by the massive bar) and that there are numerous subsets of stars in a kinematic-metallicity space, which indicates multiple epochs of early star formation and/or early accretion episodes.

Low-redshift quasars in the SDSS Stripe 82: associated companion galaxies and signature of star formation

Jari Kotilainen (FINCA) and collaborators obtained optical spectroscopy of close (< 80 kpc) companion objects of a sample of 12 low-redshift quasars ($z < 0.3$) selected from the SDSS Stripe82 area and that are in the subsample of 52 quasars for which both multicolour host galaxies properties and galaxy environment were recently investigated in detail. They found that for 8 out of 12 sources the companion galaxy is associated with the quasar having a difference of radial velocity < 400 km s^{-1}. Many of these associated companions exhibit [OII] 3727 emission lines suggestive of episodes of (recent) star formation possibly induced by past interactions. The star formation rate of the companion galaxies as derived from [O II] line luminosity is, however, modest, with a median value of 1.0 ± 0.8 $M_{\odot}$ yr^{-1}, and the emission lines are barely consistent with expectation from gas ionization by the quasar. These results suggest (albeit still based on a scanty statistics) a modest role of the quasar emission for inducing the star formation in nearby companion galaxies. For three objects, they are also able to detect the starlight spectrum (Fig 3.2) of the quasar host galaxy.

Evidence of bar-driven secular evolution in the gamma-ray narrow-line Seyfert 1 galaxy FBQS J164442.5+261913

Jari Kotilainen (FINCA) and collaborators continued their studies of the host galaxies of AGNs and presented near-infrared imaging of FBQS J164442.5+261913, one of the few γ-ray emitting narrow line Seyfert 1 galaxies detected at high significance level by Fermi Large Area Telescope. This study is the first morphological analysis performed of this source and the third performed of this class of objects. Conducting a detailed 2D modelling of its surface brightness distribution and analysing its J - Ks colour gradients, they find that FBQS J164442.5+261913 is statistically most likely hosted by a barred lenticular galaxy (SB0). They find evidence that the bulge in the host galaxy of FBQS J164442.5+261913 is not classical but pseudo, against the paradigm of powerful relativistic jets exclusively launched by giant ellipticals. Their analysis also reveals the presence of a ring (Fig. 3.3) with diameter equalling the bar length, whose origin might be a combination of bar-driven gas rearrangement and minor mergers, as revealed by the apparent merger remnant in the J-band image. In general, their results suggest that the prominent bar in the host galaxy of FBQS J164442.5+261913 has mostly contributed to its overall morphology driving a strong secular evolution, which plays a crucial role in the onset of the nuclear activity and the growth of the massive bulge. Minor mergers, in conjunction, are likely to provide the necessary fresh supply of gas to the central regions of the host galaxy.

Shutting down or powering up a (U)LIRG? Merger components in distinctly different evolutionary states in IRAS 19115-2124 (the Bird)

Jari Kotilainen (FINCA) and collaborators presented VLT+SINFONI near-infrared integral field spectroscopy and SALT optical long-slit spectroscopy characterizing the history of a nearby merging luminous infrared galaxy, the Bird (IRAS19115-2124). The line maps of the SINFONI data cubesand stellar population fitting of the SALT spectra allow dating of star formation (SF) over the triple system uncovered from their previous adaptive optics data. The distinct components separate clearly in line-ratio diagnostic diagrams, with both thermal and non-thermal excitation present. An

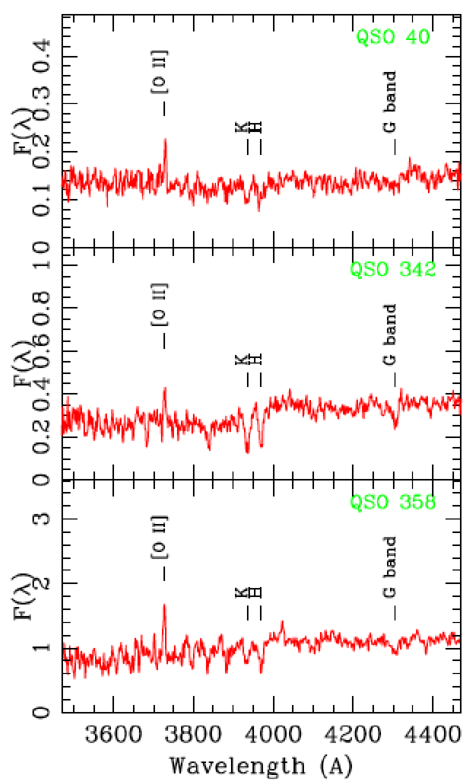


Figure 3.2: The rest frame spectra of a subset of the quasar host galaxies. Clear signature of the underlying stellar population is apparent. In all cases a significant [OII] 3727A emission line is detected. The spectra were obtained through a slit that was offset from the nucleus

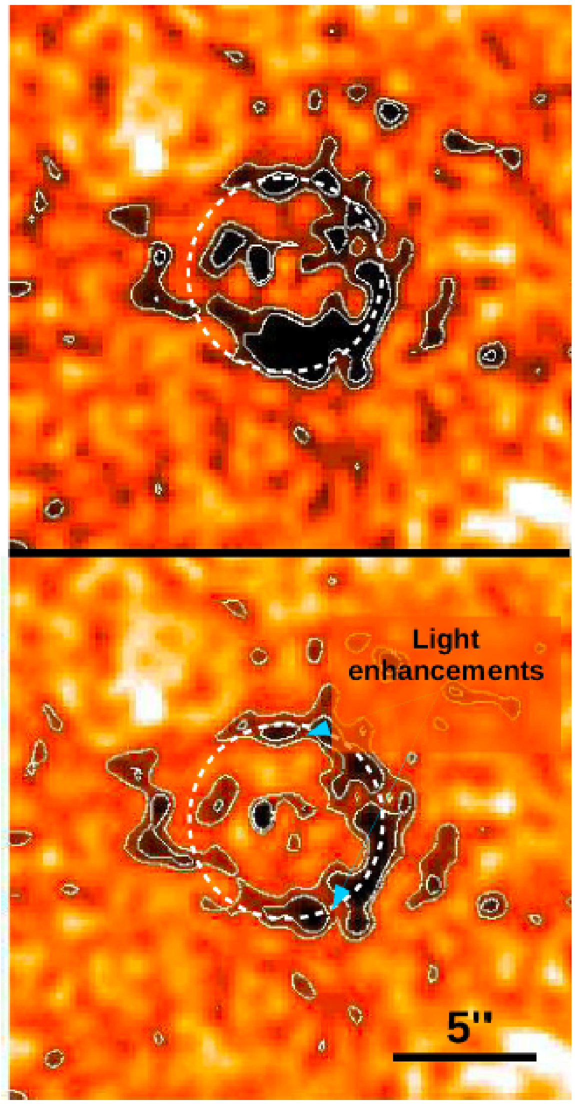


Figure 3.3: Residuals of the J-band AGN+bulge model (top panel) and AGN+bulge+disc model (bottom panel). North is up and east is to the left. To enhance S/N and to detect faint structures, the residuals were smoothed to < 1 arcsec resolution. The segmented white circle has a 3.2 arcsec radius and guides through the ring feature. Blue arrows show the light enhancements at the ends of the bar (ansae). A likely minor merger event feature is observed in the east part of the galaxy (from $R \approx 3$ up to 5 arcsec).

off-nuclear starburst dominates the current SF of the Bird with 60-70 per cent of the total, with a 4-7 Myr age. The most massive nucleus, in contrast, is quenched with a starburst age of >40 Myr and shows hints of budding AGN activity. The secondary massive nucleus is at an intermediate stage. The two major components have signs of an older stellar population, consistent with a starburst triggered 1 Gyr ago in a first encounter. The simplest explanation of the history is that of a triple merger, where the strongly star-forming component has joined later. (Fig. 3.4). The Bird offers an opportunity to witness multiple stages of galaxy evolution in the same system; triggering as well as very recent quenching of SF, and, perhaps, an early appearance of AGN activity. It also serves as a cautionary note on interpretations of observations with lower spatial resolution and/or without infrared data. At high redshift the system would look like a clumpy starburst with crucial pieces of its puzzle hidden in danger of misinterpretations.

Brightest group galaxies (BGGs): the relative contribution of BGGs to the total baryon content of groups at $z < 1.3$

We (**Gozaliasl** and collaborators) performed a detailed study of the evolution of the star formation rate (SFR) and stellar mass of the brightest group galaxies (BGGs) and their relative contribution to the total baryon budget. We find that BGGs constitute two distinct populations of quiescent and star-forming galaxies and their mean SFR is ~ 2 dex higher than the median SFR at $z < 1.3$. Both the mean and the median SFRs decline with time by > 2 dex. The mean (median) of stellar mass has grown by 0.3 dex since $z = 1.3$ to the present day. We show that up to $\sim 45\%$ of the stellar mass growth in a star-forming BGG can be due to its star-formation activity. We separately show the BGGs with the 20% highest $f_{b,200}^{BGG}$ are generally non-star-forming galaxies and grow in mass by processes not related to star formation (e.g., dry mergers and tidal stripping).

Chandra centers for COSMOS X-ray galaxy groups: Differences in stellar properties between central dominant and offset brightest group galaxies

We (**Gozaliasl** and collaborators) present result of a search for galaxy clusters and groups in the ~ 2 square degree of the Cosmic Evolution Survey (COSMOS) field using all X-ray observations from the XMM-Newton and Chandra X-ray observatories and the COSMOS multi-band photometric redshift catalogs. We investigate differences in the stellar mass distributions between the central dominant brightest group galaxies (BGGs) and BGGs with a large offset from X-ray centroid. We also examine the impact of the offset on the scatter in the stellar mass of BGGs at fixed halo mass and compare our results with predictions from two semi-analytic models. We find that the stellar mass in observations extend a wide dynamic range compared to model predictions.

A closer look at the deep radio sky: Multi-component radio sources at 3-GHz VLA-COSMOS

In this data paper, we (**Gozaliasl** and collaborators) present and characterise the multi-component radio sources identified at the VLA-COSMOS Large Project at 3 GHz (0.75 arcsec resolution, 2.3 μ Jy/beam rms), the radio sources which are composed of two or more radio blobs [**eleni2018**]. We have identified 67 multi-component radio sources at 3 GHz: 57 sources with AGN powered radio emission, 5 possibly associated with an AGN, and 5 star-forming galaxies.The majority of the AGN lie below the main-sequence for star-formation, in the green valley, supporting a scenario for star-formation quenching.

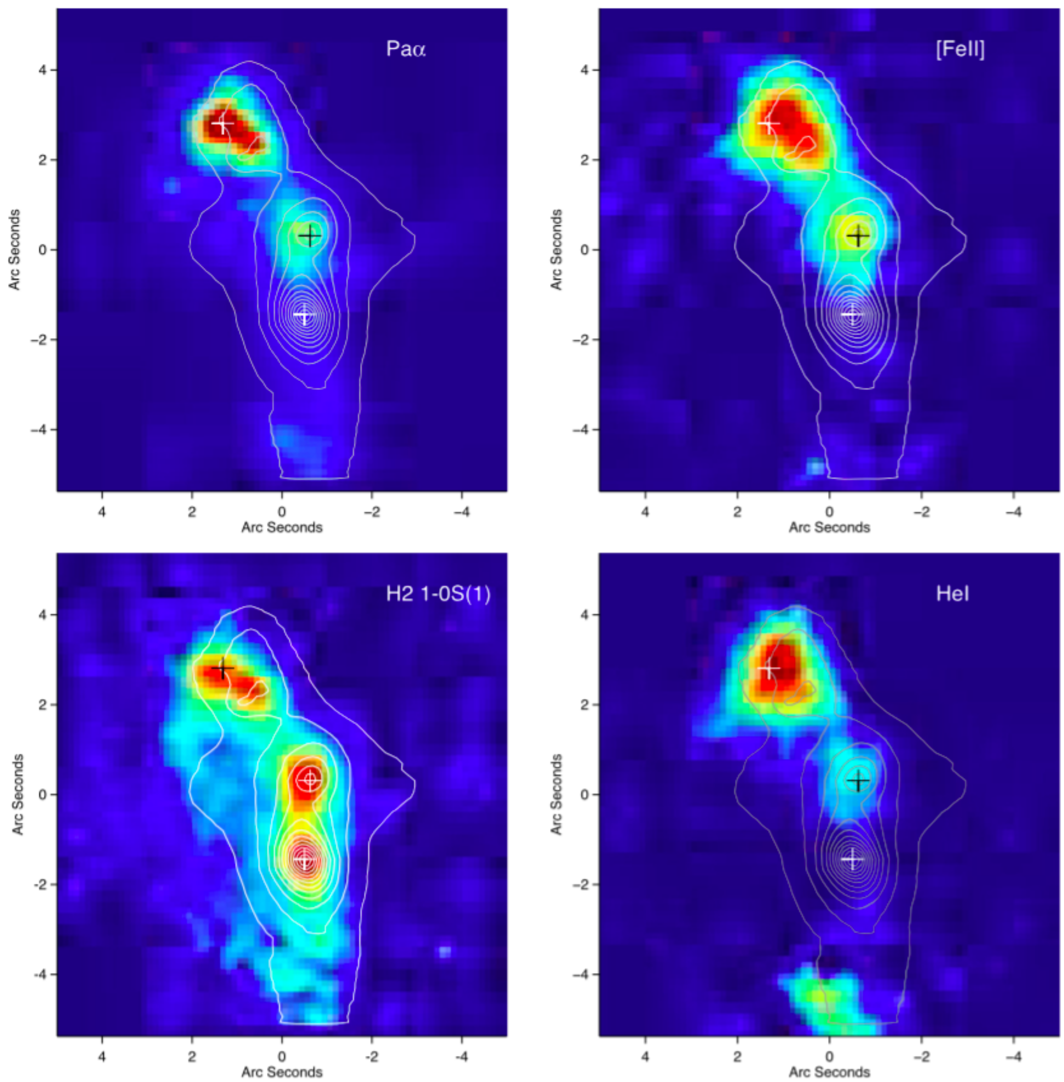


Figure 3.4: Continuum-subtracted line maps from the SINFONI data cubes of the Bird over all velocities. Each feature map is scaled linearly between the strongest emission in the corresponding band and the background level. The K-band continuum is shown as contours in all the panels. The crosses mark the main nuclei of the Bird. The maps show, clockwise from the top left, Pa α, [Fe II], He I 1.083 μm, and H2 (1-0) S(1). Both [Fe II] and He I are more diffusely spread around the youngest regions of the Head and Heart than the more peaked Pa α emission. The molecular gas is concentrated in all the nuclei, and at the same time is also significantly more diffuse over the whole system than the other line emission.

OJ 287

The 2015 campaign of optical monitoring of OJ287 has been continued during 2017. The most exciting event in 2017 was the fading of the AGN component of this source in November. It provided a good opportunity to study the host galaxy of OJ287. The Grantecan 10-m telescope was used for deep Sloan *i*-band imaging of OJ 287 to directly detect the host galaxy. A clear excess with respect to a point source is evident (Fig. 1) Modeling this excess with a two component model (AGN + host galaxy with de Vaucouleurs profile) yields $i = 18.5$ ($M_i = -23.9$) and effective radius 2.9 arcsec (13 kpc). In addition, multicolor photometry of the object was collected from many observers, covering over 30 years. Altogether the data point to the host being a very bright galaxy. It may be similar to NGC4889 in the Coma cluster of galaxies (Fig 3.5).

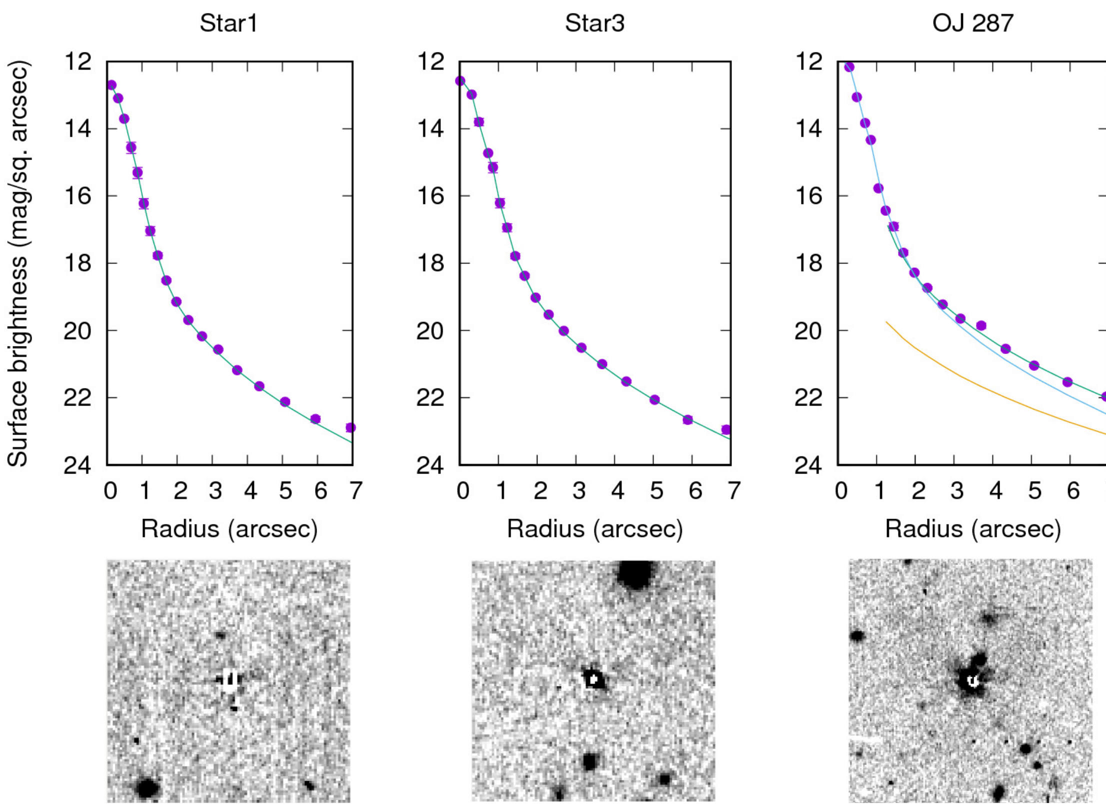


Figure 3.5: Surface brightness profiles and best models for the host of OJ287

A large number of historical data points have been added to the light curve of OJ287. In addition to the 5 large outbursts which were used in 1995 to solve the orbit, 17 more outbursts have now been identified between year 1900 and today. They all fit to the pattern of the published theoretical light curve from 1900 to 2030 by Sundelius et al. (1997). Thus the original orbit model has been confirmed. The last two predictions, the 2019 and 2022 outbursts, are still to be observed. They represent special difficulty since primary peaks occur in July when OJ287 is close to the sun and difficult to observe from the ground. The FINCA participants in this work are **Kari Nilsson** and **Mauri Valtonen**, as well as visitor to FINCA Lankeswar Dey.

3.2.2 Stellar astrophysics

Close interacting binary stars

Vitaly Neustroev has continued studying interacting binary stars such as cataclysmic variables (CVs) and low mass X-ray binaries. The focus of his research has been on the study of the late evolution of CVs and the physics of accretion discs

Vitaly Neustroev with collaborators also continued their work on the study of the best period-bounce candidate SSS J122221.7-311525 (Neustroev et al. 2017). Until recently, only a handful of WZ Sge-type CVs have been observed in X-rays, and GW Lib was the only binary of this type with complete coverage of an X-ray light curve throughout a superoutburst. Vitaly Neustroev analysed extensive X-ray observations of SSS J122221.7-311525 during its superoutburst in 2013, decline and subsequent quiescence. The results were compared with the properties of GW Lib, for which new X-ray observations were also nbtained. Vitaly Neustroev with collaborators showed that the X-ray flux exhibits changes at the times of changes in the superhump behaviour of both SSS J122222 and GW Lib. This result demonstrates a relationship between the outer disc and the white dwarf boundary layer for the first time, and suggests that models for accretion discs in high mass ratio accreting binaries are currently incomplete.

Vitaly Neustroev has also been involved in work undertaken to study long- and short-period (below the period minimum) WZ Sge-type CVs (Wakamatsu et al. 2017; Namekata et al. 2017), and to examine a distribution of emission regions in long-period nova-like CVs (Hernandez et al. 2017). This work has been performed in cooperation with the researchers from Japan and Mexico.

The birth environments of cosmic explosions and the dawn of multi-messenger astronomy

Some of the most energetic phenomena observed in the universe are related to the death of massive stars. Gamma-ray bursts (GRB) are the brightest electromagnetic events known, sending high-energy gamma rays and electromagnetic radiations across the distant universe. A type of GRB, those that typically last a few seconds or longer, are thought to be produced when the core of a highly massive star collapses inward and produces a black hole with collimated jets. As these explosions occur mostly in distant galaxies, there is not much opportunity to study the host galaxies and stellar populations that give rise to these transient events. **Hanindyo Kuncarayakt**i was involved in a study of galaxies hosting two nearby GRBs, GRB 980425 (SN 1998bw) and GRB 100316D using MUSE integral field spectrograph at the VLT. These comprise the best examples of resolved spectroscopy of GRB host galaxies. The study found that the explosion sites of the two GRBs generally have the lowest metallicity, highest star formation rate, and youngest age compared to the rest of the galaxy. From the stellar population age, stars between 20-40 solar mass are expected to still be present in the explosion sites and the GRB progenitors likely belonged to this mass range. This confirms that high mass and low metallicity are the typical characteristics of GRB progenitors. (Kruehler et al. 2017; Izzo et al. 2017).

The short-duration (<2s) GRBs are thought to be caused by an entirely different phenomenon. When a neutron star, another kind of product of collapsed massive star core, merges with another neutron star or black hole, it will be disrupted and produce a fainter phenomenon called kilonova, which may be accompanied by a short GRB. Gravitational wave (GW) emissions are also produced in this merger, and the detection of this emission has been intensely pursued due to the fact that GW acts as a new messenger of information and opens a new observing window of the universe, in addition to photons from electromagnetic radiation. The historic year 2017 saw the first detection of an electromagnetic counterpart of a GW event, which occured in GW170817. Following the GW signal detection by LIGO/VIRGO collaboration, a multitude of astronomers around the world (including Kuncarayakti) collaborated together using various facilities including ESO telescopes, to catch for the first time the radiation from gamma ray through radio wavelengths following a GW event. The transient turned out to be a merger of two neutron stars, and the comprehensive observations show that it produced a significant amount of heavy elements, including gold and platinum, as predicted by theoretical calculations. This extraordinary event marks the dawn of an era where electromagnetic radiation, previously the sole messenger of information in the universe, is now used together with GW emissions to probe deeper and advance our understanding of the universe. (Smartt et al. 2017; Abbott et al. 2017).

Studies of millisecond pulsars (Hakala & Kajava)

Millisecond pulsars are very fast rotating neutron stars that emit typically either radio or X-ray emission with a pulse period of the order of milliseconds. Radio pulsars are known to be the "most accurate clocks in the universe", however the question how these pulsars have been spun up to such high frequencies has not fully been understood. Even if theories have predicted that these pulsars are actually born in binary systems and spun up due to transfer of mass and angular momentum from a companion star (i.e. the pulsar recycling process, Alpar et al., Nature, 300, 728, 1982), direct observational evidence for such behaviour in action has been scarce. However, relatively recently, Papitto et al. (Nature, 501, 517, 2013) discovered that in one binary system, namely PSR J1023+0038, the pulsar changes in between being a radio and X-ray pulsar yielding direct evidence in support of the "recycling" model.

PSR J1023+0038 is an X-ray binary consisting of a neutron star and a "normal" star in an orbit around each other with a period of 4.75h. The neutron star has been spun up to a spin period on 1.4 msec. The system spends a couple of years at the time in either of the two states: In accreting state, the neutron star receives matter (and angular momentum) from the companion star and is spun up and shows up as an X-ray pulsar. In non-accreting state the neutron star appears as a radio pulsar with the same 1.4msec period. Currently the source is in accreting, X-ray emitting state and in 2017 FINCA researchers **Hakala & Kajava** have studied the accretion process using the Nordic Optical Telescope (results published in Hakala & Kajava, 2018, MNRAS, 474, 3297). The source shows strong flaring in its optical emission (as well as in X-rays) on time scales of minutes. By obtaining high time resolution optical polarimetry Hakala & Kajava have discovered that the flaring is associated with the changes in optical polarisation indicative of changes in underlying accretion physics. They also obtained optical spectroscopy in hydrogen H_α line, which allowed them to build up so called Doppler tomograms of the accretion disc in the system. Doppler tomograms base on flaring and non-flaring data separately also highlight the changes in accretion structure (Fig 3.6). This is the first time such changes have been seen in a system like PSR J1023+0038.

The enigmatic microquasar Cyg X-3: a gravitational wave source progenitor and a key to jet evolution studies in X-ray binaries?

Cyg X-3 is a unique high-mass X-ray binary in our Galaxy with a short orbital period of 4.8-hours. It is known for massive outbursts that emit throughout the electromagnetic spectrum from radio to γ-rays and produce major radio flaring episodes during which the source is the most radio-luminous object in our Galaxy. The combination of short orbital period, and the presence of a compact object with a massive companion star makes it a good prototype candidate for being a progenitor of a

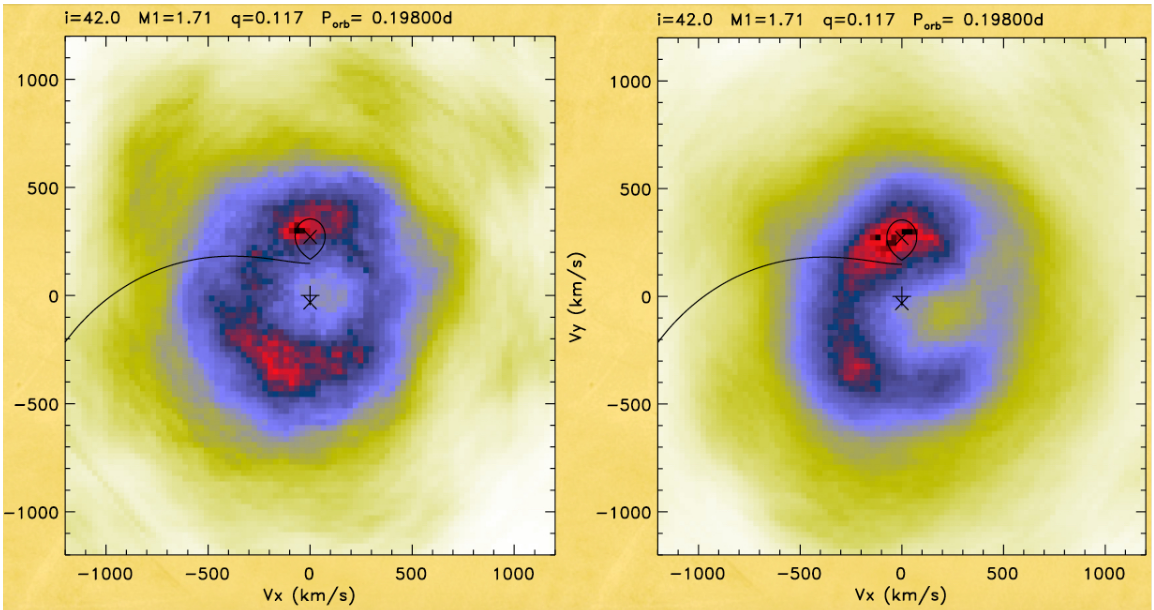


Figure 3.6: Doppler tomogram of the accretion disc structure during normal (left) and flaring (right) states.

gravitational wave source, and thus its properties merit a closer look.

Karri Koljonen et al. observed Cyg X-3 several times first with the Gemini Near-IR Spectrograph on the 8.1 m Gemini North telescope while the source was in the hard X-ray state (Koljonen & Maccarone 2017), and during two major radio flare episodes with several radio/X-ray/γ-ray facilities (Koljonen et al. 2018, in press). Koljonen & Maccarone (2017) described the observed infrared spectra as arising from the stellar wind of the companion star and suggested its classification as a Wolf-Rayet (WR) star of a type WN 4–6. They described the orbital variations of the emission line profiles as caused by the intense X-ray emission from the compact object that causes variations in the temperature and ionization structure of the stellar wind. Unable to reproduce earlier results from which the mass function for the WR star was derived, they derived the properties of the companion star using non-LTE atmosphere models (Fig. 1). Assuming a detached binary system, limits on the masses of the binary could be derived resulting to a 14 solar mass companion and a low-mass black hole of 5 solar masses. These values are consistent with the scenario that produces a double black hole system in the future (Belczynski et al. 2013).

The observations presented in Koljonen et al. (2018) concentrated on a very specific period of time in the evolution of the binary prior to the massive outbursts observed from the source. During this period Cyg X-3 is in a so-called hypersoft state. Motivated by the results provided by joint radio/X-ray/γ-ray observations, they showed that a coherent picture of the behavior of the system can be developed if one considers the effects of the stellar wind on the radio emission, and of the jet on the stellar wind density. In the hard state, the jet constantly evacuates a cocoon in the stellar wind, while in the hypersoft state, the wind refills this region, providing a work surface for the jet when the disk returns to the hard state (Fig. 3.7). This provides evidence that the jets actually are quenched in the soft states, rather than becoming radiatively inefficient or travelling with very high Lorentz factors such that the flux outside the beaming cone is strongly deboosted.

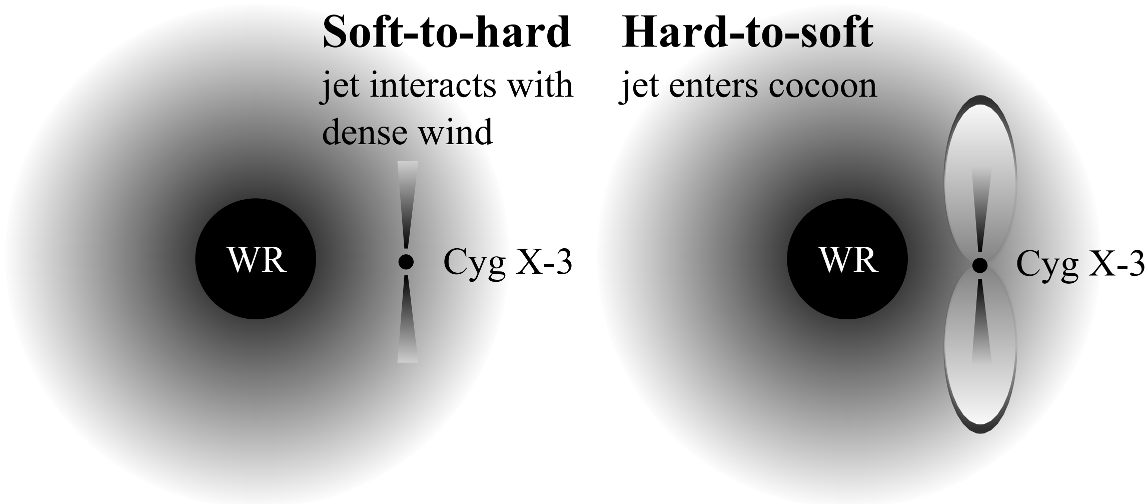


Figure 3.7: The cartoon of the jet-wind interaction for Cyg X-3. Left: In the hypersoft state the jet is turned off, and the stellar wind is allowed to expand freely close to the compact object. When the jet turns back on during the state transition, it encounters a dense medium at rest relative to the jet which leads to efficient shock production and subsequently to strong radio and γ-ray emission. Right: When Cyg X-3 is transiting from the hard state to the hypersoft state, the hard state compact jet has blown out a cocoon in the stellar wind, into which the episodic jet can then expand more freely producing weaker radio emission than when expanding directly into a stellar wind.

Black hole binaries

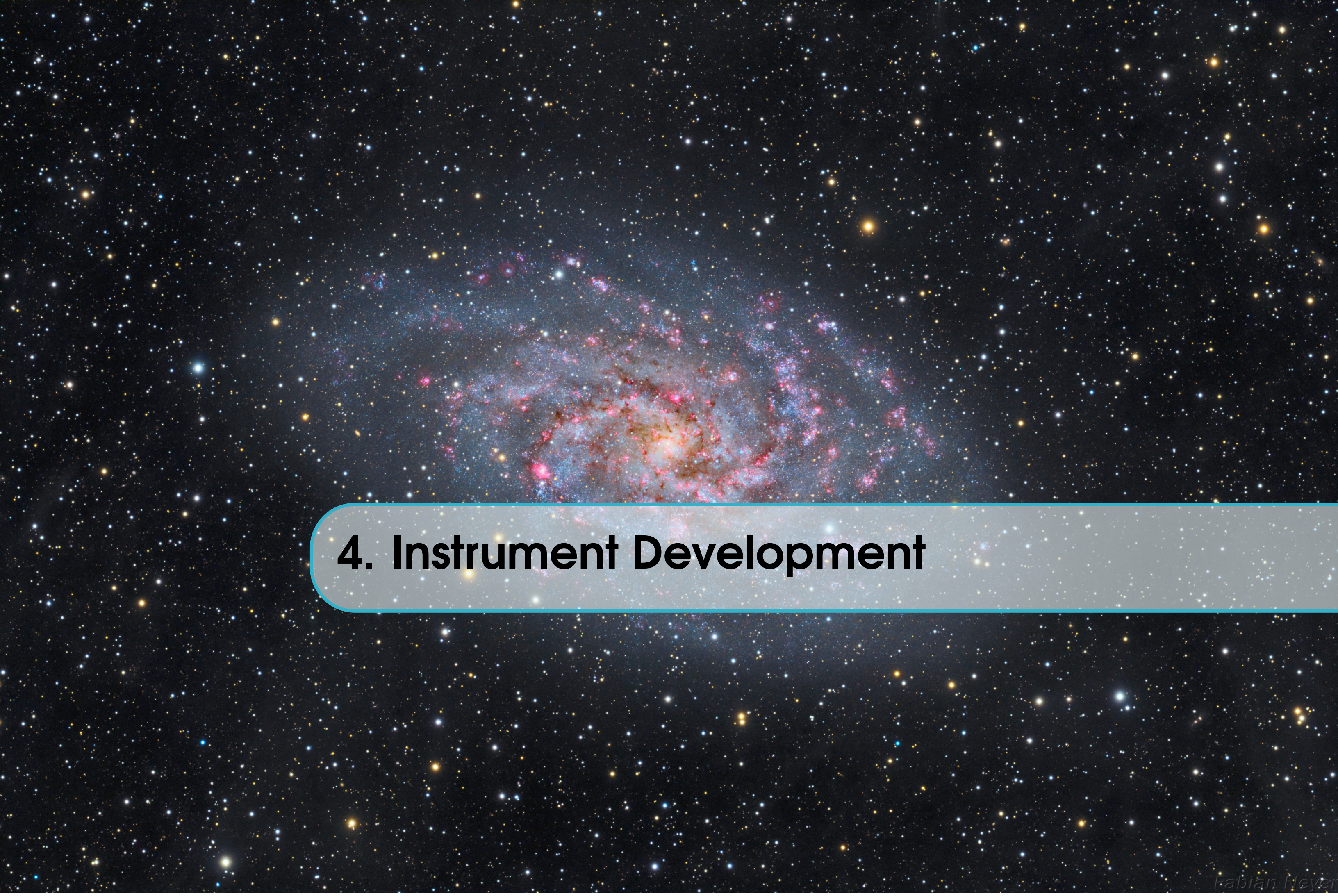
Jari Kajava and collaborators have studied the 2015 X-ray outburst of the black hole binary V404 Cyg (Motta et al. 2017a, Motta et al. 2017b, Sánchez-Fernández et al. 2017). This binary star consist of a 9 solar mass black hole that accretes gas from a mass-losing low-mass companion star. The peculiarity of V404 Cyg is that it shows unprecedented flaring episodes with up to factor of thousand swings in its brightness in time-scales of hours. Their work showed that these brightness swings are strongly influenced by mass outflows from the accretion disk that surrounds the black hole. The outflow was found to be occasionally so dense that the innermost regions of the disk are completely obscured – much like in the so called Compton-thick active galactic nuclei in the centres of some galaxies. **Jari Kajava** also collaborated with Veledina et al. (2017) in a study of another black hole binary system Swift J1753.5–0127, using archival multi-wavelength observations from VLT/FORS2 and ULTRACAM when it was mounted on UT3. This work revealed that the correlated sub-second variations in the optical and X-ray emission can be understood in terms of the so-called hot flow paradigm, where the innermost parts of the accretion disk near the black hole puffs up to a hot, geometrically thick flow. These observations could be well explained if this hot flow extends progressively further from the black hole as the X-ray brightness gradually decreased over the years. In addition the results indicated that in this system a large fraction of the optical emission is produced within this hot flow.

Low-level activity of Be/X-ray binaries

In Alfonso-Garzon et al. (2017) **Jari Kajava** and collaborators analyzed optical and X-ray observations of the Be/X-ray binary 1H 1145-619 taken over the past 40 years. The project first started with a realization that the brightness of the decretion disc that is expelled by the massive Be star is at a historically high level. As optical monitoring of this source was initiated the system started to show renewed X-ray activity as well, as the neutron star that is orbiting the Be star is now again able to capture some this expelled gas. The new observations showed that the disk around the Be star is forming a density wave and that the X-ray activity is expected to increase in the following years. In a similar study, Jari Kajava and collaborators studied another Be/X-ray binary EXO 2030+375. The X-ray activity of this system was seen to gradually decrease in 2016, and thus target of opportunity observations were taken with X-ray and optical telescopes, including the Nordic Optical Telescope. The most detailed picture of this low-luminosity period were presented in Fuerst et al. (2017).

X-ray bursts from neutron stars

X-ray bursts are thermonuclear explosions that occur in the envelopes of neutron stars. **Jari Kajava** and collaborators in Tuorla and abroad continued their work in refining methods to extract neutron star masses and radii from the X-ray burst observations (Suleimanov et al. 2017a, Suleimanov et al. 2017b, Nättilä et al. 2017). One of the outstanding issues in making such measurements is the role of the continuous accretion flow that can disturb the X-ray emitting neutron star atmosphere. In Kajava, Koljonen et al. (2017) it was shown that the thermonuclear explosions strongly influence the disk structure in certain cases, causing the entire neutron star to be engulfed momentarily underneath the accretion flow. This finding resolved one of the main issues why the atmosphere model predictions do not match the data in certain cases. In addition, in Kuuttila et al. (2017) it was shown that the cooling of the neutron star atmospheres during X-ray burst flux decays are strongly dependent on the chemical composition of the binary companion (i.e. fuel composition of the burst), but as well the state of the accretion disk prior to the explosions plays an important role. The latter finding suggests that structure of the accretion flow above the neutron star surface has some connection to the great depths within the neutron star atmosphere where the X-ray bursts are triggered.



4. Instrument Development

4.0.1 SOXS, a dual-beam spectrograph for rapid transient followup

FINCA is currently involved in the development of the SOXS (Son of X-Shooter) spectrograph. The instrument will be installed at the NTT telescope at ESO La Silla Observatory, Chile, replacing both EFOSC2 and SOFI instruments by 2020. The instrument Preliminary Design Review (PDR) phase was successfully passed in mid-2017, and now the consortium is preparing for the Final Design Review (FDR) phase. SOXS employs a high-efficiency dual-beam design to simultaneously cover a wide wavelength region from near UV to near IR (300-2000nm), with spectral resolution similar to X-Shooter (R 4500). This wide coverage will be extremely useful for studying transient objects, for which large survey projects are being set up for the next decade (e.g. Zwicky Transient Factory, Large Synoptic Survey Telescope, etc.). As these surveys aim to detect transients from asteroids to supernovae and gravitational wave electromagnetic counterparts through imaging observations, the deployment of SOXS as a major spectroscopic facility is critical. The consortium will be awarded half of the SOXS observing time for at least the first five years of operation, while the other half will be used for ESO open time.

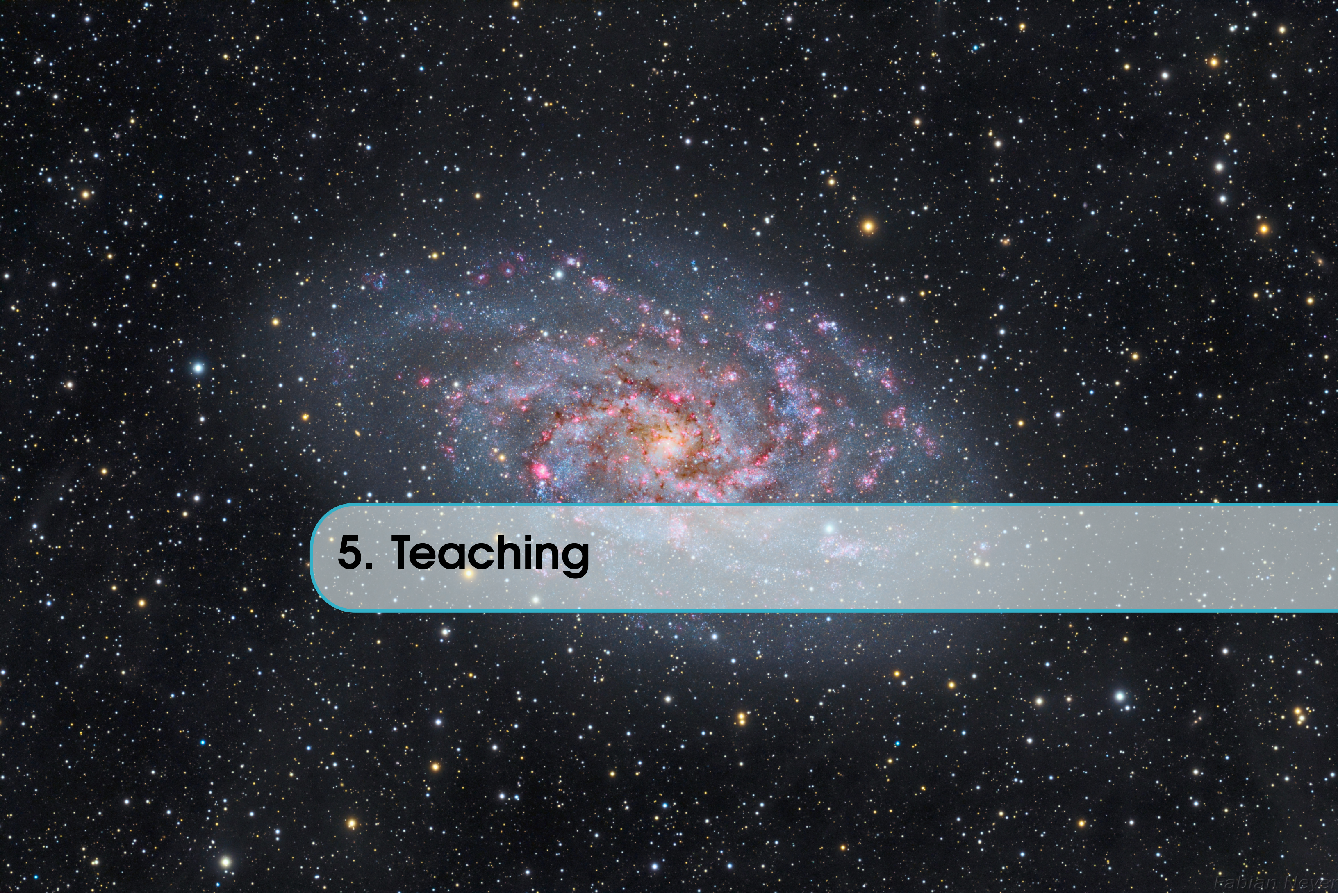
For SOXS, FINCA is contributing the calibration unit subsystem (Work Package Manager: H. Kuncarayakti). In this work, FINCA is collaborating with the local industry in Finland for the design and implementation of the system. This includes designing the optical components, mechanical assembly, and control electronics. The procurement, assembly, and tests for the subsystem are expected to be performed in late 2018 following the FDR, and in 2019 integration with the main instrument will be performed in order to achieve the goal of instrument commissioning in 2020.

4.0.2 EUCLID: Probing Dark Energy

Euclid is the next cosmology mission of ESA after Planck, complementing Planck ideally in improving our understanding of the universe. The principal objective of the Euclid mission is to solve the central problem in modern cosmology, the mystery of dark energy, the cause of the accelerated expansion of the universe. Euclid will also map the distribution of dark matter in the universe, based on its gravitational lensing effect on the light from galaxies, and help to solve the questions of the nature of dark matter and the origin of structure in the universe. The mission will also produce immense amounts of legacy data to study cosmology related questions like evolution of the black holes and host galaxies of active galactic nuclei and evolution of the cosmic star formation rate.

Euclid will be launched in 2020 and will take data for at least six years. Euclid will produce a very large amount of observational data that will be complicated to analyse. The main effort before the launch will be the development of the methods, software, and infrastructure that will be able to perform this analysis. Finnish researchers have also the obligations to operate SDC-FI, one of the 9 Euclid Science Data Centers, where the data will be analyzed. The team will develop data quality common tools, a task in the Euclid System Team for which the team members have the main responsibility and participate in the development of methods to produce simulated Euclid data.

To ensure the participation of Finnish cosmologists and astronomers in the most important observational cosmology project of the next decade, a research team consist- ing of physicists and astronomers from the Univeristy of Helsinki, University of Turku and University of Jyv´askyl´a was set up. The team members have key responsibilities in Euclid data analysis and is ideally positioned to reap a rich scientific benefit from the data. The team includes the people who carried the main Finnish responsibilities in Planck data analysis This consortium received funding from the Academy of Finland for 2016-2020 in 2016 with FINCA receiving 314 910 eur (FINCA PI Kari Nilsson).



5. Teaching

5.0.1 National and International Schools

The national remote observing school using the Nordic Optical Telescope, was organised in early November. Seppo Mattila was the main organiser of this school and from FINCA Jari Kotilainen, Kari Nilsson, Vitaly Neustroev and Pasi Nurmi participated to organising the school. The course collected 18 students from all the universities in Finland that have astronomy teaching (Aalto, Helsinki, Oulu and Turku). This year also students from Tartu Observatory, Estonia were participating the course. The stu- dents were organised in small groups, in which they planned, obtained, reduced and analysed data with an experienced tutor. The tutors and lectures came from FINCA, and Helsinki, Oulu and Turku University. The group projects covered many different astronomical topics from Solar System objects to galaxy clusters, and from cataclysmic variable stars to blazers and star-formation in quasars. The final results from the group projects were presented at the Physics Department of the Helsinki University in December 2017.

5.0.2 Lectured Courses

Basic Level (in Finnish)

J. Kotilainen	Observational Astronomy I	5	Turku
K. Nilsson	Optics	4	Turku
P. Nurmi	Project in Physics	3	Turku

Intermediate Level (Finnish or English)

V. Neustroev	Observational Astronomy and Data Analysis	6	Oulu
K. Nilsson	Laboratory in Astronomy	4	Turku

Advanced Level (English only)

R. De Propris	Galactic Astronomy	6	Turku
J. Kotilainen	Methods of Observational Astrophysics II		Turku + Helsinki
V. Neustroev	Methods of Observational Astrophysics I		Turku + Helsinki
K. Nilsson	Methods of Observational Astrophysics I		Turku + Helsinki
K. Nilsson	Methods of Observational Astrophysics II		Turku + Helsinki
P. Nurmi	Methods of Observational Astrophysics I		Turku + Helsinki
K.Koljonen	Space Instrumentation	5	Aalto
V. Neustroev	Astronomical Data Analysis with Computers	7	Oulu
V. Neustroev	Astrophysics of interacting binary stars	7	Oulu

Theses

J. Kajava	MSc thesis, Jere Kuuttila, Turku, co-supervisor
J. Kajava	PhD thesis, Joonas Nättilä, Turku, co-supervisor

6. Other Research Activities

Membership in conference SOC/LOC and other committees

Jari Kotilainen — Finland's ESO Council delegate

Jari Kajava — Secondary member of the SMARTS consortium, 2017A and 2017B semesters
Member of ESAs ATHENA Science Working Group 2.5
Member of ESAs XIPE Science Working Group 2.2 and Science Working Group 3.4
Full Member of the EUCLID Consortium
Member of the EUCLID Consortium Calibration Working Group

Ghassem Gozaliasl — Membership in the ESO-4MOST project
Membership in the Euclid OU-VIS team
Member of ESA's Athena Science Working Group 1.1

Conference Presentations

J. Kotilainen — *Quasars at all cosmic epochs*, 2.-7.4.2017, Padova, Italy.
The host galaxies of active galactic nuclei with powerful relativistic jets (oral).

SUNBIRD : Workshop on IR Bright Galaxies and Nuclear Transients, 20.-21.11.2017, Cape Town, South Africa. Secular evolution in the host galaxies of gamma-ray emitting Narrow Line Seyfert 1s (oral).

V. Neustroev — *The Golden Age of Cataclysmic Variables and Related Objects IV*, 2017 September 11-16, Palermo, Italy. Voracious vortexes and accretion disc radii in cataclysmic variables: a short review. (invited)
Systematic search for post period-minimum cataclysmic variables: A short review. (invited)

K. Koljonen — EWASS 2017, Czech Republic, Prague, 26.-30. June 2017 A connection between plasma conditions near black hole event horizons and outflow properties (oral)
EWASS 2017, Czech Republic, Prague, 26.-30. June 2017 Physical properties of the Wolf-Rayet star in the high-mass X-ray binary Cyg X-3 (poster)
When microquasars go wild, Porquerolles, France. 25.-29. September 2017 The hypersoft state of Cyg X-3: A key to jet quenching in X-ray binaries? (oral)
FinCOSPAR 2017, Finland, Seili, 23.-25. August 2017 The hypersoft state of Cyg X-3: A key to jet quenching in X-ray binaries? (oral)
29th Texas Symposium, South Africa, Cape Town, 3.-8. December 2017 The hypersoft state of Cyg X-3: A key to jet quenching in X-ray binaries? (oral)
29th Texas Symposium, South Africa, Cape Town, 3.-8. December 2017 Decomposing thermonuclear X-ray bursts (oral)

J. Kajava — *When microquasars go wild*, Porquerolles, France. 25.-29. September 2017 Outflows from super-Eddington accretion in V404 Cyg (oral)
FinCOSPAR 2017, Finland, Seili, 23.-25. August 2017
The 2015 outbursts of the black hole transient V404 Cyg (oral)

H. Kuncarayakti — FinCOSPAR 2017, Finland, Seili, 23.-25. August 2017
Mass and metallicity constraints on supernova progenitors from integral field spectroscopy of the environments (oral)
Southern Horizons in Time Domain Astronomy, IAU Symposium 339 Stellenbosch, South Africa, 13-17 Nov. 2017. "A type-Ic supernova interacting with circumstellar medium (invited)

R. De Propris — *The Amazing Life of Stars*, Cefalú, Italy, 4-8 September 2017.
Barium enhancement in NGC2808's He enriched stars (oral)

Meetings

G. Gozalialsl — EUCLID Consortium 2017 Meeting, Imperial College London, 5-9 June

	2017 COSMOS 2017 meeting, Kyoto, Japan, 3–8 July 2017 Euclid OU-VIS meeting, IAP, Paris, France, 20–21 November 2017 SPIDER meeting, MPE, Garching, Germany, 9–12 October 2017
J. Kajava	Euclid Consortium (EC) Meeting, UCL, London, Feb 20-21, 2017 EC System Team Meeting, RAS, London, Feb 24, 2017 ESA/EC Meeting, ESAC, Madrid, Mar 7-8, 2017
H. Kuncarayakti	NUTS collaboration meeting, 17-18 Aug, Stockholm, Sunbird collaboration meeting, 18-21 Nov, Stellenbosch, South Africa

Other talks

V. Neustroev	2017 May 10, Instituto de Astrofísica de Canarias - IAC (Tenerife, Spain): A systematic search for highly-evolved post-period-minimum cataclysmic variables. The case of SSS J122221.7-311525 - the most-evolved CV known to date. 2017 October 10, University of Concepción (UdeC), Chile: "Revealing new candidates for highly-evolved post period-minimum cataclysmic variables among WZ Sge-type stars. 2017 October 11, ESO Santiago (Chile), ESO Colloquium: "Revealing new candidates for highly-evolved post period-minimum cataclysmic variables among WZ Sge-type stars.
J. Janz	03.10.2017, Oulu, On the zoo of low-mass early-type galaxies 16.11.2017, Turku, On the mass-size diagram of early-type galaxies – clues about the origins of low-mass early types 17.11.2017, Helsinki, On the mass-size diagram of early-type galaxies – clues about the origins of low-mass early types

Research Visits

V. Neustroev	Nordic Optical Telescope, La Palma, Spain, 2017 May 1-9 Collaborator: Anlaug Amanda Djupvik University of Copenhagen, Dark Cosmology Centre, 2017 May 11- 15. Collaborators: Lise Christensen and Heidi Korhonen ESO Santiago & University of Concepción, Chile, 2017 October 7- 11, Collaborator: Ronald Mennickent
H. Kuncarayakti	Saas-Fee Advanced Course Supernovae: Cosmic Explosions, 12-18 Mar, Universite de Geneve (S. Ekström, C. Georgy et al.) SOXS PDR meeting, 20-21 Jul, INAF-Brera Milano, SOXS consortium (S. Campana, P. Schipani et al.)
K. Koljonen	New York University Abu Dhabi, 26.11.-31.11.,

	collaborator Dave Russell
J. Kajava	University of Oxford, Feb 22-23, 2017; Visit Sara Motta ESAC, Madrid, June 11-15, 2017, Visit Celia Sanchez-Fernandez and Felix Fuerst ESAC, Madrid, September 11-22, 2017; Visit Guillermo Buenadicha and Luca Conversi
G. Gozaliasl	School of Astronomy, IPM, Tehran, Iran, 3 October 2017

Hosted Visitors

J. Kotilainen	3.-27.7.2017 Petri Väisänen, SAAO 18.-21.9.2017 Malte Schramm, NAOJ, Japan 12.-15.12.2017 Andreas Schulze, NAOJ, Japan
H. Kuncarayakti	7.8-25.8.2017, Keeichi Maeda, Kyoto University 20.3-1.4.2017, Lluis Galbany, University of Pittsburgh
R. De Propris	October 2017, Michael West (Lowell Observatory)
V. Neustroev	12-26.8.2017, Sergey Zharikov, UNAM

7. Publications

1. 2017 A&A 597 A86 – Poudel, A.; Heinämäki, P.; Tempel, E.; Einasto, M.; Lietzen, H.; Nurmi, P.
   The effect of cosmic web filaments on the properties of groups and their central galaxies

2. 2017 A&A 597 A92 – Kangas, T.; Portinari, L.; Mattila, S.; Fraser, M.; Kankare, E.; Izzard, R. G.; James, P.; González-Fernández, C.; Maund, J. R.; Thompson, A.
   Core-collapse supernova progenitor constraints using the spatial distributions of massive stars in local galaxies

3. 2017 MNRAS 464 2784 – Somero, A.; Hakala, P.; Wynn, G. A.
   High-resolution optical spectroscopy of RS Ophiuchi during 2008-2009

4. 2017 ApJ 836 A205 – Abeysekara, A. U. et al.
   A Luminous and Isolated Gamma-ray Flare from the Blazar B2 1215+30

5. 2017 MNRAS 465 843 – Mancini, L. et al.
   Orbital alignment and star-spot properties in the WASP-52 planetary system

6. 2017 PASJ 69 2 – Namekata, K. et al.
Superoutburst of WZ Sge-type dwarf nova below the period minimum: ASASSN-15po

7. 2017 MNRAS 466 3600 – Bettoni, D.; Falomo, R.; Kotilainen, J. K.; Karhunen, K.
Low-redshift quasars in the SDSS Stripe 82: associated companion galaxies and signature of star formation

8. 2017 MNRAS 466 4492 – Ciocca, F.; Saracco, P.; Gargiulo, A.; De Propris, R.
Colour gradients in cluster ellipticals at z $\sim$ 1.4: the hidden content of the galaxy central regions

9. 2017A&A 601 94 – Rivera-Ingraham, A. et al.
Galactic cold cores. VIII. Filament formation and evolution: Filament properties in context with evolutionary models

10. 2017 MNRAS 467 597 – Neustroev, V. V. et al.
The remarkable outburst of the highly evolved post-period-minimum dwarf nova SSS J122221.7-311525

11. 2017 MNRAS 467 3712 – Olguin-Iglesias, A.; Kotilainen, J. K.; Leon Tavares, J.; Chavushyan, V.; Anorve, C.
Evidence of bar-driven secular evolution in the gamma-ray narrow-line Seyfert 1 galaxy FBQS J164442.5+261913

12. 2017A&A 602 A40 – Sanchez-Fernández, C.; Kajava, J. J. E.; Motta, S. E.; Kuulkers, E.
Hard X-ray variability of V404 Cygni during the 2015 outburst

13. 2017A&A 602 A85 – Kruhler, T.; Kuncarayakti, H.; Schady, P.; Anderson, J. P.; Galbany, L.; Gensior, J.
Hot gas around SN 1998bw: Inferring the progenitor from its environment

14. 2017A&A 604 A3 – Zaprudin, B.; Lehto, H. J.; Nilsson, K.; Somero, A.; Pursimo, T.; Snodgrass, C.; Schulz, R.
Solar-insolation-induced changes in the coma morphology of comet 67P/Churyumov-Gerasimenko. Optical monitoring with the Nordic Optical Telescope

15. 2017 MNRAS 468 4362 – Kosenkov, Ilia A.; Berdyugin, Andrei V.; Piirola, Vilppu; Tsygankov, Sergey S.; Palle, Enric; Miles-Páez, Paulo A.; Poutanen, Juri
High-precision optical polarimetry of the accreting black hole V404 Cyg during the 2015 June outburst

16. 2017 Nature Astronomy 1 A157 – West, Michael J.; De Propris, Roberto; Bremer, Malcolm N.; Phillipps, Steven
Ten billion years of brightest cluster galaxy alignments

17. 2017 A&A 604 A77 – Kuuttila, J.; Kajava, J. J. E.; Nättilä, J.; Motta, S. E.; Sanchez-Fernandez, C.; Kuulkers, E.; Cumming, A.; Poutanen, J.
Flux decay during thermonuclear X-ray bursts analysed with the dynamic power-law index method

18. 2017 ApJ 844 A165 – Pjanka, Patryk; Greene, Jenny E.; Seth, Anil C.; Braatz, James A.; Henkel, Christian; Lo, Fred K. Y.; Läsker, Ronald
Circumnuclear Structures in Megamaser Host Galaxies

19. 2017 MNRAS 469 1655 – Kapanadze, B.; Dorner, D.; Romano, P.; Vercellone, S.; Mannheim, K.; Lindfors, E.; Nilsson, K.; Reinthal, R.; Takalo, L.; Kapanadze, S.; Tabagari, L.
The prolonged X-ray flaring activity of Mrk 501 in 2014

20. 2017 MNRAS 469 2539 – Kalinova, V. et al.
Towards a new classification of galaxies: principal component analysis of CALIFA circular velocity curves

21. 2017 A&A 605 A82 – Mäkelä, M. M.; Haikala, L. K.; Gahm, G. F.
Rosette nebula globules: Seahorse giving birth to a star

22. 2017 ApJ 846 167 – Knežević, Sladjana; Läsker, Ronald; van de Ven, Glenn; Font, Joan; Raymond, John C.; Bailer-Jones, Coryn A. L.; Beckman, John; Morlino, Giovanni; Ghavamian, Parviz; Hughes, John P.; Heng, Kevin
Balmer Filaments in Tycho's Supernova Remnant: An Interplay between Cosmic-ray and Broad-neutral Precursors

23. 2017 MNRAS 470 48 – Veledina, Alexandra; Gandhi, Poshak; Hynes, Robert; Kajava, Jari J. E.; Tsygankov, Sergey S.; Revnivtsev, Michail G.; Durant, Martin; Poutanen, Juri
Expanding hot flow in the black hole binary SWIFT J1753.5-0127: evidence from optical timing

24. 2017 MNRAS 470 1960 – Hernandez, M. S.; Zharikov, S.; Neustroev, V.; Tovmassian, G.
Structure of accretion flows in nova-like cataclysmic variables: RW Sextantis and 1RXS J064434.5+334451

25. 2017 MNRAS 470 L107 – Jimenez-Andrade, E. F.; Chavushyan, V.; Leon-Tavares, J.; Patino-Alvarez, V. M.; Olguin-Iglesias, A.; Kotilainen, J.; Falomo, R.; Hyvönen, T.
Detection of helicoidal motion in the optical jet of PKS 0521-365

26. 2017 A&A 606 89 – Furst, F. et al.
Studying the accretion geometry of EXO 2030+375 at luminosities close to the propeller regime

27. 2017 ApJ 848 104 – Schulze, A., Schramm, Malte; Zuo, Wenwen; Wu, Xue-Bing; Urrutia, Tanya; Kotilainen, Jari; Reynolds, Thomas; Terao, Koki; Nagao, Tohru; Izumiura, Hideyuki
Near-IR Spectroscopy of Luminous LoBAL Quasars at $1 < z < 2.5$

28. 2017 ApJ 848 L12 – Abbott, B. P. et al.
Multi-messenger Observations of a Binary Neutron Star Merger

29. 2017 MNRAS 471 1634 – Herrero-Illana, R. et al.
Star formation and AGN activity in a sample of local luminous infrared galaxies through multiwavelength characterization

30. 2017 MNRAS 471 1797 – Motta, S. E. et al.
Swift observations of V404 Cyg during the 2015 outburst: X-ray outflows from super-Eddington accretion

31. 2017 MNRAS 471 2059 – Väisänen, Petri; Reunanen, Juha; Kotilainen, Jari; Mattila, Seppo; Johansson, Peter H.; Ramphul, Rajin; Romero-Cañizales, Cristina; Kuncarayakti, Hanindyo
Shutting down or powering up a (U)LIRG? Merger components in distinctly different evolutionary states in IRAS 19115-2124 (the Bird)

32. 2017A&A 607 A52 – Alfonso-Garzon, J.; Fabregat, J.; Reig, P.; Kajava, J. J. E.; Sanchez-Fernandez, C.; Townsend, L. J.; Mas-Hesse, J. M.; Crawford, S. M.; Kretschmar, P.; Coe, M. J.
Long-term optical and X-ray variability of the Be/X-ray binary H 1145-619: Discovery of an ongoing retrograde density wave

33. 2017 ApJ 849 120 – Roettenbacher, Rachael M et al.
Contemporaneous Imaging Comparisons of the Spotted Giant σ Geminorum Using Interferometric, Spectroscopic, and Photometric Data

34. 2017 MNRAS 472 78
Kajava, J. J. E.; Koljonen, K. I. I.; Nättilä, J.; Suleimanov, V.; Poutanen, J.
Variable spreading layer in 4U 1608-52 during thermonuclear X-ray bursts in the soft state

35. 2017 Nature 551 75 – Smartt, S. J. et al.
A kilonova as the electromagnetic counterpart to a gravitational-wave source

36. 2017A&A 608 A21 – Saajasto, M et al.
Correlation of gas dynamics and dust in the evolved filament G82.65-02.00

37. 2017A&A 608A A22 – Aalto, S. et al.
Luminous, pc-scale CO 6-5 emission in the obscured nucleus of NGC 1377

38. 2017A&A 608 A31 – Nättilä, J.; Miller, M. C.; Steiner, A. W.; Kajava, J. J. E.; Suleimanov, V. F.; Poutanen, J.
Neutron star mass and radius measurements from atmospheric model fits to X-ray burst cooling tail spectra

39. 2017A&A 608 A68 – Fallah Ramazani, V.; Lindfors, E.; Nilsson, K.

Empirical multi-wavelength prediction method for very high energy gamma-ray emitting BL Lacertae objects

40. 2017 MNRAS 472 2181 – Koljonen, K. I. I.; Maccarone, T. J.
Gemini/GNIRS infrared spectroscopy of the Wolf-Rayet stellar wind in Cygnus X-3

41. 2017 MNRAS 472 3789 – Carnerero, M. I. et al.
Dissecting the long-term emission behaviour of the BL Lac object Mrk 421

42. 2017 MNRAS 472 3905 – Suleimanov, Valery F.; Kajava, Jari J. E.; Molkov, Sergey V.; Nättilä, Joonas; Lutovinov, Alexander A.; Werner, Klaus; Poutanen, Juri
Basic parameters of the helium-accreting X-ray bursting neutron star in 4U 1820-30

43. 2017 MNRAS 472 4480 – Izzo, L. et al.
The MUSE view of the host galaxy of GRB 100316D

44. 2017 Nature Astronomy 1 A865 – Kankare, E. et al.
A population of highly energetic transient events in the centres of active galaxies

45. 2017 PASJ 69 89 – Wakamatsu, Y. et al.
ASASSN-16eg: New candidate for a long-period WZ Sge-type dwarf nova