German node : Violent Star Formation, Massive Stars & Feedback

September 8, 2003

Main Node : Göttingen, Sub-Node : Munich

Researchers involved:

Göttingen		Munich	
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1 Objectives:

Study of starbursts & the role of massive stars & feedback in a wide variety of astrophysical environments (dwarf and giant galaxies, isolated and interacting galaxies, low and high metallicity environments) to assess key questions, such as:

- universality of the star-forming (SF) process vs. environmental/metallicity dependence
- violent vs normal (=low-level) SF
- what triggers starbursts/violent SF episodes (internal properties/dynamics vs external triggers/interactions)
- star vs. star cluster formation processes
- role of feedback in regulating and terminating starbursts

2 Originality and Timelines:

Long-standing tradition for isolated studies of different aspects, types of systems, wavelength regions, theory/observations, nearby resolved vs more distant unresolved systems, small scale vs large scale studies, ... in all the proposing institutes.

FP6-RTN offers the possibility to combine, compare and push foreward decisively by synergy effects the individual approaches. In several aspects preparatory work and development of theoretical models, observational possibilities and techniques and sophisticated data reduction methods have gone on for many years. Time is ripe now to gather the fruits and make decisive progress within few years by combining the approaches and knowledge at hand in the participating institutes. This is only possible within the framework of an large FP6 network and goes far beyond what would be possible within existing collaborations.

Violent vs. "normal" SF in massive galaxies

In parallel to detailed studies of SF rates, efficiencies, and thresholds in relation to the overall content, surface density, kinematic properties and geometrical distribution of neutral and molecular gas, and of the physical processes at the origin of SF in spiral galaxies – their "normal" SF – the violent SF observed in nuclear and global starbursts in interacting and merging galaxies has attracted much attention in recent years. Enormously strong starbursts have been discovered in the relatively local Universe in the form of Ultraluminous Infrared Galaxies (ULIRGs), the bulk of them being advanced mergers of massive gas-rich galaxies. They have enormous central gas concentrations up to the point where the gas is by far the dynamically dominant mass component – almost fully molecular. Of order 10^{10} $M_\odot$ of gas within regions of ≤ 1 kpc feature the highest densities found in the comparatively tiny cores of Galactic molecular clouds. This clearly raises the question if the extremely violent SF process in massive and gas-rich interacting systems is the same, just upscaled in effieciency by about a factor of 100, or completely different in nature from what it is in undisturbed spirals, SFing or even starbursting dwarf galaxies.

Moreover, the very reasons for these differences are not really understood yet: be it the difference in total mass and, hence, potential depth, or related to the dynamics of the interaction that e.g. gives rise to to large-scale compression, gas flows and shocks.

Evidence has been accumulating over the last few years that burst-like, i.e. violent SF has been the rule rather than the exception in the early Universe. Hierarchical structure formation scenarios as well as observations of galaxy pair rates, morphologies, and SF rates agree on the increasing importance of accretion- or interaction-induced starbursts at higher redshifts.

A key to these very fundamental questions that can only be answered by a big and coordinated effort among observers at all wavelengths and theorists using various approaches (dynamical modelling of galaxy interactions including SF on large scales and of processes within molecular clouds on small scales, evolutionary synthesis models to assess SF rates, histories, and efficiencies) – as contributing to this proposed RTN project – is for certain the comparison between analyses of SF in giant and dwarf, isolated and interacting galaxies.

In both fields, the investigation of starbursts in interacting massive and starbursting and non-starbursting dwarf galaxies, Göttingen has a long and strong record and developed many dedicated tools.

Starbursts and low-level SF in dwarf galaxies

Gas-rich dwarf galaxies in the local Universe span a wide range in their star formation amplitude and recent-to-past star-forming (SF) rate. In spite of more than two decades of intensive work, we are still far from a comprehensive understanding of the processes regulating the global SF process in the two main representants of this extragalactic class, the blue compact dwarf (BCD) and dwarf irregular (dI) galaxies. For a comprehensive study of the long-term evolutionary history of these systems it is necessary to understand which physical processes give rise to recurrent starburst activity in the first one, while supressing any large-scale, collective SF process in the other case. Is the observed diversity a natural consequence of the stochastic nature of SF or rather the outcome of distinct merging histories? Alternatively, could differences in the SF history be accounted for by differences in intrinsic dynamical properties, as they are dictated by the interplay of luminous and dark matter?

Such questions will undoubtedly become central to the extragalactic research during this decade. As the process of violent star formation is intimately linked to galaxy formation itself, as well as a major driver of heavy-element enrichment in the early Universe, understanding its origin and implications using nearby extragalactic probes could lead to new important constraints to observational cosmology.

It is important to keep in mind that both dIs and BCDs possess an evolved stellar LSB host galaxy underlying their irregular SF component. This host, showing in either case an exponential intensity profile, is composed of an evolved stellar population which, due to its higher mass-to-light (M/L) ratio, may strongly influence the gravitational potential at small radii. Only recently is has been realized that the stellar density distribution in the LSB component of BCDs is significantly more compact than in dIs (Papaderos et al. 1996; hereafter P96). This finding suggests that a prerequisite for the ignition of violent SF activity in an isolated dwarf is a steep gradient in its gravitational potential.

Also other lines of evidence support the notion that the structural properties of the LSB component play a key role in regulating the global SF process. Optical surface photometry indicates that violent SF activity in BCDs is not occurring out to a fortuitous galactocentric distance but, typically, within 2 scale lengths of their underlying LSB host galaxies (Papaderos et al. 1996). Furthermore, the fractional area of a BCD being susceptible to violent star formation, as well as the burst parameter increase with decreasing mass of the stellar LSB component (P96; Krüger et al. 1995) in agreement with predictions of stochastic self-propagating SF scenarios and strongly at variance with what is seen in massive interacting galaxies.

An extensive study of the BCD structure in NIR wavelengths, completed recently at Göttingen (Noeske et al. 2003a-c) strengthens previous findings and points to a minimum LSB density as necessary condition for the ignition of starburst activity. Interestingly, this empirical criterion naturally accounts for several differences in the structural properties of bursting and non-bursting gas-rich dwarfs.

Goals to be achieved within this projects:

These recent results open up a new promising conceptual framework for investigating origin and implications of violent SF activity in the local Universe and at higher redshift. The determination of the gaseous, stellar and dark matter density distribution and its time evolution using both observational and theoretical tools appears to be a prime task. Such an endeavor requires multiwavelength studies which can be carried out efficiently only by combining the expertise from different research groups, specialized in kinematical modeling under consideration of radio, optical or NIR data. Moreover, for real progress to be made it is important to refine existing theoretical tools and confront them with a wider range of observational constraints. Existing models focus mainly on luminosity-weighted observables, averaged over the whole galaxy (e.g., total color, equivalent widths). However, various other spatial and dynamical indicators of violent star formation await to be determined systematically and modelled; as an example, one may think of luminosity and color gradients, or the starburst-to-LSB size ratio.

The nature of stellar sources contributing to the starburst emission is another, widely unexploited piece of information. The young stellar population seems to be composed of both, compact and diffuse young stellar sources. A key question is whether these two populations are fundamentally different with respect to their nature and the physical conditions required for their formation. Alternatively, they may have formed coevally or sequencially, as the latter may have emerged through the gradual evaporation of the former.

In the violent starbursts accompanying interactions/mergers of massive gas-rich galaxies, the formation of massive and compact star clusters seems to be the dominant mode of SF (de Grijs et al. xxx, ...) with indications for an increase in the ratio of compact star cluster - to - diffuse (= C2D) SF with increasing burst strength, i.e. violence of SF.

The light (and mass) fraction of compact-to-diffuse stellar sources evolving in a starburst environment has been never previously systematically studied and checked for a possible correlation to other galactic properties. First, is a C2D of the order of unity a characteristic of violent star formation, as frequently hypothesized? Furthermore, is C2D correlated with, e.g., the SF efficiency, burst parameter, or the structural properties of the underlying LSB component? Are isolated starburst galaxies distinct from interacting/merging ones with respect to their C2D? A first requirement for addressing such questions is to precisely infer the C2D ratio and the total starburst luminosity in a wide range of extragalactic sources. The latter task is not straightforward and requires a meaningful decomposition of surface brightness profiles.

3 Work plan:

We are proposing to employ a postdoctotal and a PhD student, both of whom will be based in Göttingen, but who will maintain a tight collaboration with other nodes.

The **PhD student** will focus on specific questions pertaining to the nature and formation history of young stellar populations in a BCD sample, spanning a wide range in morphology, oxygen abundance and other physical properties (mass, gas content, environment).

At a first stage she/he is going to get acquainted with 1D and 2D surface photometry techniques and, based on the extensive package of numerical routines developed for this purpose at Göttingen, construct a semi-automatic analysis package. In addition, real ground-based and HST data, as well as artificial images will be used to test techniques, such as unsharp-masking, wavelet transform and source detection algorithms for recovering the compact-to-extended light ratio (C2E) in more distant star-forming galaxies.

These software tools will be applied to a representative sample of 40 to 50 BCDs in order to investigate the photometric structure of their old LSB and young starburst population, puting particular emphasis on the formation history of the latter and its multiwavelength luminosity evolution. Among the issues to be addressed is the C2E ratio and its possible relations to the structural properties of the underlying LSB host galaxy (for instance, central mass density, exponential scale length, Sérsic shape parameter), as well as color, metallicity and age gradients within the extended star-forming component of BCDs. These issues have never been studied systematically.

The star formation history (SFH) will be investigated most efficiently combining age-date techniques, based both on spectrophotometric data of the unresolved stellar population and color-magnitude studies of point sources. This approach allows to cope with methodic limitations inherent to a given age-dating technique and allows to infer in a self-consistent manner tight constraints to the SFH. Our research group at Göttingen has used simultaneously four techniques to constrain the age of stellar populations: a) broad-band colors, b) the spectral energy distribution of the stellar continuum, and the equivalent width of Balmer c) emission and d) absorption lines. The first two sets of observables depend both on the SFH and extinction, whereas the last two are extinction-insensitive. These four techniques, have been continuously refined in our group in a series of dedicated studies and applied to several SF systems (Papaderos et al. 1998, Izotov et al. 2001, Guseva et al. 2001,2003abc). Complemented whenever applicable with CMDs, they offer a powerful tool to constrain simultaneously the SFH and the extinction in the sample galaxies.

A large set of spectroscopic and photometric data is already available and is going to be further enlarged using HET and other instruments. The South African Large Telescope (SALT; 2004) and its Prime Focus Imaging Spectrograph PFIS (2005) will allow, in the second part of the PhD project for Fabry-Perot studies of the kinematics of the warm ISM in star-forming galaxies, taking advantage of a superb instrument with adequate spectral resolution, large field of view and excellent throughput. Kinematical models, based on Hα kinematics in connection with photometric constraints to the LSB disk density distribution and HI data will allow us to, e.g., put constraints to the dark matter content *inside* the Holmberg radius of BCDs and correlate the visible-to-dark matter ratio with the SFH and C2E. Such observables may be of vital importance for the understanding of the dynamical evolution of the gaseous and stellar matter of dwarf galaxies in the presence of violent SF activity and for studying possible evolutionary links between dIs and BCDs (see, e.g., Papaderos et al. 1996).

The PhD thesis student will work in close collaboration with the Postdoc, who is also going to take advantage of SALT and its instruments in order to study stellar and gaseous kinematics in interacting starburst galaxies.

The **Postdoc** will work on violent SF in massive gas-rich interacting galaxies and on the comparison of results obtained for these with results obtained by the PhD student on SF in dwarf galaxies. She/he shall, in close collaboration with the other nodes, analyse a sample of interacting galaxies with a wide range of properties: pairs/mergers of 2 masssive gas-rich galaxies, of 1 gas-rich and 1 gas-poor galaxy, of 1 massive and 1 dwarf galaxy, of interacting systems with known orbital parameters, i.e. in various stages of the interaction, in prograde and retrograde encounters, galaxies with and without stabilising bulges. She/he will be supported by a couple of undergraduate students (diploma and master theses) and PhD students paid on other fundings (DFG, BMBF, graduate school grants, ...) that we routinely have. She/he shall analyse integrated spectra, spatially resolved spectra, imaging from U through K from the ground (VLT, HET, SALT, ...) and from HST (available through our ASTROVIRTEL project) and interprete them by means of our evolutionary synthesis code GALEV with respect to the key questions mentioned above. She/he shall contribute in collaboration with the nodes in Wien and St. Andrews to the coupling of the GALEV code with a dynamical model including different gas phases, stars, a SF criterium, and feedback, and apply the spatially resolved galaxy modelling to analyse the interplay between underlying stellar components, neutral and molecular gas, burst SF and feedback.

4 Training:

Göttingen University: Göttingen is a world-wide well renowned center for astrophysical research and education in northern Germany with a longstanding tradition in stellar evolution theory and extragalactic research, including normal, dwarf, starburst, and interacting galaxies with and without AGN, both in terms of theory and observations over wavelength regions from X-rays through optical/NIR up to radio wavelengths. We have an extensive curriculum with introductory courses into all aspects of stellar, galactic and extragalactic astrophysics and advanced courses on ISM, normal, LSB, dwarf, starburst, interacting, and AGN galaxies, SF, star clusters, observational and numerical techniques. Our institute has got a lifely visitor program and all of our groups are involved in numerous national and international collaborations.

We recently started teaching courses using internet/Beamer presentations, that could easily be made accessible to RTN students based at other nodes/subnodes. We typically have 15 undergraduate and 20 graduate students.

Few years ago, the Göttingen Graduate School of Physics was founded with particular focus on Astrophysics, offering courses in English as well as in German. It has received a great deal of interest from students from all over the world. Very recently the German Ministry for Education and Research (BMBF) has selected Göttingen as one of the first Universities that will now be funded with 1.2 MEuro to become a *notebook university* in the sense that availability of mobile computers and use of modern information and communication technologies shall be provided for students as well as dedicated learning software be developed and distributed as an integrated part of science and research training. This will certainly be of great advantage to FP6 students based in Göttingen as well as at the other nodes.

Involvement in observational/instrumental projects Göttingen Observatory, in particular the Dept. for Galactic and Extragalactic Research (Dept. II) has been pursuing since more than 10 years an extensive program devoted to the design and construction of instrumentation, notably the FORS I+II focal reducer spectrographs for the VLT. Dept. II also succeeded to make Göttingen a partner in the 10m-telescope Hobby-Eberly (HET) in Texas within a 5-university international consortium and to its 10m South African counterpart (SALT) and to ensure guaranteed time observations with these instruments for a period of at least ten years. The director of Dept. II, Klaus Fricke is a member of the Board of Directors of HET.

HET with its medium resolution spectrograph offers an excellent opportunity to establish a high-quality, high-S/N spectroscopic data basis to be used for comparison with models on the evolution of, e.g., the Ca-, H_δ- absorption line, as those calculated by Gonzalez Delgádo and her group. Refining this models in close collaboration with Göttingen and Granada will be one important task of the PostDoc.

Besides the direct imager SALTICAM, the Prime Focus Imaging Spectrograph (PFIS, under consctruction at Wisconsin) will become a workhorse of extragalactic studies with the SALT. The excellent capabilites of this instrument, especially the spectral resolving power of up to 12000 it offers in its Fabry-Perot modus makes possible to study the kinematics of the ionized gas and of the stellar component in BCDs and interacting/merging galaxies, respectively with a velocity resolution better than 20 km/s.

In addition to VLT FORS I and II, Göttingen has been engaged in the construction of the OmegaCAM for the VST. The latter will be available in the framework of guarantee time observation for project-related tasks.

We currently host a Marie Curie Postdoc (Luz-Maria Cairós) from IAC (Teneriffe). Peter Anders, one of our current PhD students, had a Marie Curie grant to visit R. de Grijs at the IoA Cambridge for 6 months earlier this year.

Subnode Munich Ludwigs-Maximilian University: The *Sternwarte der LMU* is a traditional center for stellar and extragalactic research in the south of Germany with a strong international recognition. Particular focus in recent years has been on the evolution of massive stars with mass loss (models for radiative transfer in expanding atmospheres, quantitative spectroscopy of hot stars from X-rays, EUV/UV, optical through IR) and large galaxy surveys (MUNICS NIR survey).

5 Expertise:

Node Göttingen: In Göttingen we have developed over several years an evolutionary synthesis code for simple and composite stellar populations like star clusters and galaxies, widely known as GALEV. It is unique in combining a description of the detailed chemical evolution of the gas in terms of individual element abundances with a description of the spectral evolution of the stellar population. This allows for what we call a *chemically consistent* description of both the chemical and the spectrophotometric evolution of composite stellar systems like galaxies in the sense that it accounts for the increasing metallicity of successive stellar generations and, hence, provides a realistic modelling of stellar metallicity distributions in galaxies. Accounting for the contributions of stars with lower than solar abundances is of particular importance for late-type (Sc, Sd, Irr) and dwarf galaxies (FvA 2000, ASP Conf. Ser. 221, 179). This code has been extended over the years to cover the spectral range from X-rays and UV through NIR, includes gaseous continuum and line emission, spectra, broad band colors for many filter systems, and stellar absorption features (FvA 1989, Leitherer et al. 96, Möller et al 97, Kurth et al. 99, Schulz et al. 02, Anders & FvA 03). It has been successfully applied to the interpretation of normal, interacting, and starburst galaxies, in the local Universe and to higher redshifts, of dwarf and, in particular, Blue Compact Dwarf Galaxies, as well as to star clusters and star cluster systems (FvA & Gerhard 94a, b, Krüger et al. 91, 92, 94, 95, Lindner et al. 96, 99, FvA 98, 99, Weilbacher et al. 00, 01, 02, 03, Weilbacher & FvA 01, Möller et al. 01a, b, Bicker et al. 02, de Grijs et al. 03a, b).

Göttingen has dedicated experience in the fields of observations and interpretation of integrated optical and NIR photometry of SFing galaxies: BCDs, interacting and merging galaxies, Tidal Dwarf Galaxies (=TDGs), as well as in the field of spectroscopy (UV - opt. - NIR) for Blue Compact, Wolf-Rayet, and Tidal Dwarf galaxies (references!!!). Here the focus was on the kinematic and thermodynam. properties of the ISM, on chemical abundances & abundance ratios, on spectral synthesis and chemical analysis, and on the derivation of Star Formation Histories (=SFHs).

In its present state, the GALEV code is a 1-zone model without spatial resolution or dynamics. Several years ago, we made a first attempt to consistently couple it into a combined hydrodynamical (=SPH) and N-body code for structure formation in a hierarchical cosmological context including a local SF criterium (in collaboration with M. Steinmetz and his group). At that time, this turned out to be fairly complicated but the first attempt gave very promising results (cf. Contardo, FvA & Steinmetz 98). Meanwhile, our GALEV code has been largely transformed to be very directly and easily coupled into any kind of dynamical model, provided it includes a SF criterium (Schulz, FvA & Fricke 2002). The dynamical codes developed and available in St. Andrews/Cambridge and Vienna (G. Hensler) offer ideal possibilities for such a coupling that would provide a wealth of directly observable quantities related to the stellar component forming from molecular clouds.

Göttingen also has experience with dynamical modelling of galaxies consisting of gas and stars in terms of an N-body/SPH code originally developed by Heller (1991) and adapted by I. Berentzen in collaboration with L. Athanasoula (Marseille) to run on a special purpose hardware GRAPE and model stellar and gaseous galaxy disks including internal instabilities and bars as well as external perturbations (Berentzen et al. 1998, 2003).

Starburst galaxies constitute a major subject of observational work at Göttingen since more than two decades. Our expertise includes surface photometry and profile decomposition for multicomponent extragalactic systems, such as BCDs and interacting/merging galaxies, spectrophotometric observations of TDGs. A great deal of observational effort has been devoted to the study of the structural properties of the stellar LSB component in the two main types of gas-rich dwarf galaxies (dIs and BCDs) and the investigation of possible evolutionary links (Papaderos et al. 1996ab, Papaderos 1998, Cairós et al. 2001). These studies have been now complemented with deep NIR imagery (Cairós et al. 2003, Noeske et al. 2003abc). The study of the LSB component of local SF galaxies and similar systems at higher redshift (CNLEGS) continues between the Göttingen group and Kai Noeske (Lick/California).

The process of dwarf galaxy formation has been studied observationally on types of objects: a) TDGs. A wide multiwavelength optical and spectroscopic data set has been used and interpreted using GALEV. At present our common studies with P. Weilbacher/Durham and

P.-A. Duc (Saclay) focus on selected TDG caindidates observed with the VLT. b) Metal-poor ($Z < Z_{\odot}/20$) BCDs lacking signatures of an evolved underlying LSB stellar population. The evolutionary history, dynamical evolution and chemodynamic properties of the ISM in such systems is being investigated from radio through X-ray wavelengths (Papaderos et al. 1998,1999; Fricke et al. 2001, Izotov et al. 2001, Guseva 2001, 2003abc). Already in the early stage of these studies we have cautioned the strong effect of nebular emission on the observed broad-band colors and modelled this effect.

In the course of this project we have developed and used simultaneously a set of evolutionary synthesis models, based on high S/N spectra, to reproduce the SED, colors and equivalent widths of Balmer emission and absorption lines in young BCD candidates. These tools could be be easily combined with GALEV thanks to its versatile concept, as well as with the theoretical tools specially adapted to absorption line spectroscopy (Gonzalez-Delgado; Lancon) can become

Besides stellar populations and ionized gas, our group has been focussing on the search of hot, X-ray emitting plasma in starburst galaxies, and the study of morphological and thermodynamic properties. Other fields of related research include X – FIR & X – radio correlations & evolution along the Toomre sequence and the onset of non-thermal activity in gravitatively perturbed systems. These subjects have been studied using ROSAT, XMM and Chandra (e.g. Papaderos & Fricke 1998, Papaderos 1998 and Thuan et al. 2003).

Researchers at the Göttingen observatory have ample experience in the study of isolated and gravitationally perturbed star-forming galaxies. Our field of expertise includes optical and NIR photometry and surface photometry of complex stellar systems, profile decomposition. For this purpose we developed a dedicated and extensive software package. Our expertise also includes CMD studies using ground-based and HST data, long-slit and multi-slit spectroscopy, determination of element abundances and kinematic investigations. The thermodynamic properties of discrete and diffuse X-ray emitting sources in BCDs, interacting/merging galaxies and Ultraluminous Infrared Galaxies have been studied using ROSAT, XMM and Chandra. Accompanying models on the X-ray evolution were provided by H. Krüger (1989).

Sub-node Munich:

Stellar modelling: stellar atmospheres and radiation transfer of expanding atmospheres; state of the art models for massive OB stars; radiation-hydrodynamics of stellar envelopes; SNIa and their progenitors; and diffuse ionized gas.
Stellar populations: Photoionization modelling of HII regions using state of the art evolutionary synthesis models for stellar clusters – excitation and metallicity.
Quantitative spectroscopy of hot stars: X-ray - UV/EUV - opt. - IR. **Involvement in observational projects:** HST project: O-stars in the Andromeda Galaxy; VLT: IR spectroscopy mit ISAAC; Subaru: IR spectroscopy mit IRCS

Ongoing collaborations related to this RTN project:

a) with RTN members:

- R. de Grijs, G. Gilmore (Sheffield, Cambridge): ESO ASTROVIRTEL project **The Evolution and Environmental Dependence of Star Cluster Luminosity Functions**
- L. Smith (UCL London): ionising fluxes of massive stars
- G. Hensler (Wien): dynamics of the ISM, galaxy interactions, SF process
- G. Stasinska (Paris): chemical and thermodynamic properties of the warm ISM

- D. Schaerer (Geneva): study of massive stellar populations in metal-deficient galaxies.
- J.M. Vilchez (Granada): Environmental properties of SF dwarf galaxies
- P. Mazzali (Trieste): Spectroscopy of supernovae envelopes
- F. Najarro (Madrid): Models of hot star atmospheres
- S. Smartt (Cambridge): Spectroscopy of massive stars
- A. Herrero (Tenerife): Spectroscopy of extra-galactic massive stars

b) with non-RTN members:

- C. Leitherer (STScI Baltimore): Star Clusters, starburst galaxies in the local universe and at high redshift
- P. Weilbacher (Durham): formation of star clusters and tidal dwarf galaxies in galaxy interactions
- F. Schweizer (Pasadena): interacting galaxies: integrated light studies
- R. Kennicutt (Tucson): samples of interacting galaxies, SF rates & efficiencies
- J. Hibbard (NRAO Charlottsville): star clusters and tidal dwarf galaxies
- J. Gallagher (Madison/Wisconsin): PFIS for SALT
- K. Noeske (Lick/California): BCDs and CNLGS
- A. Sternberg (Tel Aviv): Starbursts and star formation history of stellar clusters.

6 Management experience:

Göttingen has rich experience in contracting large projects, e.g. building the FORS (1+2) instruments for the VLT. Currently we are involved in building OmegaCam for the VST and instrumentation for HET and SALT. Göttingen is a member of the HET and SALT consortia and has an outstanding record of raising funds from the Deutsche Forschungsgemeinschaft, the Volkswagen Stiftung, as well as support in terms of an ESO Astrovirtel project.
Munich is also involved in VLT instrumentation: FLAMES, FORS.