Very large telescope and naco instrumentation

Food & Diet

This report describes the Very Large Telescope array in Chile, the VLT consists of four Unit Telescopes with main mirrors of 8. 2m diameter and four movable Auxiliary Telescopes with main mirrors of 1. 8m diameter.

One of the Unit Telescopes, UT 4, is discussed in more detail, specifically its location, mounting, optics, the range and focus locations and the available instruments.

The last part of the report is an example of an observation planning to image the Becklin-Neugebauer (BN) object with the NACO S13 camera and K band filter.

Introduction

The Very Large Telescope array (VLT) is at this moment the world's most advanced optical instrument (1), the VLT is located on the Paranal Observatory, see Figure 1, in the Atacama desert Northern Chile (70° 24′ 11″ West; 24°37'31" South).

The Paranal mountain is probably the best site for astronomical observations in the southern hemisphere, with e. g a humidity of 5-20% and a maximum rainfall of about 100 mm per year.

The observatory is divided into two areas, a telescope platform at the top of the mountain at an altitude of 2635 meters. and a base camp at the foot at an altitude of 2360 m.

The observations take place at the telescope platform, the base camp contains staff quarters, maintenance facilities, including a visitors'centre for the public.

Overview of the VLT

The VLT consists of four identical Unit Telescopes (UT) with main mirrors of 8. 2m diameter and four movable 1. 8m diameter Auxiliary Telescopes, located on the telescope platform, see Figure 2 .

The Unit Telescopes are Ritchey-Chrétien telescopes, they can operate in Cassegrain, Nasmyth or Coudé focus. The four Unit Telescope have an altitude-azimuth (alt-az) mounting (2).

The Unit Telescopes have fixed locations, the Auxiliary Telescopes can be repositioned on 30 different stations, the UT and AT telescopes can be used in several different modes:

- independent telescope mode
- combined coherent mode or VLT interferometer (VLTI)
- combined incoherent mode

In the independent telescope mode each UT is used separately, in the combined coherent mode the UT and AT telescopes work together, in groups of two or three, to form a giant interferometer giving an angular resolution equivalent to a telescope with a diameter of 200 meters and in the combined incoherent mode the four UTs are combined providing the total light collecting power of a 16-metre single telescope.

For the four Unit Telescopes, names of objects in the sky in the Mapuche language were chosen and they are now known as Antu (UT1, The Sun), Kuyen (UT2, The Moon), Melipal (UT3, The Southern Cross), and Yepun (UT4, Venus – as evening star). Unit Telescope 4 (Yepun), see Figure 3 is discussed in more detail in the next section

The VLT instruments includes large-field imagers, adaptive optics corrected cameras and spectrographs, high-resolution and multi-object spectrographs operating at wavelengths ranging from deep ultraviolet (0. 3 nm) to mid-infrared (24 µm).

With these instruments important data can be collected for a large range of research topics such as:

- formation and evolution of galaxies
- search for extra-solar planetary systems
- distances to galactic Cepheids
- circumstellar disks around young stellar objects
- active galactic nuclei
- stellar evolution
- fundamental parameters of the Universe

Unit Telescope 4

Optical set-up

Unit Telescope 4 can operate in four foci two Nasmyth, one Cassegrain and one Coudé focus (2), for the optical lay-out, including the eight mirrors (M1 to M8) and the main dimensions see Figure 4.

Light is collected by the primary mirror M1 and concentrated by the secondary mirror M2 either to the Cassegrain focus below the primary mirror or to one of the two Nasmyth foci, at the side of the telescope.

In the Nasmyth configuration the optical layout is of the Ritchey-Chrétien type, the Cassegrain focus however is not of the Ritchey-Chrétien type, changing between the two foci means repositioning of the secondary mirror and changing the curvature of the primary mirror.

By transferring one Nasmyth focus to another location in the telescope basement the Coudé focus is obtained (mirror M4 to M8), from the Coudé focus the light can be sent to the combination mode focus or to the interferometric focus.

The Coudé focus is located below the main telescope structure.

The primary mirror (M1)

The 8. 2 m primary mirror of UT4 is made of Zerodur and is 175 mm thick the shape is actively controlled by means of 150 axial forces actuators, the mirror has a central hole of about 1. 0 m. . Zerodur is a glass-ceramic made by Schott Glaswerke AG (Mainz, Germany).

The secondary mirror (M2)

The secondary mirror is a convex hyperbolic mirror made of Beryllium with an external diameter of 1. 12 metres and a thickness of 50 mm.

By changing the position and orientation of the mirror it is possible to correct some optical aberration of the telescope (defocus and decentring coma) and to change the pointing .

The secondary mirror is supported by the M2 Unit at the top of the telescope and reflects the light from the M1 mirror towards the M3 plane mirror

The optical quality depends on the mode of the mirror, if the mirror is in the active mode (active optics correction in operation) , the Central Intensity

Ratio is larger than or equal to 0. 98, with an atmospheric coherence length of 250 mm at a wavelength 500 nm.

In the passive mode, active optics correction not in operation, the root mean square (RMS) slope error of the surface of the mirror is less than 0. 7 arcsec.

The tertiary mirror (M3)

The tertiary mirror is flat and elliptically shaped (890x1260mm2), the mirror is made of Zerodur and produced by Schott Glaswerke AG.

In Nasmyth configuration, see Figure 5, the M3 mirror deflects the light beams towards the scientific instruments located at one or the other Nasmyth focus.

In Cassegrain configuration, Figure 5, the M3 mirror assembly is remotely flipped in towed position, parallel to the axis of M3 Tower.

Mirror M4 to M8 (the Coudé train)

The Coudé Train is based on a combination of cylindrical and spherical mirrors, the light

is sent to the Coudé Train by mirror 4 (M4) a concave cylindrical mirror in front of the Nasmyth adapter.

Relay optics provide an image of the sky at the Coudé focus, the relay optics consists of the following mirrors:

M5 a concave spherical mirror (R = 8975 mm)

M6 a concave cylindrical mirror (R = 290, 000 mm) , the cylinder direction is rotated

by 90° with respect to M4

M7 a concave spherical mirror (R = 5176. 2mm)

M8 a flat mirror.

Technical description

The telescope mounting of Unit Telescope 4 (3) is altitude-azimuth (alt-az), the telescope tube moves around a horizontal axis (the altitude axis), the two bearings which support the telescope tube are mounted on a fork rotating around a vertical axis (the azimuth axis)

The telescope tube is a steel structure, supporting at the bottom the primary mirror (M1) , and at the top the M2 Unit, with the secondary mirror, by metallic beams (spiders).

Unit Telescope 4 is protected by an enclosure, this enclosure also provides access for operation and maintenance to certain areas of the telescope and a protection against the wind during observations. The telescope is mounted on a concrete foundation, the telescope pier. The geographical coordinates of UT4 are: latitude 24° 37′ 31. 000″ South and longitude 70 ° 24″ 08. 000″ West

The structure of Unit Telescope 4 consists of a large number subassemblies and parts see Figure 6 , some of the main assemblies are:

the tube structure with the M2 spiders which hold the M2 unit .

the fork structure with two Nasmyth platforms that support the Nasmyth instyruments.

the Coudé tube that provides the interface to the Coudé mirror units.

azimuth tracks which support the fork structure.

an azimuth platform which provides access for the Cassegrain instrument.

Specifications

Adaptive and active optics

UT4 has adaptive optics (AO) correction both at Nasmyth and at Cassegrain foci, UT4 is also equipped with a sodium laser guide star facility for active optics.

For the non-AO telescope operation the Central Intensity Ratio (CIR) quantifies the image quality. A high CIR implies high signal throughput, high contrast and small image size.

The peak signal in the long-exposure point spread function is given by (4):

Equation

where is ta the transmissivity of the atmosphere, r0 the coherent wave-front size, tt the transmissivity of the telescope optics, D the diameter of the telescope and CIR the Central Intensity Ratio.

The Central Intensity Ratio defined by :

Equation

where y0 is the Strehl ratio of the telescope. (Strehl ratio is the ratio of peak diffraction intensities of an aberrated wavefront versus a perfect wavefront).

The optical quality specification is that the Central Intensity Ratio CIR = 0. 82 with a coherent wave-front of size r0 = 500 mm (seeing angle 0. 2 arcsec) at = 500 nm.

Field of view

The total field of view (FOV) for UT4 in the Cassegrain focus is 15 arcmin, in the Nasmyth focus 30 arcmin and in the Coudé focus 1 arcmin.

Atmospheric dispersion

The atmospheric dispersion is corrected up to zenith angles of 50° for instruments requiring high image and spectrophotometric quality.

Pointing and tracking

UT4 is able to get any target to within 70° zenith distance in less than 3 minutes. Offset pointing of 45° and 60° in altitude and azimuth respectively is possible within 35 seconds, to within 0. 1 arcsec accuracy.

UT4 tracks better than 0. 05 arcsec RMS over a period of 15 seconds without using guide-star position information, and over a one hour period when using guide-star tracking.

Zenith distance

The UT4 can operate at zenith distances ranging from 0. 5° to 70°, obstruction by adjacent enclosures is limited to zenith angles larger than 60°.

Instrumentation

The instruments that are mounted on Unit Telescope 4 are shown in table 1.

HAWK-I

HAWK-I is a near-infrared (0, 85 – 2. 5µm) wide-field imager installed at the Nasmyth A focus of UT4 , the operating temperature of the instrument is 120 K, operating temperature of the detectors is of 80 K (3).

HAWK-I has 10 observing filters placed in two filter wheels: Y, J, H, Ks , 6 narrow-band filters Brg, CH4, H2 and three cosmological filters at 1. 061, 1. 187, and 2. 090 µm.

SINFONI

SINFONI is a near-infrared (1-2. 5 µm) integral field spectrograph installed at the Cassegrain focus of UT4.

The spectrograph works with 4 gratings J, H, K, H+K with spectral resolutions of R is 2000, 3000 and 4000, corresponding to the J, H and K gratings respectively, and R is1500 with the H+K grating. The resolution power R of a spectrograph is given by :

Equation

where c is the velocity of light and dv the radial velocity .

NACO (NAOS + CONICA)

The Nasmyth Adaptive Optics System (NAOS) and the High Resolution Near IR Camera (CONICA) are installed at the Nasmyth B focus of UT4. NACO provides adaptive-optics corrected imaging, polarimetry, spectroscopy, and coronagraphy in the 1-5 Î¼m range.

The NACO instrumentation will be discussed in more detail in the next section.

Laser Guide Star

The Laser Guide Star is an artificial source, a 4W CW Sodium Laser (589 nm) will be used for this. The laser beam is focussed at an altitude of 90 km, at that height an atomic sodium layer is present which backscatters the spot image, producing an artificial star with a magnitude range from 11 mag. to 14 mag.

NACO instrumentation

Instrument characteristics

NAOS

NAOS is an adaptive optics (AO) system that has been designed to work with natural guide stars (NGS) and moderately extended sources , NAOS can also use the laser guide star facility (LGSF) and a natural tip-tilt source (TTS) to provide adaptive optics correction (3).

NAOS gives a turbulence corrected f/15 beam and a 2 arcmin field of view to CONICA. Two off-axis parabolas re-image the telescope pupil on the deformable mirror and the Nasmyth focal plane on the entrance focal plane of CONICA.

A dichroic-filter splits the light between CONICA and the wave front sensor, a field selector is placed after the wave front sensor input focus to select the reference object for wave front sensing, see Figure 7.

NAOS has two wavefront sensors one visible light and one near-IR sensor , the two sensors are of the Shack-Hartmann type. It is possible to select an off-axis natural guide star within a 110 arcsec diameter field of view (FOV). NAOS allows wave front sensing with faint natural guide stars and extended objects, observations of very bright objects are possible with the visible wave front sensor using neutral density filters.

CONICA

CONICA is an infra-red (IR) (1 – 5 Î¼m) imager and spectrograph which is fed by NAOS.

CONICA is capable of imaging, long slit spectroscopy, simultaneous differential imaging (SDI), coronagraphy, polarimetry , with a large range of plate scales, filters and masks.

The CONICA detector is a InSb Aladdin 3 array, the parameters of the array are:

format 1026´1024 pixels

pixel size 27µm

dark current 0. 05-0. 15 ADUs-1 pixel-1

wavelength range 0. 8-5. 5 µm

Quantum efficiency 80-90 %

The detector has three readout modes and four detector modes . The readout modes refer to the way the array is read out, the read our modes are :

Uncorr

The array is reset and then read once, used for situations when the background is high.

The minimum detector integration time (DIT) is 0. 1750 seconds.

Double_RdRstRd

The array is read, reset and read again, used for situations when the background is intermediate between high and low.

The minimum DIT is 0. 3454 seconds.

FowlerNsamp

The array is reset, read four times at the beginning of the integration ramp and four times again at the end of the integration ramp. Each time a pixel is addressed, it is read four times. This is used for situations when the background is low.

The minimum DIT is 1. 7927 seconds.

The detector mode refers to the setting of the array bias voltage, four modes have been defined: HighSensitivity, HighDynamic, HighWellDepth and HighBackground.

HighSensitivity has the fewest hot pixels, but it has the smallest well depth, this mode is used for long integrations in low background situations.

HighBackground has the largest well depth but has many more hot pixels, this mode is used in high background situations .

S13 camera

CONICA is equipped with several camera's such as S13, S27, S54, the characteristics of camera S13 are; scale 13. 221± 0. 017 mas/pixel, field of view (FoV)14´14 arcsec and spectral range 1. 0-2. 5 µm.

Available filters for the S13 camera are broad- and narrowband filters in the 1-2. 5 µm region,

Information on the broadband filters can be found in table 1.

Unit Telescope 4 parameters

Example observation planning

The observation planning contains the next subjects (5):

1. target
2. scientific goal
3. visibility period of target
4. required observing conditions
5. seeing

atmospheric transparency

lunar illumination

required observing time

list of required instruments, modes and configurations

Target

The chosen observation target is the Becklin-Neugebauer (BN) object located in the Orion Nebula Cluster, coordinates; right ascension (RA) 05h 35 m 14s. 117 and declination (D) -05° 22’22”. 90, epoch 2000. 0,

Scientific goal

The Becklin-Neugebauer object was discovered as a bright 2 Î¼m infra-red source (10) by Becklin and Neugebauer in 1967 (11), about 45″ in projection from the Trapezium stars of the Orion Nebula Cluster, at a distance of ~ 450 pc.

The Becklin-Neugebauer object together with the Kleinmann-Low nebula (KL) is part of the Orion Molecular Cloud 1 (OMC-1) region, a high-mass star formation region in the Orion constellation.

In 2004 Shuping, Morris and Bally (8) discovered, at 12. 5µm, an arc of emission associated with the BN object, the so-called BN SW arc.

The nature of this SW arc is still unknown, it may be externally heated gas or dust by UV radiation or is possibly a compressed shell created by an outflow or jet from BN.

The BN SW arc is an interesting feature that needs further investigations both imaging and spectroscopy at other wavelengths to determine its true nature.

Required observing conditions

Seeing/airmass

Seeing is defined as the image full width half maximum (FWHM)in arcsec , the seeing values are 0. 8″and 1. 2″ at Zenith.

Airmass quantifies the effects of all atmospheric processes, these atmospheric effects will be minimum when radiation travels vertically through the atmosphere, in this case z = 1.

During the observation period the airmass ranges between z = 1. 0 and z = 1. 5 see table A, appendix 1, average airmass z = ~1, 2.

Atmospheric transparency

During the observation period there should be no visible clouds and the transparency variations should be less than 2%.

Lunar illumination

Lunar illumination (FLI) is defined as the fraction of the lunar disk that is illuminated at local (Chile) civil midnight, where 1. 0 is fully illuminated.

Dark time corresponds to moon illumination less than 0. 4, so the best time to observe the target is when the moon is new, see subsection 7. 4.

Visibility period of target

To calculate the visibility of the target I have used the local sidereal time equation:

Equation

where LST = local sidereal, HA = hour angle and RA = right ascension.

RA of BN-object = 05h 35 m 14s. 117 = 5. 587 hr. , on 21 March RA = 12hr is on the meridian at local midnight.

RA = 5. 587 hr will be on the meridian at local midnight about (5. 587-12. 0)Ã-30/2 = ~ 96 days =~ 3 months earlier . Thus the target will be well placed in November 2011 and December 2011.

New Moon is on 25 November 2011 and 24 December 2011, so the best dates to observe the BN- object will be 22-27 November and 22-26 December 2011, see table B, appendix 2.

The chosen observation period is the night of 24/25 December 2011, between 22hr and 2hr local time.

Required observing time

Angular resolution

The theoretical angular limit of resolution is given by:

Equation

where l = wavelength, D = aperature diameter

The wavelength of the K-filter is l = 2. 18 µm, so the resolution is

The resolution however is limited by atmospheric turbulence to

where r0 is the Fried parameter.

The Fried parameter is directly linked to the strength of the turbulence and it depends on the wavelength as:

Equation

for average observing conditions, r0 is about 0. 6 m at 2. 2 Î¼m.

Seeing disk

The angular diameter of the seeing disk is

Equation

so for l = 2. 18 µm and r0 = 0. 6 m

Area of seeing disk:

Exposure time

Exposure time Equation

where: t = integration time

r = signal to noise ratio

f = flux transmitted by atmosphere

fsky = sky background flux

a = area of seeing disc

A = effective area of telescope UT4

Q = quantum efficiency

l = flux of the BN object

l = wavelength = 5. 5×10-7 m

h = Planck's constant = 6. 63×10-34 J

c = velocity of light = 3. 0×108 ms-1

The adopted signal to noise ratio S/N = r = 5.

The flux transmitted by the atmosphere f = 1. 0, see figure 3. 2 NACO User Manual (3)

The liming sky background magnitude is 13. 0 mag (3), the sky background flux

Equation

Area of seeing disk a = 0. 442 arcsec

Effective area of UT4

Quantum efficiency Q = 0. 85

The magnitude of the BN object corrected for extinction mv = 5. 2 mag (11), the extinction in the V passband Av = ~18 mag. (8) so the apparent magnitude of the BN object m = 23. 2 mag.

Flux /magnitude conversion

Equation

The flux of the BN object is

The exposure time for the BN object is:

t = 639 sec.

The exposure time calculated with ETC is 122, 320 seconds !? , see appendix 4 table D.

List of required instruments, modes and configurations

The required telescope to observe the BN object is UT4 with the NACOS instrumentation.

The NAOS with natural guide star, the CONICA imager with camera S13 and broadband filter K (2. 18 mm).

The chosen detector readout mode is FowlerNsamp and not Double_RdRstRd because the intergration time is larger than 60 seconds.

Guide star id. 0477400932, RA 05hr 35m 16s. 41, Dec -05° 23′ 23″. 0 magnitude 5. 00 see table C, appendix 3,

Conclusion

The Very Large Telescope array is at this moment the most advanced optical instrument and the most productive individual ground-based observatory in the world.

The instrumentation programme is the most ambitious programme for a single observatory and because of to the outstanding angular resolution and the use of adaptive optics VLT opens a new era of discoveries.

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Appendices

Appendix 1

Hourly airmasses for 05 35 14. 12 -05 22 22. 90

Paranal Observatory (VLT)

Sat, December 24, 2011

*** Hourly airmass for Target ***

Epoch 2000. 00: RA 5 35 14. 1, dec -5 22 23

Epoch 2011. 98: RA 5 35 49. 5, dec -5 21 57

At midnight: UT date 2011 Dec 25, Moon 0. 00 illum, 151 degr from obj

Local UT LMST HA secz par. angl. SunAlt MoonAlt HelCorr

22 00 1 00 2 31 -3 05 1. 502 -118. 5 … … -4. 27

22 30 1 30 3 01 -2 35 1. 341 -121. 5 … … -4. 32

23 00 2 00 3 31 -2 04 1. 229 -126. 1 … … -4. 38

23 30 2 30 4 01 -1 34 1. 152 -132. 8 … … -4. 43

0 00 3 00 4 32 -1 04 1. 101 -142. 9 … … -4. 50

0 30 3 30 5 02 -0 34 1. 071 -157. 8 … … -4. 56

1 00 4 00 5 32 -0 04 1. 059 -177. 2 … … -4. 62

1 30 4 30 6 02 0 26 1. 066 162. 7 … … -4. 69

2 00 5 00 6 32 0 56 1. 090 146. 5 … … -4. 75

Table A: Hourly airmasss during observation period.

SkyCalc provided by courtesy of John Thorstensen, Dartmouth College. John. Thorstensen@dartmouth. edu

http://www. eso. org/sci/observing/tools/calendar/observability. html

Appendix 2

Observability for 05 35 14. 117 -05 22 22. 90

Paranal Observatory (VLT)

RA &dec: 5 35 14. 1, -5 22 23, epoch 2000. 0

Site long&lat: +4 41 36. 8 (h. m. s) West, -24 37 30 North.

Shown: local eve. date, moon phase, hr ang and sec. z at (1) eve. twilight,

(2) natural center of night, and (3) morning twilight; then comes number of

nighttime hours during which object is at sec. z less than 3, 2, and 1. 5.

Night (and twilight) is defined by sun altitude <-18. 0 degrees.

Date (eve) moon eve cent morn night hrs@sec. z:

HA sec. z HA sec. z HA sec. z <3 <2 <1. 5

2011 Oct 11 F -8 54 down -4 28 2. 5 -0 02 1. 1 4. 7 3. 9 3. 0

2011 Oct 26 N -7 45 down -3 31 1. 7 +0 42 1. 1 5. 4 4. 6 3. 8

2011 Nov 10 F -6 33 down -2 32 1. 3 +1 29 1. 1 6. 2 5. 4 4. 5

2011 Nov 24 N -5 25 5. 7 -1 34 1. 2 +2 17 1. 3 7. 0 6. 2 5. 3

2011 Dec 9 F -4 13 2. 2 -0 29 1. 1 +3 15 1. 6 7. 4 7. 2 6. 1

2011 Dec 24 N -3 05 1. 5 +0 37 1. 1 +4 19 2. 4 7. 4 7. 0 6. 1

2012 Jan 8 F -2 02 1. 2 +1 44 1. 2 +5 30 6. 3 6. 8 6. 0 5. 1

Table B: Observability of Becklin-Neugebauer object

SkyCalc provided by courtesy of John Thorstensen, Dartmouth College. John. Thorstensen@dartmouth. edu

http://www. eso. org/sci/observing/tools/calendar/observability. html

Appendix 3

ESO GSC Online Server – Query Result

Center:

RA: 05: 35: 14. 117

DEC: -05: 22: 22. 90

Search radius:

20 arcminutes

nr gsc_id ra (2000) dec mag mu d’ pa

1 0477400932 05 35 16. 41 -05 23 23. 0 5. 00 F; 1. 15 150

2 0477400931 05 35 16. 47 -05 23 22. 8 5. 09 F; 1. 16 150

3 0477400933 05 35 22. 83 -05 24 57. 8 5. 09 F; 3. 37 140

4 0477400871 05 35 17. 10 -05 23 40. 6 5. 51 F; 1. 49 150

5 0477400934 05 35 26. 27 -05 24 58. 2 6. 40 F; 3. 98 131

6 0477400930 05 35 17. 16 -05 23 12. 7 6. 69 F; 1. 12 138

7 0477801369 05 35 54. 09 -05 37 43. 2 7. 09 T; 18. 28 147

8 0477400906 05 35 31. 37 -05 16 02. 7 7. 19 T; 7. 65 34

9 0477400906 05 35 31. 26 -05 16 02. 0 7. 58 T; 7. 65 34

10 0477801369 05 35 53. 99 -05 37 42. 1 7. 74 T; 18. 25 147

11 0477400935 05 35 31. 33 -05 25 14. 1 8. 18 F; 5. 15 124

12 0477400915 05 35 06. 10 -05 12 15. 5 8. 28 F; 10. 32 349

13 0477400809 05 34 46. 89 -05 34 14. 3 8. 30 F; 13. 66 210

14 0477400849 05 35 09. 73 -05 27 52. 6 8. 53 F; 5. 60 191

15 0477400823 05 34 55. 20 -05 30 21. 7 9. 04 F; 9. 27 211

16 0477400867 05 35 58. 44 -05 22 31. 0 9. 11 F; 11. 03 91

17 0477400855 05 36 27. 09 -05 24 31. 0 9. 28 F; 18. 29 97

18 0477400792 05 34 42. 19 -05 07 14. 2 9. 39 T; 17. 10 332

19 0477400894 05 35 34. 18 -05 06 20. 9 9. 45 F; 16. 79 17

20 0477400830 05 35 18. 12 -05 03 54. 5 9. 48 F; 18. 50 3

21 0477400792 05 34 42. 19 -05 07 14. 3 9. 55 T; 17. 10 332

22 0477400890 05 35 31. 28 -05 33 08. 5 9. 74 F; 11. 58 158

23 0477400829 05 35 35. 71 -05 12 20. 5 9. 78 F; 11. 39 28

24 0477400877 05 35 21. 17 -05 09 15. 7 9. 79 F; 13. 24 8

25 0477400812 05 35 00. 05 -05 25 15. 7 9. 85 F; 4. 53 231

26 0477400878 05 34 52. 14 -05 33 08. 1 9. 96 F; 12. 06 207

27 0477400810 05 34 49. 89 -05 18 44. 4 9. 96 F; 7. 04 301

gsc 1. 0 – 25/Sep/1995.

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Send comments to HYPERLINK “ http://archive. eso.

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Table C: Guide stars Becklin-Neugebauer object