THE ALIGNMENT OF THE JACOBUS KAPTEYN TELESCOPE OPTICS

Technical Note No. 58

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1 Equipment Needed

a.) RP1 micro-alignment telescope and accessories. (see Sect. 3)

b.) Adaptor plate to fit micro-alignment telescope to Cassegrain turntable.

c.) Tools:

For adjusting f/8 secondary,

- 30mm socket spanner for tilt adjustment and lock nuts (2)
- Mole wrench to grip the above spanner
- 17mm spanner for tilt clamp screws (2)
- 4mm Allen key for translation adjustment screws (4)
- 8mm spanner for translation adjustment screw locknuts (4)
- 6mm Allen key for translation clamp screws (8)

For adjusting f/15 secondary,

- 30mm spanner for tilt adjustment and lock nuts (3)
- 17mm spanner for tilt clamp screws (3)
- 5mm Allen key for translation clamp screw (6)
- 4mm Allen key for translation adjustment screw (4)

d. Torch for reading micro-alignment telescope scales.

2 Definition of the optical axis

The Mechanical axis of the Cassegrain turntable is adopted as the optical axis. The Primary mirror is set up so that these two axes coincide. The micro-alignment telescope is used to define this axis and to determine adjustments to be made. The adaptor plate, with the micro-alignment telescope mounted has been keyed to fit on axis to within about 0.05mm.

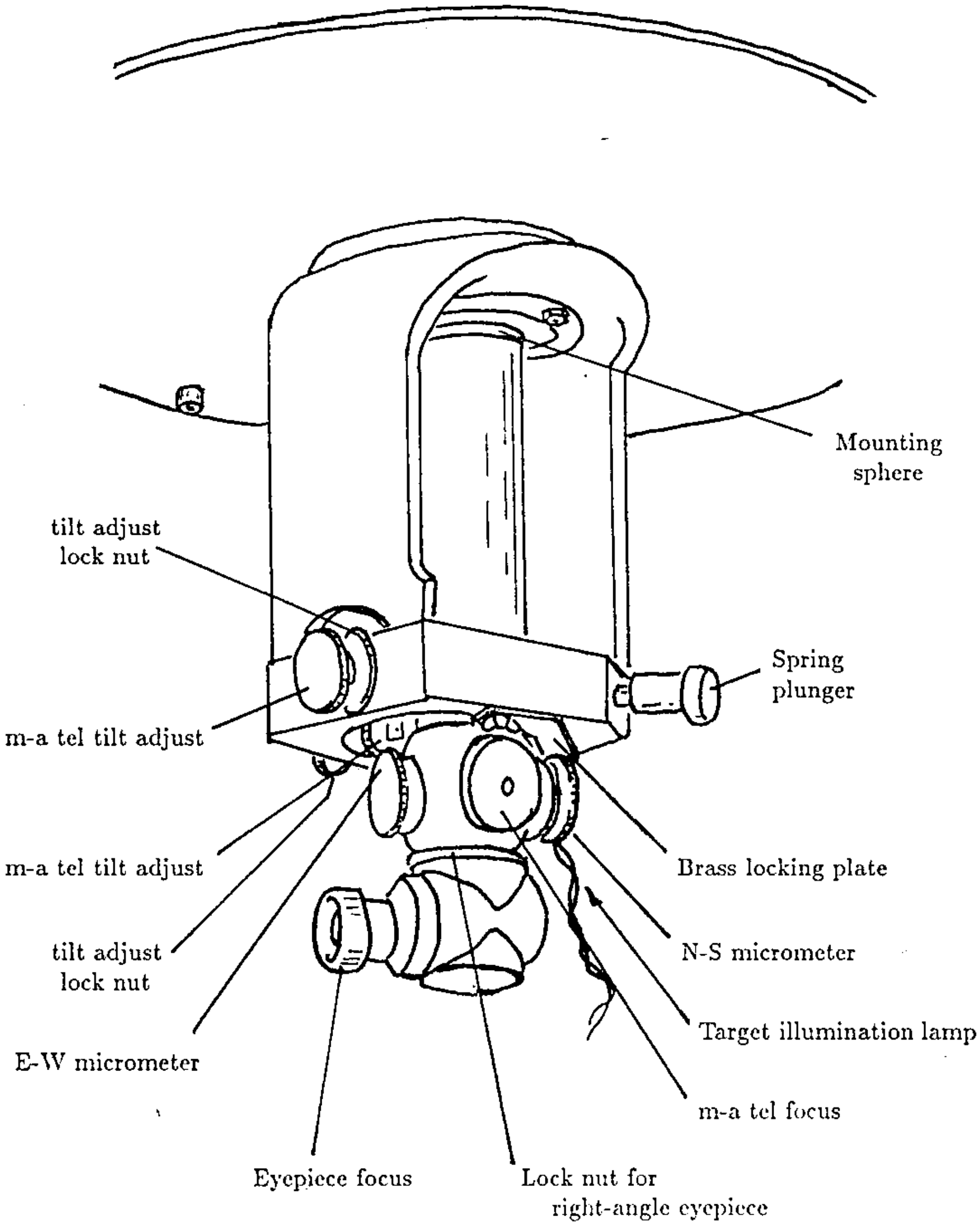

Figure 1: The microalignment telescope

3 Use Of The Microalignment Telescope

1. The micro-alignment telescope is mounted as shown in Fig. 1. The "target illumination lamp" is supplied from a dedicated power supply.

2. The micro-alignment telescope is adjusted for tilt in two mutually perpendicular directions by means of the "tilt adjust" screws, each with a lock nut. One screw has its lock nut inside its head, while the other has its lock nut outside its head.

3. The tilt adjustment is round the "mounting sphere".

4. The "spring plunger" holds the micro-alignment telescope against the "tilt adjust" screws. It may be released by turning it anticlockwise and pulling. It is assisted by a "brass locking plate" held by two butterfly nuts. This must be released whenever making tilt adjustments and, after adjustment, the telescope pushed firmly against the tilt adjust screws and the locking plate locked.

5. The micrometers are labelled N-S and E-W for convenience. They have a just-feelable click stop at the zero positions and a range of ± 1.3mm. Their action is to rotate a glass block to displace the target image in two orthogonal directions.

6. The "right angle eyepiece" may be swivelled for convenience and may be locked by the "lock nut".

7. The micro-alignment telescope measures transverse displacements of an object from the line of sight, directly in mm (irrespective of distance) in two orthogonal directions. The line of sight (0,0 on micrometers) is maintained at all focus settings.

8. The tilt of a reflecting surface with respect to the line of sight can be determined by focussing on the reflection of the micro-alignment telescope lens target (a series of concentric rings), and measuring its transverse displacement. Conversions from apparent displacement to tilt <u>for a plane mirror</u> are given by:

$$Tilt(arcsec) = \frac{Displacement(mm) \times 206.3}{2D}$$

   Where D is distance from micro-alignment telescope to target in metres.

9. Conversions from apparent displacement to tilt for components of the 1.0 metre telescope (with micro-alignment telescope at Cassegrain focus) are as follows:

COMPONENT	TILT (arcsec) FOR 1.0mm DISPLACEMENT
f/8 secondary mirror	57
f/8 corrector surface 1	125
f/15 secondary mirror	85

4 F/8 System Secondary Mirror Adjustment

(a) Fit f/8 top end to telescope (see Section 3, para. 3.6 in "Operation and Maintenance Manual. Vol 1")

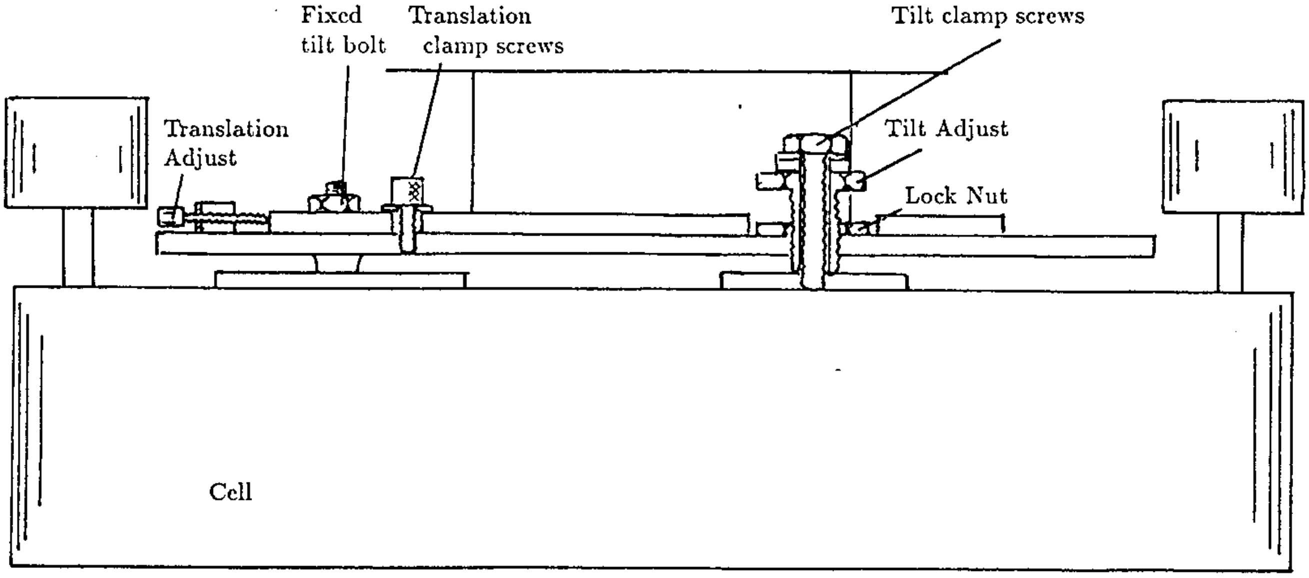

Figure 2: The JKT f/8 secondary mirror cell

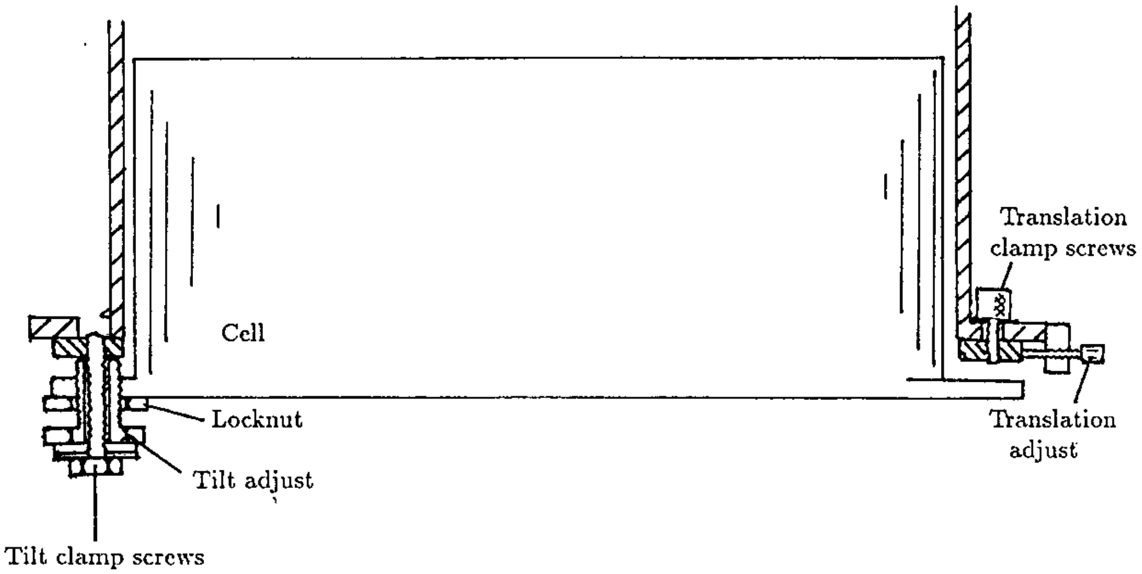

Figure 3: The JKT f/15 secondary mirror cell

(b) Fit afocal corrector lens on 3-point kinematic mounting. Do not fit sky baffles at this stage.

(c) Fit micro-alignment telescope with JKT vertical and ties in place (see Fig. 6)

4.1 Secondary mirror translation adjustment

For this, the micro-alignment telescope does not need to be on the axis of rotation. The aim is to direct it at the intersection of the axis of rotation and the mirror surface, and to translate the mirror centre to this intersection.

4.2 Procedure (see Fig. 4)

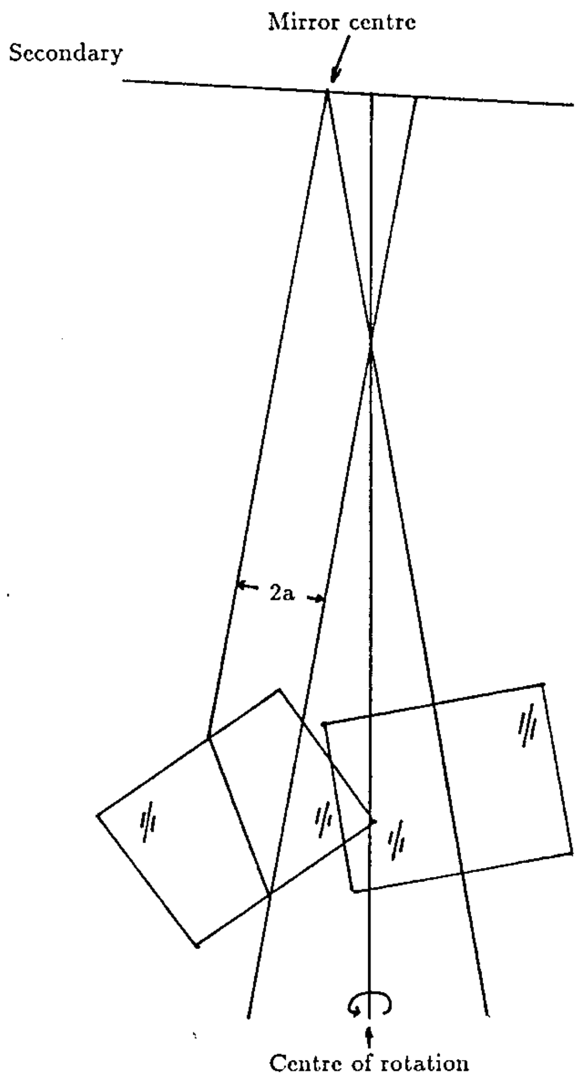

Figure 4: Translation adjustment

(d) Focus micro-alignment telescope on the 5mm diam. ring target on the secondary mirror (BEWARE: there is also a ring target on the corrector lens. You may also see this target reflected in the secondary mirror. The image you want is at a focus of about 3 metres on the micro-alignment telescope.)

(e) Set micro-alignment telescope on the centre of the ring target with the scales at 0,0. Adjustment is by the micro-alignment telescope tilt screws (see para.3)

(f) Rotate the turntable through 180 °

(g) Adjust the micrometers to recentre the ring target and read off $(2a_{N-S}, 2a_{E-W})$

(h) Set the micrometers to half these values (a_{N-S}, a_{E-W})

(i) Translate the secondary mirror until the ring target is centred on the crosswires to within 0.1mm by the following method. (See Fig. 2.)

   i. Release the 8 clamp screws with the 6mm Allen key

   ii. Release one translation adjustment screw (see Figs. 2 & 6) and tighten its opposite screw with the 4mm Allen key till translation is correct in one direction. (Pay attention to the locknuts).

   iii. Repeat for the orthogonal direction.

   iv. Tighten the clamp screws and check that translation is correct.

4.3 Secondary Mirror Tilt Adjustment

For this, the aim is to have the micro-alignment telescope on the rotation axis and to centre the concentric ring target, reflected in the secondary mirror, on the crosswires. (Fig. 5).

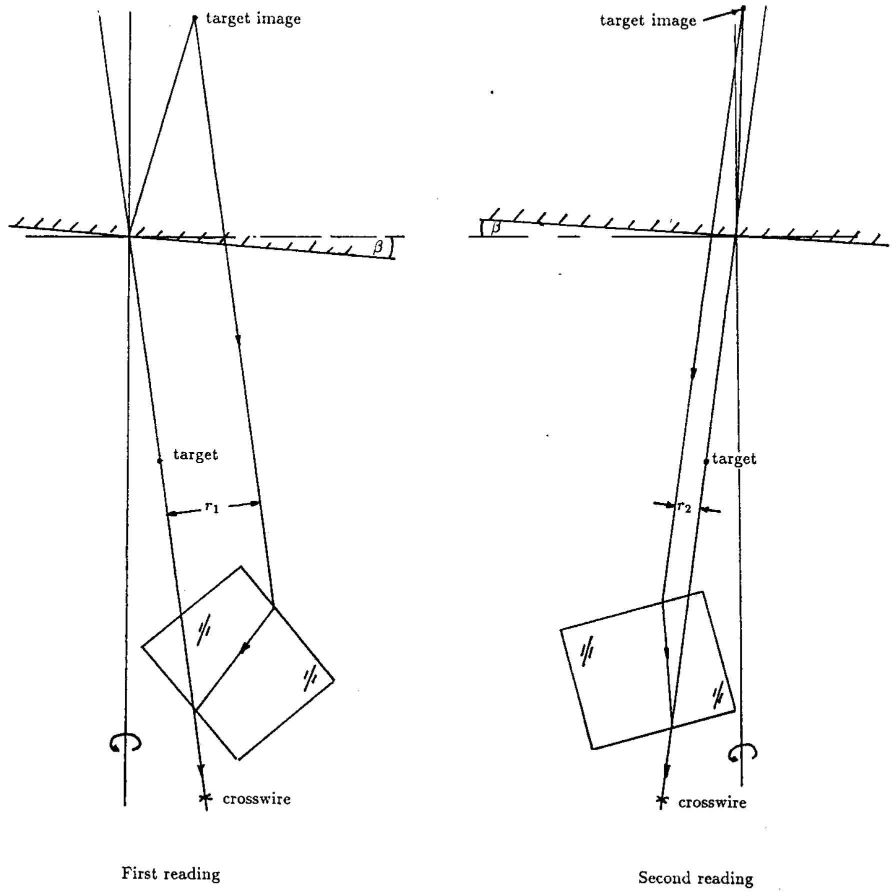

Figure 5: Tilt Measurement

4.3.1 Procedure

10. Set the micro-alignment telescope on the secondary mirror ring target centre with the micrometers reading 0,0
11. Focus on the micro-alignment telescope target image (the concentric rings.) The image will be at a focus of just over 5 meters on the micro-alignment telescope.
12. Adjust the micrometers to centre the target on the crosswires and read. (r_{1N-S}, r_{1E-W})
13. Rotate the turntable through 180 °
14. Recentre the target by adjusting the micrometers, and read (r_{2N-S}, r_{2E-W}).
15. The first reading, r_1, gives the displacement due to the displacement of the micro-alignment telescope from the rotation centre, a, <u>plus</u> the tilt of the mirror surface, β.

    The second reading, r_2, gives the displacement due to the displacement of the micro-alignment telescope from the rotation centre, a, <u>minus</u> the tilt of the mirror surface, β. Now the tilt is obtained from:

$$r_1 = a + \beta/57$$

$$r_2 = a - \beta/57$$

    where β is in arc seconds. (See Section 3, Para 9). Thus:

$$\beta_{N-S} = {}^1\!/\!_2(r_1 - r_2)_{N-S} \times 57$$

$$\beta_{E-W} = \tfrac{1}{2}(r_1 - r_2)_{E-W} \times 57$$

and the displacement of the micro-alignment telescope from:

$$a_{N-S} = \tfrac{1}{2}(r_1 + r_2)_{N-S}$$
$$a_{E-W} = \tfrac{1}{2}(r_1 + r_2)_{E-W}$$

16. Set the micro-alignment telescope scales to a_{N-S} and a_{E-W}

17. Adjust the secondary mirror tilt until the concentric rings are centred on the crosswires to within 0.1mm by the following method (see Fig. 2):

    (a) Release the two tilt clamp screws with the 17mm spanner.

    (b) Rotate the tilt adjustment screws (see Figs. 2 & 6) with the 30mm spanner, paying attention to their locknuts (which, at present, are glued to the plate).

    (c) Tighten the clamp screws (no check is possible until the clamp screws are tight) and check tilt.

    (d) Repeat until tilt is correct.

18. If a large tilt adjustment has been made, remeasure the translation and adjust if more than 0.1mm off-centre.

5 F/8 system afocal corrector lens adjustment

1. Focus the micro-alignment telescope on the secondary mirror ring target and, with the micrometers reading 0,0, centre the target on the crosswires.

2. Refocus the micro-alignment telescope on the corrector lens ring target (focus just over 1 metre).

3. Check that the target is on axis. This was set at RGO with an error of 0.14mm in RA and 0.09mm in Dec. An error in this range (total displacement 0.17mm) is acceptable, but a total displacement greather than 0.2mm should be corrected. This can only be done by altering the thickness of the shims located between the cube and the support vanes. (0.2mm displacement yields a relative distortion of 0.04 arcsec and a coma of 0.06 arcsec).

4. For tilt adjustment, locate the reflections of the micro-alignment telescope lens target in the corrector surface. A cover should be put on the lens target, as the reflections are weak and of low contrast. Four reflections will be found, two nearer to the micro-alignment telescope than the ring target and two further away. Use the most distant image (formed by surface 1), at micro-alignment telescope focus setting about 2.1m. Procede as in Section 4.3 paragraphs 10 - 14.

   In this case, the tilt is obtained from:

$$r_1 = a + \beta/125$$
$$r_2 = a - \beta/125$$

where β is in arc seconds. (See Section 3 Para.9) Thus:

$$\beta_{N-S} = \tfrac{1}{2}(r_1 - r_2)_{N-S} \times 125$$
$$\beta_{E-W} = \tfrac{1}{2}(r_1 - r_2)_{E-W} \times 125$$

5. Set the micro-alignment telescope scales to $\frac{1}{2}(r_1 + r_2)_{N-S}$ and $\frac{1}{2}(r_1 + r_2)_{E-W}$

6. Adjust the corrector tilt to centre the image to the micro-alignment telescope to within 0.2mm. There are 3 tilt screws beside 3 mounting screws. To adjust, slacken a mounting screw, adjust its adjacent tilt screw and retighten the mounting screw. The pairs of screws are at 0 °, 90 ° & 225 ° around the mounting ring, so that, leaving the 225 ° tilt screw alone, adjustment can be made in orthogonal directions by adjusting the other two simultaneously in the same sense or in opposite senses.

7. After all adjustments have been made, fit the two sky baffles.

6 F/15 System Secondary Mirror Adjustment

1. Fit f/15 top end to telescope (see section 3, para 3.6 in "Operation and Maintenance Manual. Vol 1")

2. Fit sky baffle.

3. Fit micro-alignment telescope with JKT vertical and ties in place (see Fig. 6)

4. Use the procedure already described for the f/8 secondary (para 4) to align the mirror in translation and tilt.

5. To translate the secondary mirror: (see Fig. 3)

   (a) Release the 6 clamp screws with the 5mm Allen key.
   (b) Release one translation adjustment screw (see Figs. 3 & 6) and tighten its opposite screws with the 4mm Allen key until translation is correct in one direction.
   (c) Repeat for the orthogonal direction
   (d) Tighten the clamp screws and check that translation is correct.

6. The tilt for the f/15 secondary mirror is given by:

$$r_1 = a + \beta/85$$
$$r_2 = a - \beta/85$$

   where β is in arc seconds. (See Section 3, para 9) Thus:

$$\beta_{N-S} = \tfrac{1}{2}(r_1 - r_2)_{N-S} \times 85$$
$$\beta_{E-W} = \tfrac{1}{2}(r_1 - r_2)_{E-W} \times 85$$

7. Set the micro-alignment telescope scales to $\frac{1}{2}(r_1 + r_2)_{N-S}$ and $\frac{1}{2}(r_1 + r_2)_{E-W}$

8. To adjust the tilt (see Fig. 3)

   (a) Release 2 of the 3 clamp screws with the 17mm spanner.
   (b) Rotate the tilt adjustment screw (see Figs. 3 & 6) with the 30mm spanner paying attention to their locknuts (which must be tightened as they are not glued to the plate.)
   (c) Tighten the clamp screws and check tilt (no check is possible until the clamp screws are tight).
   (d) Repeat until tilt is correct.

9. If a large tilt adjustment has been made, remeasure the translation and adjust if more than 0.1mm off-centre.

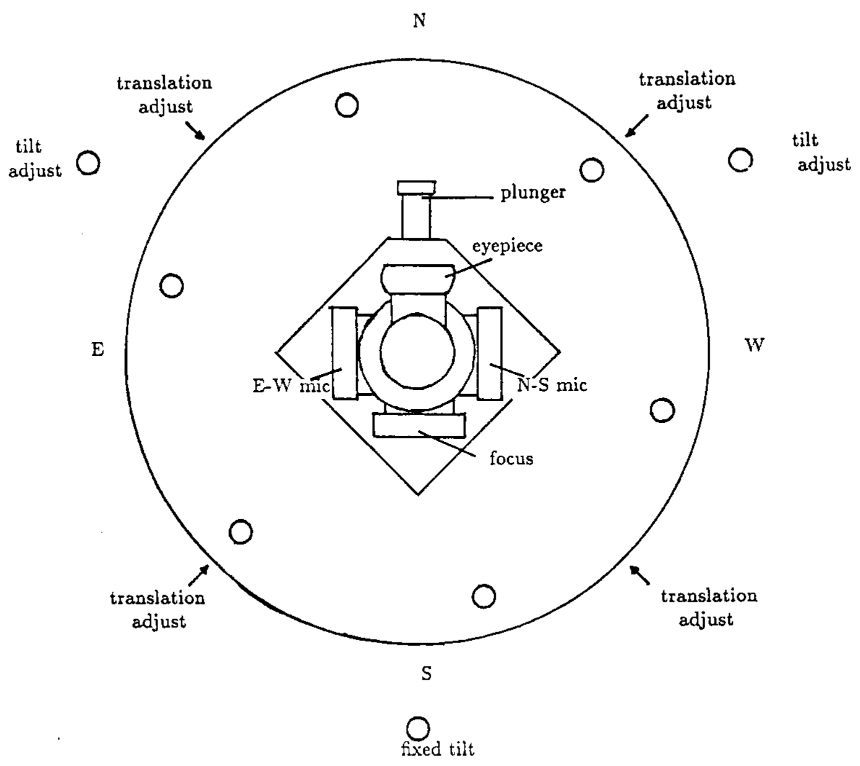

Figure 6: Mounting of microalignment telescope

7 Mounting Of Microalignment Telescope

Mount the micro-alignment telescope as shown looking up at mounting surface and with the turntable at 0 ° .

FOR f/8 AND f/15 SYSTEMS

After measurement of translation error if a_{N-S} is positive, tighten NW adjusting screw. If negative, tighten SE screw. If a_{E-W} is positive, tighten NE screw. If negative, tighten SW screw.

For tilt, with turntable at 180°, turning tilt adjustment screws:

- at ENE clockwise and at WNW anticlockwise moves target to right.
- at ENE anitclockwise and at WNW clockwise moves target to left.
- at ENE and at WNW clockwise moves target down.
- at ENE and at WNW anticlockwise moves target up.

8 Effects Of Misalignments Upon Optical Performance

Component centring and tilt errors cause image aberrations (mainly tangential coma) in both optical systems and distortion (relative to the axial image) in the case of the f/8 system. These effects are tabulated below; the sign convention is given in Fig. 7.

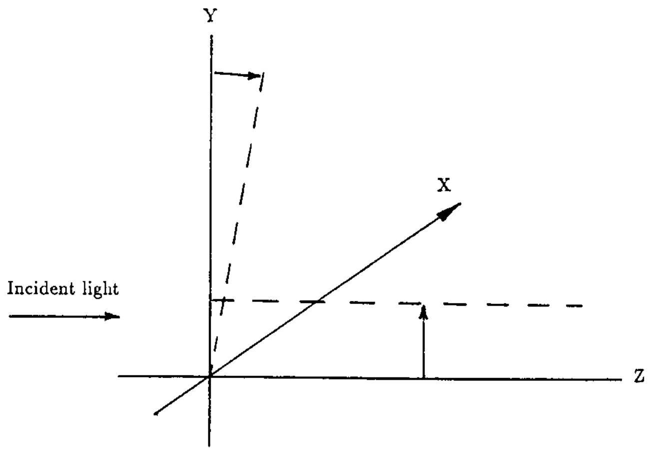

Figure 7: Sign convention (Tilt is rotation about X axis. Translation is in Y axis, parallel to Z axis.)

8.1 f/8 system

	Coma Change (arcsec)	Relative Distortion (arcsec)	Disp. Tol. for 0.05" coma (mm) (each axis)
Primary Mirror tilt, per arcsec	−0.0089	+0.0145	
Secondary Mirror tilt, per arcsec	+0.0047	−0.0059	
Secondary Mirror tilt, per mm (at Cass)	+0.2679	−0.3363	0.13
Secondary Mirror translation, per mm	+0.1113	−0.1376	0.32
Corrector tilt, per arcsec	+0.0014	+0.0010	
Corrector tilt, per mm (at Cass)	+0.1750	+0.1250	0.20
Corrector translation, per mm	+0.2879	−0.1885	0.12

8.2 f/15 system

	Axial image coma(arcsec)	Disp. Tol. for 0.05" coma(mm) (each axis)
Primary mirror tilt, per arcsec	−0.0089	
Secondary Mirror tilt, per arcsec	+0.0024	
Secondary Mirror tilt, per mm (at Cass.)	+0.2040	0.17
Secondary Mirror translation, per mm	+0.3976	0.09

8.3 Sign convention

See Fig. 7.

9 Acknowledgements

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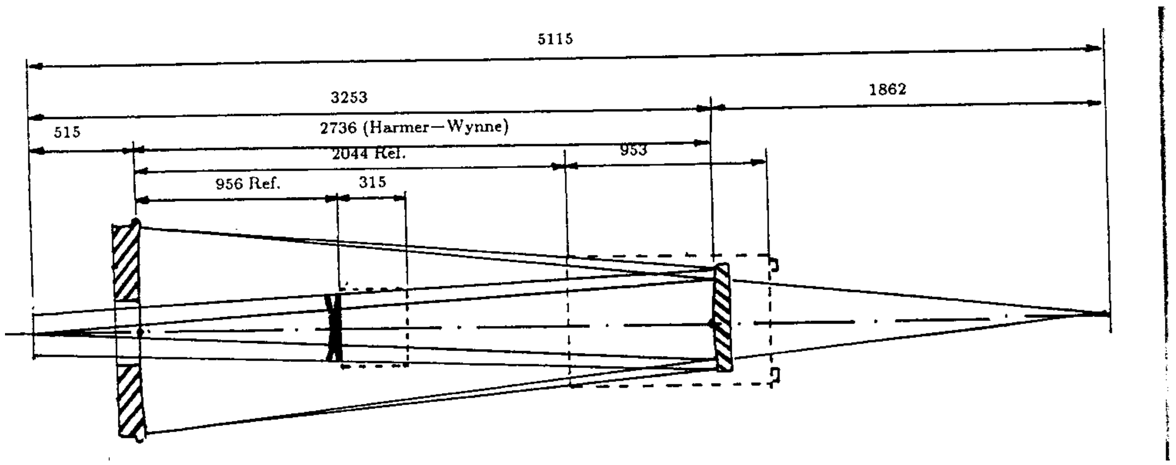

Figure 8: F/8.06 Cassegrain Optical Diagram

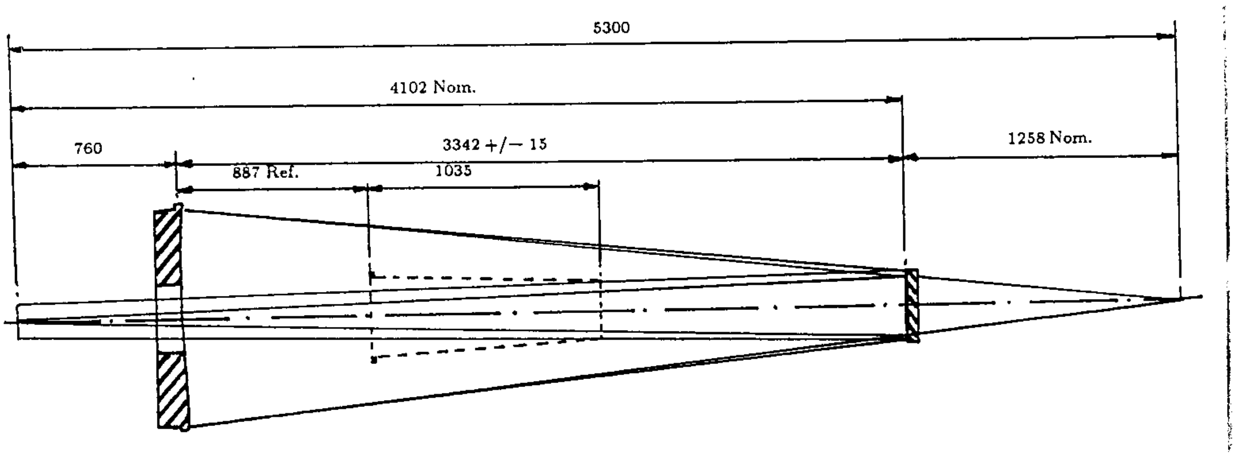

Figure 9: F/15 Cassegrain Optical Diagram