The Calar Alto Observatory - Present and Future Instrumentation

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Abstract

The Calar Alto Observatory, located at 2168m altitude in the Sierra de los Filabres in southern Spanish province of Andalucia, was founded in the early 1970s in order to provide astronomers in Germany and in Spain with modern observational facilities in the northern hemisphere. This role is not going to change over the next decade as 2–4-m telescopes are still essential and more efficient than 8-m telescopes, for wide-field and surface-brightness limited surveys, for support of surveys at other wavelengths (X-ray, radio), for regular monitoring work, for pursuing innovative ideas, for obtaining accurate astrometry and photometry of reference objects and unknowns, etc. In order to pursue these challenges, state of the art instrumentation is required. In the following, the existing facilities on Calar Alto are summarised, and future instrumentation projects are briefly discussed.

Key words: Calar Alto; Telescopes; Instrumentation

1 Introduction

Construction on Calar Alto began in 1973 after an agreement between Spain and Germany, and between the Max-Planck society and the Spanish 'Comision Nacional de Astronomia', was signed. The contracts guarantee a protected site of about 100 square kilometers. The observatory is operated by the 'Max-Planck Institut für Astronomie (MPIA)' in Heidelberg/Germany and provides four telescopes of diameter 3.5-m, 2.2-m, 1.23-m, and a 80-cm Schmidt telescope. Spain runs independently a 1.5-m telescope. Telescope time is awarded semi-annually on a competitive basis through peer-reviewed proposals. The typical time allocation for the MPIA telescopes is about 40% MPIA, 50%

[1] Invited talk given at this conference

German community represented by the 'Rat Deutscher Sternwarten', 10% Spanish community, and a few percent for technical and engineering work. Weather patterns are similar to Arizona and southern California, and the number of photometric nights is similar to those at Kitt Peak, Mt. Graham, Palomar, and Lick observatories, for example.

Modern instrumentation exists at all telescopes. The adaptive optics system ALFA is state of the art. It employs a sodium laser artificial guide star to obtain diffraction-limited images at the 3.5-m telescope. The 3.5-m prime focus near-infrared (NIR) camera OMEGA Prime, with its field of view (FOV) of about $7'$, the focal reducer instruments MOSCA and CAFOS, the TWIN and FOCES spectrographs, and the NIR camera OMEGA Cass, provide a broad range of competitive and complementary facilities. Detailed information about the Calar Alto Observatory is available via our website[2].

2 The Calar Alto Telescopes

The main optical characteristics of the three MPIA telescopes are given in Table 1. Columns 2–9 list the FOV in arcmin and the plate scale in arcsec per millimetre, for the 1.23-m, the 2.2-m RC focus with and without corrector, the 2.2-m Coudé focus, the 3.5-m prime focus with the 2-lens and the 3-lens corrector, the 3.5-m RC focus, and the 3.5-m infrared (IR) focus, respectively. The telescopes are designed as Ritchey-Chrétien (RC) 2-mirror systems, with large field of views (FOV) — at the 3.5-m telescope with its 3-lens corrector, the usable field is one degree diameter. The mirrors are made from the glass-ceramic Zerodur, which is characterised by the extremely small thermal expansion coefficient of 0.15×10^{-7} per degree centigrade.

3 Available Instrumentation

The 1.23-m telescope, whose main mirror has recently been replaced by Schott free of charge, operates a direct imaging CCD camera and MAGIC, a NIR camera with a Rockwell 256×256 NICMOS3 array, at its RC focus, as well as visitor instruments. Its Nasmyth focus is not in use.

At the 2.2-m telescope, CAFOS and FOCES are the commonly used instruments. CAFOS, the Calar Alto Faint Object Spectrograph, is a focal reducer which operates at f/4.4. It provides various observing modes such as direct

[2] http://www.mpia-hd.mpg.de/CAHA/index.html

Table 1
Optical characteristics of Calar Alto Telescopes

	1.23-m	2.2-m			3.5-m			
		RC		Coudé	prime focus		RC-focus	IR-focus
		with	w/o C.		2 lens	3 lens		
f/ratio	1/8	1/7.744	1/8.005	1/40	1/3.48	1/3.93	1/10	1/45
FOV[a]	90	67	33	5	28.2	60.7	29.5	2.4
scale[b]	0.048	12.1	11.7	2.34	16.9	15.0	5.89	7.6

[a] FOV in arcmin
[b] plate scale in arcsec per millimetre

imaging, spectroscopy, multi-object spectroscopy (MOS), and polarimetry, including a rotating $\lambda/2$ plate. FOCES, a fibre-fed optical echelle spectrograph built by the University of Munich, is located in the Coudé room of the 2.2-m telescope. A commonly used $1k \times 1k$ Tektronik detector covers an optical spectrum of some 300nm, or about 70 orders. The resolution is about $R = \lambda/\Delta\lambda \approx 50\,000$. MAGIC is used at the 2.2-m telescope as well, either at the RC focus or together with the Coudé spectrograph. The vertically mounted Coudé spectrograph from Perkins Elmer extends over several floors of the building. It houses 30cm gratings from Bausch & Lomb and provides a theoretical spectral resolution of $R > 100\,000$ in the optical, with the long camera.

The 3.5-m telescope, commissioned in 1984, provides the following work-horse instruments at its prime, its RC, and its IR focus. Its Coudé focus has never been in use.

- MOSCA, a focal reducer installed at the Ritchey-Chrétien focus, with an effective focal ratio of f/2.7, recently upgraded with a SITe 15μm $2k \times 4k$ thinned CCD. Observing modes are direct imaging, low-resolution spectroscopy using grisms and a Fabry-Perot interferometer, and MOS
- TWIN, a Cassegrain instrument designed for spectroscopic observations of point sources or extended objects at intermediate spectral resolution in the 300–1100nm wavelength range, with two channels for simultaneous observations in the 'blue' and in the 'red' wavelength region
- OMEGA Prime, a dedicated wide field NIR imager for the prime focus, equipped with a $1k \times 1k$ HgCdTe array by Rockwell, and a FOV of $6.'8 \times 6.'8$
- OMEGA Cass, equipped with a $1k \times 1k$ HgCdTe array by Rockwell as well, used in the RC focus of the 3.5-m telescope and with ALFA, with imaging and medium resolution long slit spectroscopy capability up to a resolving power of about 5000 and with Wollaston prisms for high sensitive polarimetry for compact sources

3.1 ALFA

ALFA, which stands for adaptive optics with lasers for astronomy, is based on a conventional optical design. An f/10 paraboloid images the telescope pupil onto a 97-channel deformable mirror (DM) from Xinetics Inc. A second f/24 paraboloid re-images the telescope focus onto the science camera via a visible/ IR dichroic mirror. Science cameras presently in use are OMEGA Cass and the MPE-3D Integral Field Spectrograph.

An artificial laser guide star (LGS) is created by a commercially available dye ring laser pumped by a continuous wave (CW) Argon ion laser. The laser system is located in the 3.5-m Coudé laboratory. The sodium light is directed to the launch telescope via a train of mirrors. The location of the laser beam is measured with positional sensitive detectors and stabilised by an active regulation. An accurate alignment is required for optimal illumination of the pupil of the launch telescope. The process is partly automated but the complexity is huge. The resulting beacon has a magnitude of about $m_V = 9 - 10$ mag and a diameter of about $3''$. ALIENS, an aircraft detection system which works in the optical, is mounted on the front ring of the telescope. A complete description of the LGS system is found in e.g. Davies et al. (1998).

Large-scale aberrations are sensed by a AstroCam CCD with readout rates up to 120Hz, and corrected for by a 'tip-tilt' 125mm diameter Beryllium mirror. This field-stabilisation is obtained by observations of a natural star of $m_V \leq$ 15 mag within the isoplanatic angle. If a natural guide star instead of the LGS is used, the tip-tilt mirror is controlled by the Shack-Hartmann sensor.

The high order aberrations are detected by a Shack-Hartmann system which is specifically designed to observe the LGS. A second dichroic divides the optical light into the sodium light and the rest. Subapertures are varied by selectable monolithic lenslets 3×3 to 12×12. The detector is a thinned 64×64 CCD from Lincoln Labs used in frame transfer mode. It is characterised by a read noise of 3.5–5.5 electrons and a maximum read speed of 1200 frames per second. Further control of the surface of the DM is achieved by an interferometer from FISBA, to an accuracy of less than about 100nm r.m.s. aberration of the reflected wave. The tip-tilt mirror and the first dichroic can be removed, which allows to use OMEGA-Cass or 3D directly at f/10. A detailed description of ALFA is given in e.g. Hippler et al. (1998) and references therein.

There are a number of remaining problems related to the LGS. A coupling of the laser to the launch telescope by an optical fibre is presently under study. This should increase the brightness of the beacon on the sky as the multiple reflections by the mirrors are avoided.

First experiments show, however, that Brillouin scattering which arises from the high intensities in the fibre may limit the practical use of this technique.

Second, the mesospheric sodium layer, a byproduct of meteoritic ablation, shows seasonal variations in its height and column density (see e.g. paper by Dainty, this issue). It not clear yet how pronounced the variations are above Calar Alto, but variations by a factor of a few within hours have been observed. Short-term height variations impose a serious problem of the focusing of the laser.

Third, the vertical structure of the turbulent layers in the atmosphere is not well determined. It is an important parameter for the understanding of the isoplanacity of an AO system. Preliminary measurements obtained on Calar Alto with SCIDAR (Scintillation Detection and Ranging) stipulate that the dominant layer of turbulence is based at very low altitudes, presumably at the telescope altitude. This effect may also be responsible for the relatively large width of the LGS.

And fourth, the tip-tilt modes cannot easily measured by the laser beacon. This limits the sky coverage as the presence of a 'tip-tilt' star within the isoplanatic angle is required. Tip-tilt may be determined from the LGS if it is observed from another telescope. Alternatively, a polychromatic beacon affords the possibility to determine tip-tilt, but significantly higher pump intensities than available are required. Simultaneous measurements involving ALFA at the 3.5-m, a SITe camera at the 2.2-m, and SCIDAR at the 1.23-m, are again scheduled for October 1999 in order to study some of these questions in further detail.

ALFA now allows to routinely obtain diffraction limited images, with FWHM $< 0.''13$ in K and $< 0.''10$ in J. Strehl ratios of 62% in the K-band on SAO 37418 (V=4.9mag) and 12% in the J-band on SAO 56114 (V=7.0mag) were measured. he MPE 3D spectrometer was used to obtain K-band spectra of the two components of HEI 7, a close multiple system with two resolved components at $0.''27$ separation, of spectral class K0 V and M0 V, respectively. Individual spectra have been obtained of the two resolved components, and show, as expected, significant differences in equivalent widths of the CO first overtone vibrational bands. The barred spiral galaxy UGC1347 was observed using a LGS. Tip-tilt was corrected using a V=12mag star some $40''$ away, and higher order abberations were corrected using a LGS, resulting in a spatial resolution of some $0.''4$.

4 Future Instrumentation on Calar Alto

Given the increasing access to 8-m class telescopes of the German and Spanish astronomical community, the future rôle of the Calar Alto observatory is a matter of detailed discussion at the time of the writing of this article. The following is a brief summary of ideas and ongoing instrumentation projects. Two projects, PMAS and BUSCA, are external to the MPIA and about to be commissioned at the telescope. Two other instruments, OMEGA 2000 and LAICA, wide field imagers for the NIR and the optical wavelength region, have not yet entered the conceptual design phase.

`OMEGA 2000`
An upgrade of OMEGA Prime with the $2k \times 2k$ HAWAII HgCdTe array has been discussed but would require a complete modification of the camera optics. It is presently being considered to either build a dedicated NIR camera with the $2k$ detectors for the 3.5-m prime focus, or, alternatively, to design such a camera for the 2.2-m RC focus.

`LAICA`
It is planned to build a wide field imager for the 3.5-m telescope in the prime focus with the 3-lens corrector. LAICA, the large area imager for Calar Alto, may consist of four $4k \times 4k$ thinned arrays from Lockheed, with BVRIZ filters but otherwise few optical elements involved. The projected FOV is of the order of 0.5 degrees.

`PMAS`
PMAS, the Potsdam Multi-Aperture Spectrophotometer, is an integral field spectrograph built by the Astrophysical Institute Potsdam. PMAS, designed for the 3.5-m RC focus, employs a 16×16 square lenslet array to feed the spectrograph via optical 100 μm fibres. The fibres are redistributed to a linear pseudo-slit, which is dispersed by one of three gratings with dispersions of 1.35 Å/mm, 0.9 Å/mm, and 0.45 Å/mm. The spectral range covers 350–900nm with full apochromatic correction. A SITe ST002A thinned $2k \times 4k$ array is foreseen as detector. Future upgrades include a total of 1024 lenses with 50μm fibres, as well as two CCDs to form a $4k \times 4k$ mosaic.

`BUSCA`
BUSCA is designed for simultaneous direct imaging in 4 color bands and is built by the Astronomical Institutes of the Bonn University. The optics are designed for $4k \times 4k$ CCDs with 15 μm pixels. At the Calar Alto 2.2-m telescope, the corresponding FOV is $12'$. Dichroic beam-splitters separate the optical spectrum to four wavelength bands $\lambda < 430$nm, 430nm $< \lambda <$ 530nm, 530nm $< \lambda <$ 700nm, and $\lambda >$ 700nm.

References

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