Grating instrumental profile and resolution

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Chapter 1

Introduction

This paper discusses investigations of the grating instrumental profile and describes possible instrumental effects on emission lines profiles observed with ISO's Short Wavelength Grating Spectrograph SWS.

Ground-based tests showed these Instrumental Profiles (IPs) to have a Gaussian shape up to accuracies of a few percent. To verify that this would also be the case in-flight, several observations of objects showing strong, narrow, emission lines (mostly Planetary Nebulae) were done in ISO's performance verification (PV) phase to investigate the influence of several parameters such as the position of the source in the aperture, the size of the target and the SWS AOT band.

For background reading consult sections 3.4.3, 'AOT 1', and 4.7, 'Spectral Resolution', of the SWS IDUM V3.0.

Chapter 2

AOT 1 Resolution

2.1 Observations

Preliminary measurements of the resolution of AOT 01 scans at all four speeds were carried out on observation of the PNe NGC 6543 and a speed 4 observations was carried out on the PNe NGC 7027. The assumption was made that the lines from these objects would not be resolved by the SWS01 scans. NGC 7027 contained by far the most lines of the two objects.

Note that section 3.4.3, 'AOT 1', of the SWS IDUM V3.0 discusses the resolution expected from the pipeline products of an AOT 1 observation. It is between a factor of 2 and 7 worse than that expected from the pipeline product of an AOT 2.

2.2 Results

The resolution quoted in tables 2.1 and 2.2 is the usual $\lambda/FWHM$

Wavelength μm	Resolution $\lambda/FWHM$	Wavelength μm	Resolution $\lambda/FWHM$
2.407	1388	7.902	1123
2.626	1216	9.666	1550
3.092	1458	10.51	1697
3.741	1143	12.81	1149
4.052	1236	13.10	1186
4.487	1366	13.52	1176
4.530	1347	14.32	1357
4.654	1422	15.55	1411
5.610	818	18.71	1663
6.986	1144	24.32	1004
7.319	1149	25.89	1049
7.460	1031	34.81	1619
7.653	1227	36.02	1459

Table 2.1: NGC 7027 speed 4 AOT 01 resolution

The measurements on NGC 7027 give more reliable results than those on NGC 6543. No systematic difference between the speed 4 resolutions of the two objects could be found.

Wavelength μm	Speed 4 Resolution	Speed 3 Resolution	Speed 2 Resolution	Speed 1 Resolution
7.46	983	0	0	0
8.99	1332	771	388	393
10.51	1670	0	463	538
15.55	1344	834	0	526
18.71	1718	1060	529	585
33.48	1323	677	0	560
36.00	1426	886	0	603

Table 2.2: NGC 6543 all speeds AOT 01 resolution

2.3 AOT 1 conclusions

The speed 4 resolutions vary between approximately 800 and 1700, increasing with wavelength per order. The FWHM remains nearly constant.

We can compare the resolutions of the different speeds using the NGC 6543 observations. The results are:

R(3) / R(4) = 0.6

R(2) / R(4) = 0.3

R(1) / R(4) $\approx$ 0.3 - 0.4

Chapter 3

AOT 2 & 6

3.1 Observations

Table 3.1 lists the objects used to derive the IP for AOTs 2 and 6.

Source	AOT	Size [“]	Source	AOT	Size [“]
NGC 6543	S06	< 1	NGC 6543	S06	< 1
NGC 6543	S02	< 1	NGC 6543	S02	< 1
NGC 6543	S06	< 1	NGC 6543	S06	< 1
NGC 6543	S02	< 1	NGC 6543	S02	< 1
NGC 6543	S02	< 1			
NGC 7027	S02	< 1	NGC 7027	S02	< 1
DR21 Shock-E	S06	> 20	DR21 Shock-E	S02	> 20
DR21 Shock-E	S02	> 20			
DR21-E	S02	> 20	DR21-E	S06	> 20
DR21-W	S02	> 20	DR21-W	S02	> 20
DR21-W	S06	> 20			
NGC 6826	S02	25	NGC 6826	S02	25
NGC 6826	S02	25			
IC2501	S02	4.5–5	IC2501	S02	4.5–5
IC2501	S02	4.5–5	IC2501	S02	4.5–5
NGC 6946	S02		NGC 6946	S02	
GL2591 NIRS 01	S06		NGC 3918	S02	36
WR 147	S06				

Table 3.1: Objects used for the determination of Instrumental Profiles

3.2 Preliminary IP Determination

Preliminary results of the tests on the position of the source in the aperture can be summarised as follows: changes in the instrumental profile from Gaussian become noticeable with an offset of a few arcseconds. The shape, central wavelength and the line strength can vary drastically as the source moves further away from the aperture center. This is illustrated in Fig. 3.1, showing the line profiles and object positions wrt the slit.

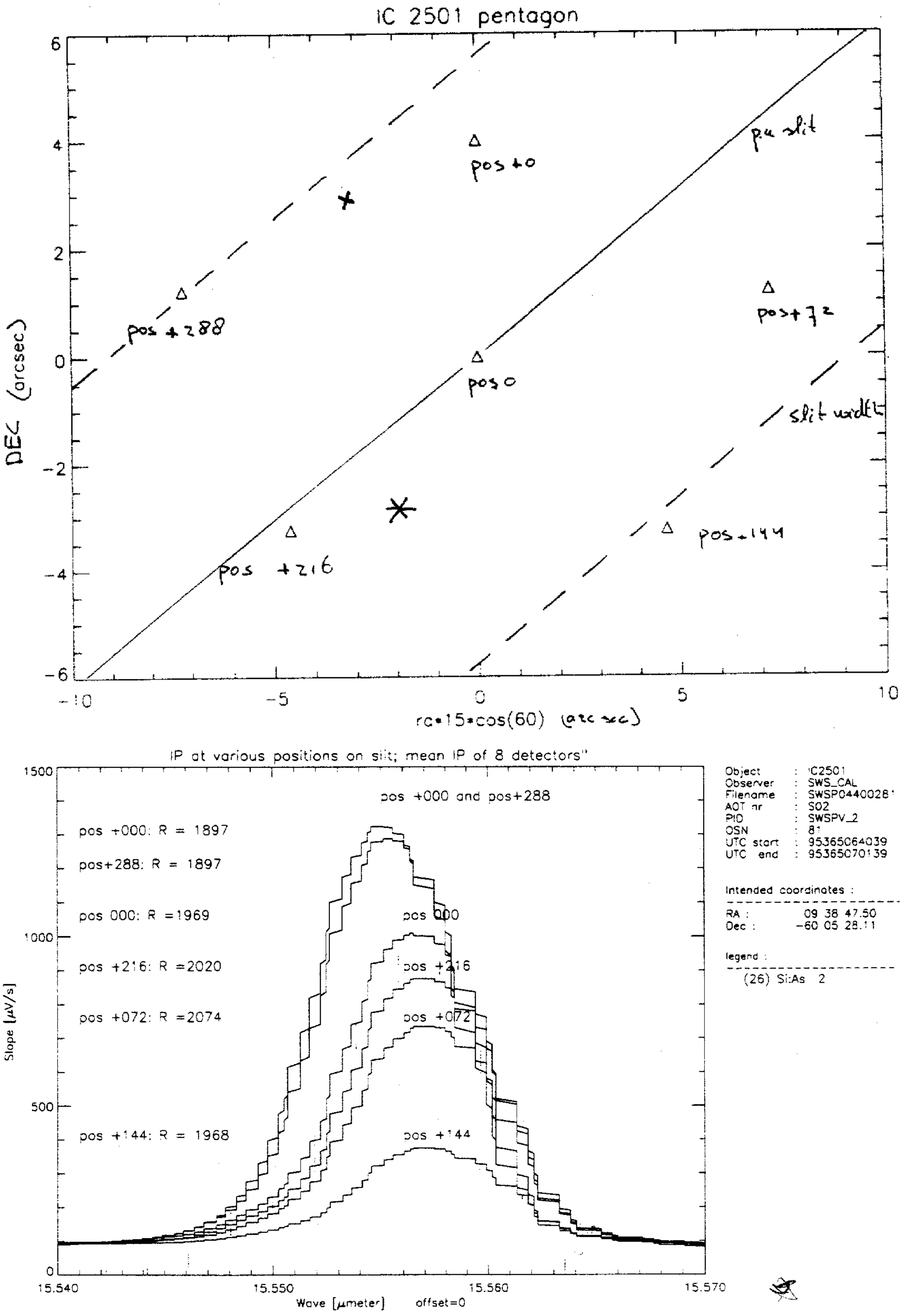

Figure 3.1: Changes in SWS instrumental profile and resolving power R with the position of the source in the slit.

3.3 IP Determination

The effect of target size, central wavelength and scanning direction on the IP was investigated using a large number of high S/N AOT S02 and S06 PV observations in all AOT bands of sources expected to show strong unresolved emission lines. Details of the observations used for this study are listed in Table 3.1. Since these data were generally taken for other purposes, these should provide a good test for what can be expected during real observations. For each measured emission line we applied some minimal reduction steps, after which the resulting line profile was plotted and compared to a Gaussian fitted to the data. Several examples of such line profiles are shown in Figures 3.2 and 3.3.

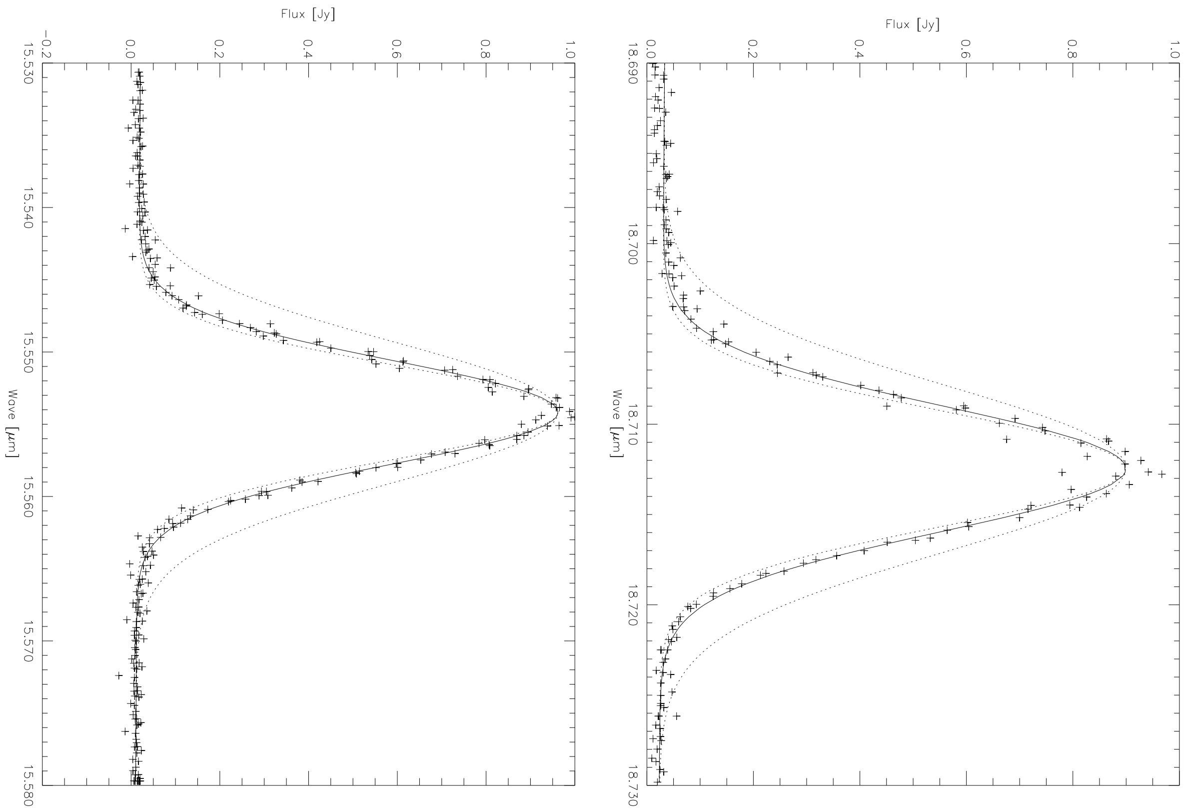

Figure 3.2: Examples of measured SWS lines (crosses) for extended sources. The measured IPs are compared to a Gaussian fit to the data (solid line), a Gaussian with the expected resolving power for a point source (lower dotted line) and a Gaussian with the expected resolving power for an extended source (upper dotted line).

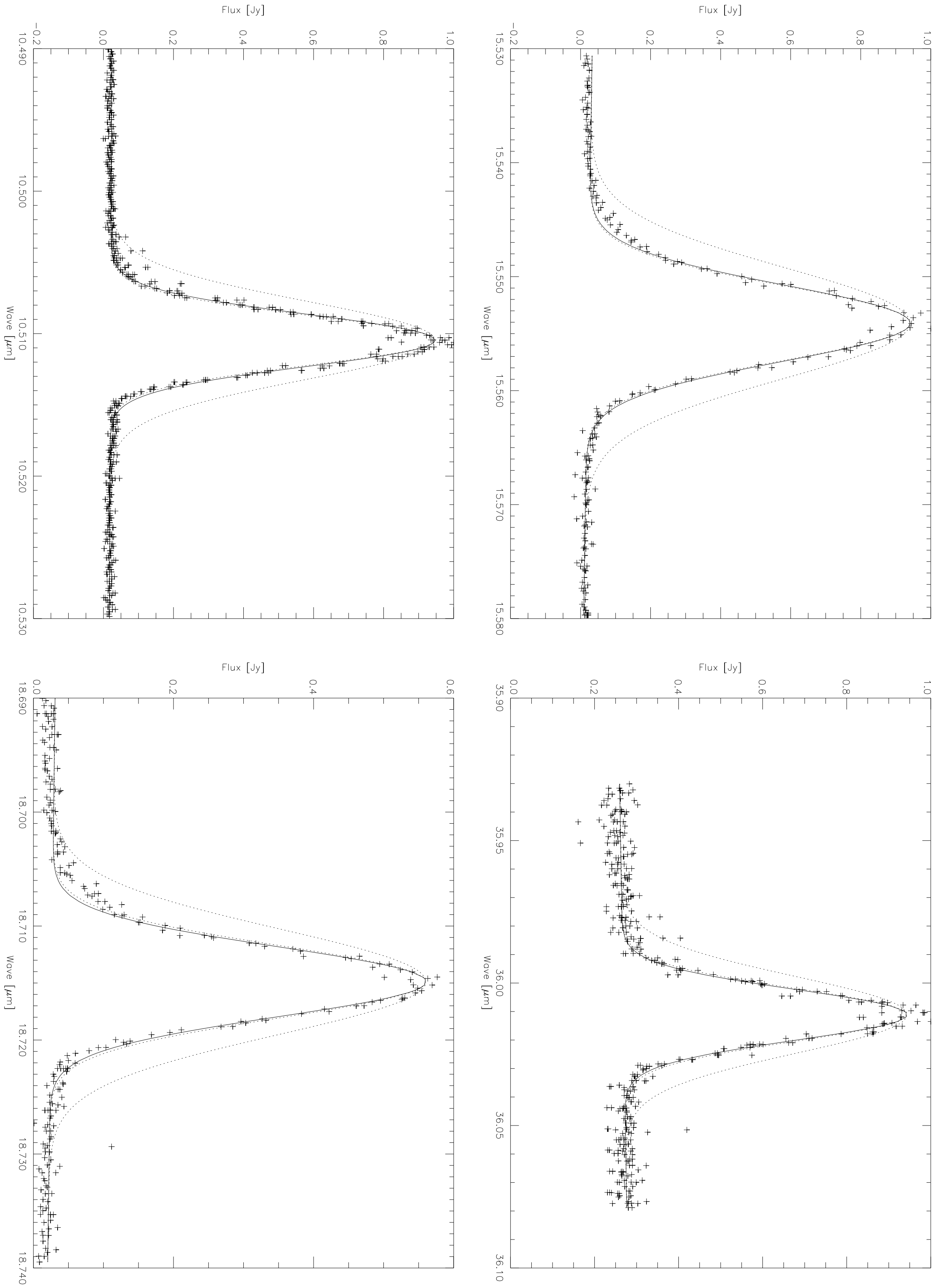

Figure 3.3: Examples of measured SWS lines (crosses) for unresolved sources. The measured IPs are compared to a Gaussian fit to the data (solid line), a Gaussian with the expected resolving power for a point source (lower dotted line) and a Gaussian with the expected resolving power for an extended source (upper dotted line).

As can be seen from figures 3.2 and 3.3, the peak of the profiles closely follow a Gaussian shape. At 10% above continuum some deviations from the Gaussian shape start to become visible – there always seems to be an indentation on the red side and a bump on the blue side. These deviations, most visible in the point source profiles and well within the few percent deviations already noted pre-launch, are present in all AOT bands and, as far as it has been possible to determine due to the different noise levels, also present in all detectors. They are also present and identical in the up- and down-scans. Interestingly, these deviations from Gaussian look like a less extreme version of those seen when offsetting the source in the slit (Fig. 3.1). Since only a small number of sources (although a large number of measurements), largely measured in the same orbits, were used in the determination of the IPs, they could be due to a systematic small (well within the pointing specifications) pointing offset for these sources. Determinations of IPs for more sources, observed during more orbits are necessary to get more insight in this.

As expected, extended sources show a broader instrumental profile than point sources. As is illustrated in Figure 3.2, a Gaussian can also adequately reproduce these profiles and, although less so than in the point sources, the same asymmetry at the shoulders of the profile can be seen here.

The resolving power $R = \lambda/FWHM$ was measured from the observed instrumental profiles. A plot of these values of R against wavelength for all measured lines is shown in Fig. 3.1. Typical errors in R are a few hundred, depending on the line strength and achieved S/N ratio. Errors in λ are much smaller than the plot symbols. From Fig. 3.4 we note that none of the points seem to be close to the expected values for fully extended sources, although several sources that are expected to completely fill the SWS aperture were also included in the study. It is possible the assumption they are extended is not valid because the line-emission in the Planetary Nebulae used for this purpose could come from a smaller region that the continuum radiation. In SWS bands 2 to 4 we note that a significant fraction of the measured points are located at higher resolutions than expected for a point source. Therefore we conclude that the resolving power of the SWS grating must be better than predicted in these wavelength regimes.

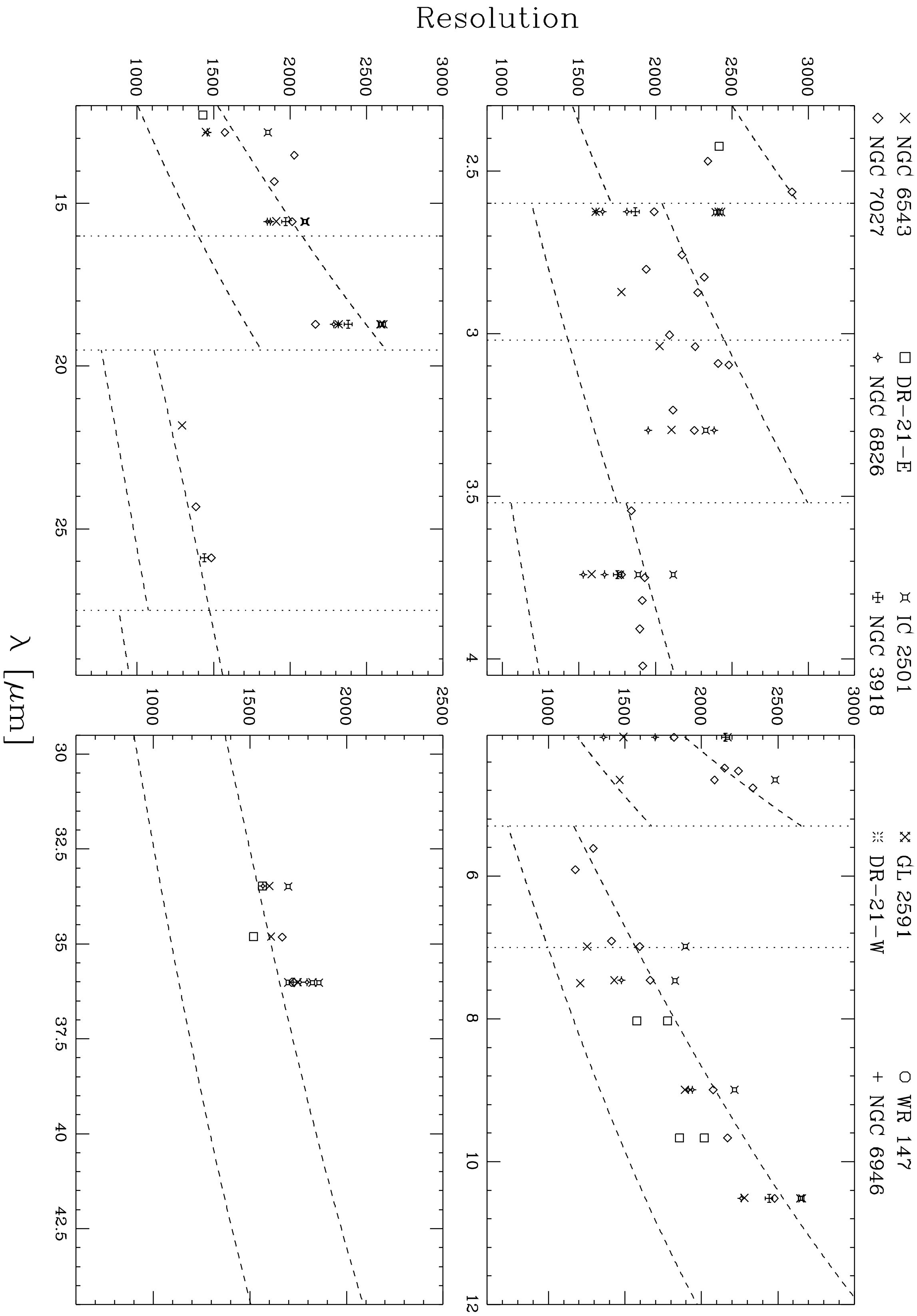

Figure 3.4: Measured SWS resolving power $\lambda/FWHM$ as a function of wavelength for different sources. The dotted lines indicate the resolving power for a point source (upper line) and a fully extended source (lower line), as given by the IA resolution module, which computes this value from the combined effects of diffraction, slit width, source size, ISO jitter and detector size.

3.4 AOT 2 & 6 Conclusions

Our main conclusions can be summarized as follows:

- The SWS grating instrumental profile is very close to Gaussian.
- The only systematic differences from a Gaussian profile are a slight "shoulder" on the blue side of the base of the profile and a depression on the red side as compared to a purely Gaussian profile. The only parameter this seems to depend on is the position of the source in the slit.
- The resolving power of SWS for all investigated sources is better than expected for extended sources at all wavelengths. This could either mean that none of line-emitting regions in any of the sources fully filled the SWS aperture, or that the SWS resolving power for extended sources is better than expected.
- In AOT bands 2 to 4 the resolving power for point sources is slightly better than predicted from the ground.