

Finding the Best Model

FBM

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Aim of the program

The aim of the program FMB (for Finding the Best Model) is to order the models resulting from the mc codes developed by K. Wood and C. H. Walker, according to how well they fit the UBV/ISO/IRAS data.

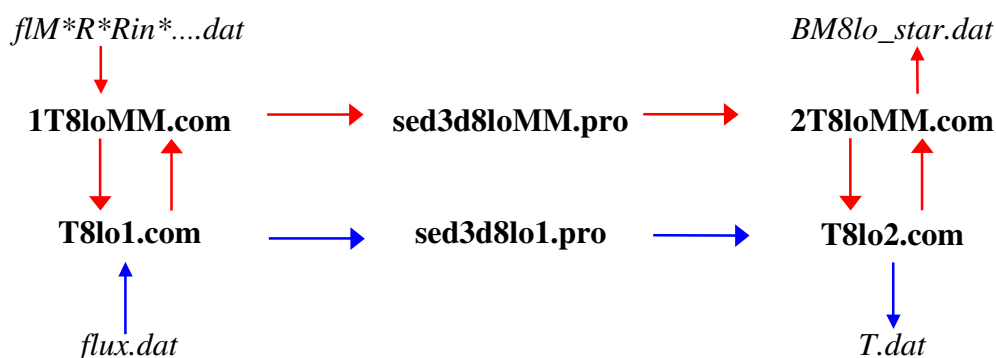
This is achieved by calculating the sum of the relative errors of each model, i.e. for each of the 20 angle-dependent models, with each of the combinations of parameters used.

The program consists of four parts and a small addition to Wood & Walker's sed3d*.pro programs. Hence, the program to calculate the best fit to 8 UBV/ISO/IRAS wavelengths is made of:

1T8loMM.com	Runs T8lo1.com for all the models indicated.	1T8loMM.com ↵
T8lo1.com	Takes results from mc code and removes unnecessary data.	
sed3d8loMM.pro	Produces files with the correct units for comparison.	IDL> .r sed3d8loMM ↵
2T8loMM.com	Runs T8lo2.com for all the models indicated.	2T8loMM.com Star ↵
T8lo2.com	Calculates relative errors and orders the results.	

T8lo1.com and T8lo2.com can be used by themselves, with sed3d8lo1.pro, when we only have one model. In this case, to run T8lo1.com, we must indicate the flux file to use: T8lo1.com *flux_file* ↵ (without .dat!) and to run T8lo2.com, we must indicate the name of the star to study: T8lo2.com *Name_of_star* ↵.

The following diagram shows how the different parts of the program fit together. The red arrows indicate the process to find the best model among models with different combination of parameters. The blue arrows are the process to find the best model (best angle) for a certain combination of parameters. The files (in italics) at the LHS are the input files, while the ones at the RHS are the output ones.



T8lo2.com also needs *_FTMM8.txt, with the photometry for the 8 wavelengths which are going to be used for comparison.

In case of only having 4 wavelengths available (between UBV/ISO/IRAS photometry) for a star, the version of the program to be used is:



TMM2.com also needs *_FTMM4.txt, with the photometry for the 4 wavelengths which are going to be used for comparison.

Some explanations

Why do we need a program?

Using Sz 68 as an example, we have plotted in Fig. I all the angle-dependent models obtained from the mc code using the combination of parameters indicated in the caption of the figure. Towards the left, the models show an increasing inner-disk hole, while the mass of the disk decreases on each row.

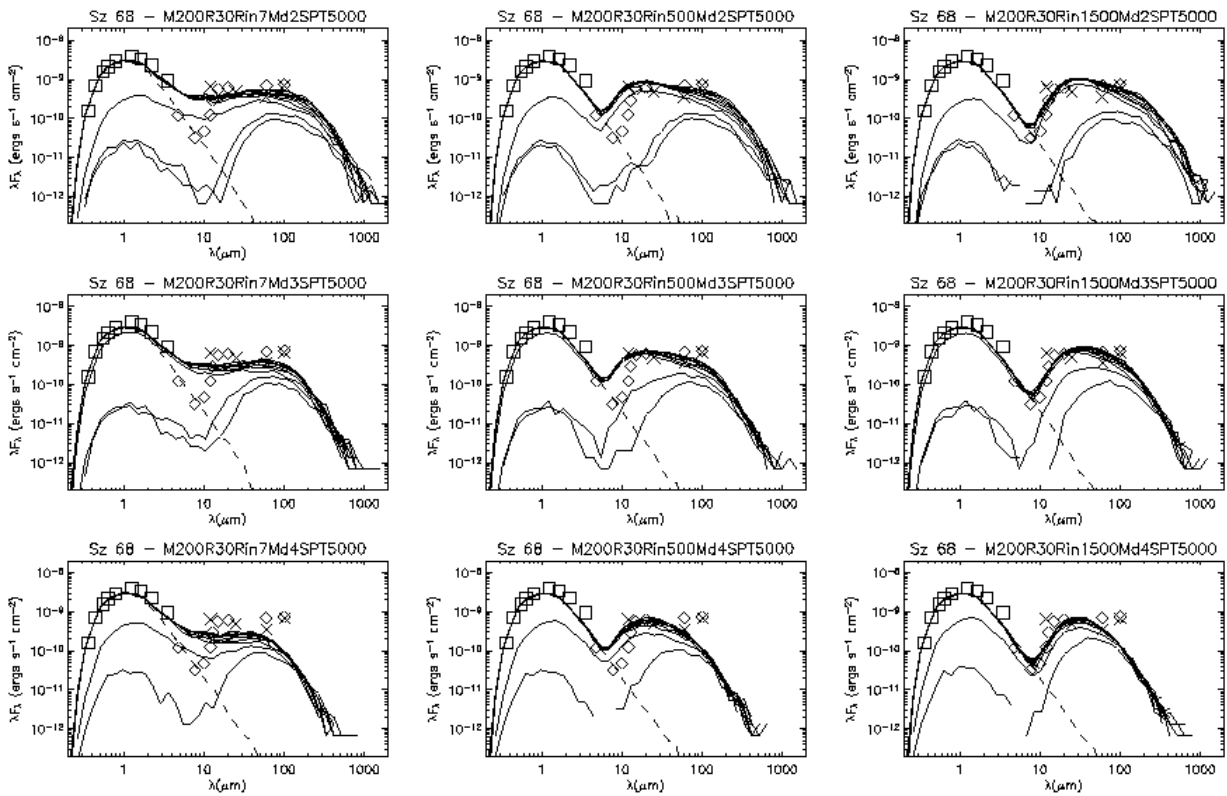


Fig. I: Different models obtained for Sz 68, assuming M_* of $2M_\odot$, R_* of $3R_\odot$, $T_* = 5000$ K, R_a of 300 AU, $h_0 = 0.0075$ and varying $M_{\text{disk}} = 5 \cdot 10^{-2}, 5 \cdot 10^{-3}, 5 \cdot 10^{-4} M_\odot$ and $R_{\text{int}} = 7, 500, 1500 R_*$, using 10^6 photons.

Although visually it is possible to say, for the given inner hole radii, the disk with $R_{\text{int}} = 1500 R_*$ fits the photometry better, it is not so clear which of the disk masses is the correct one. If a range of inner radii between e.g. 1400 and 1800 R_* were used to calculate the models it would be even less clear, which model would be the best. A more objective way to determine the best fit to our data is needed.

Why use relative errors?

Using the values taken from a model obtained for star T Cha, we have calculated the differences between the theoretical (result of the mc code*) and observed (from UBV/ISO/IRAS) photometry, the logarithm of the differences and the relative errors (see Table I) for 8 wavelengths.

Table I: Comparison between the theoretical photometry obtained from the models and the observed photometry for a star with ISO and optical telescopes.

	λ [μm] (models)	λF_λ	$-\log(\lambda F_\lambda)$	λ [μm] (UBV, ISO)	λF_λ	$-\log(\lambda F_\lambda)$	$\text{abs}\{\lambda F_\lambda - \lambda F_\lambda\}$	$\text{abs}\{\Delta \log(\lambda F_\lambda)\}$	$\epsilon_r (\Delta \lambda F_\lambda / \lambda F_\lambda)$
1	59.2192	3.68E-10	9.4344	60	4.25E-10	9.3716	5.7238E-11	0.0628	1.35E-01
2	20.0708	2.81E-10	9.5509	20	6.35E-11	10.1972	2.1773E-10	0.6463	3.43E+00
3	14.5927	1.62E-10	9.7898	15	2.71E-11	10.5670	1.3515E-10	0.7772	4.99E+00
4	11.7531	9.73E-11	10.0117	12	5.37E-11	10.2700	4.3648E-11	0.2584	8.13E-01
5	10.4864	7.03E-11	10.1530	10	1.04E-11	10.9830	5.9908E-11	0.8300	5.76E+00
6	7.6242	2.70E-11	10.5680	7.7	3.97E-11	10.4012	1.2659E-11	0.1668	3.19E-01
7	4.9458	5.41E-11	10.2669	4.8	2.20E-10	9.6576	1.6592E-10	0.6094	7.54E-01
8	3.55411	1.30E-10	9.8867	3.5	1.14E-09	8.9431	1.0102E-09	0.9436	8.86E-01

Then we have ordered the wavelengths studied according to these 3 magnitudes (Tables II, III and IV).

In Fig. II, we have plotted both the theoretical and observed photometry. The difference between the data points is larger for L than the NIR wavelengths. As the flux at optical and FIR wavelengths can be up to an order of magnitude higher than at the NIR wavelengths (where the dip in the disk is found), they will weight more in the estimation of the model that fits the data better.

This is slightly corrected when the difference between the logarithm of the fluxes is used (see Fig. III), but the search for the best model will still be biased towards the wavelengths at both sides of the dip.

Hence, the comparison of the quality of the fit of the models at each wavelength is achieved better by looking at the relative errors. With this method, the differences between the observed data and the theoretical data takes into account equally, the fitting to the lower fluxes and the higher ones (see Fig. IV).

* Models obtained for: $M_* = 1.2 M_\odot$, $R_* = 1.35 R_\odot$, $T_* = 5750 \text{ K}$, $R_a = 100 \text{ AU}$, $M_{\text{disk}} = 5 \cdot 10^{-2} M_\odot$, $h_0 = 0.008$, $R_{\text{int}} = 2000 R_*$, and using $5 \cdot 10^6$ photons.

Table II: Wavelengths ordered according to the difference in flux.

	λ [μm]	$\text{abs}\{\lambda F_\lambda - \lambda F_\lambda\}$
6	7.7	1.2659E-11
4	12	4.3648E-11
1	60	5.7238E-11
5	10	5.9908E-11
3	15	1.3515E-10
7	4.8	1.6592E-10
2	20	2.1773E-10
8	3.5	1.0102E-09

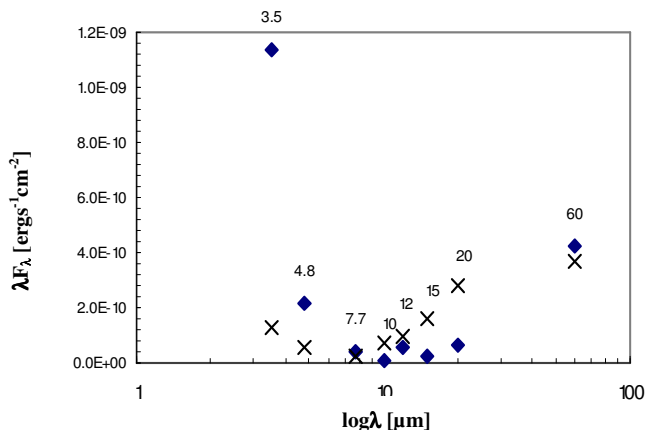


Fig. II: Fluxes from the models (crosses) and fluxes from ISO (diamonds) versus wavelengths.

Table III: Wavelengths ordered according to the difference in log of the flux.

	λ [μm]	$\text{abs}\{\Delta \log(\lambda F_\lambda)\}$
1	60	0.0628
6	7.7	0.1668
4	12	0.2584
7	4.8	0.6094
2	20	0.6463
3	15	0.7772
5	10	0.8300
8	3.5	0.9436

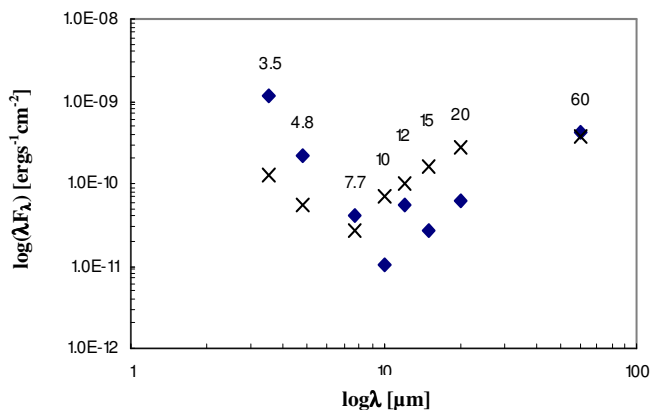


Fig. III: Log of the fluxes from the models (crosses) and fluxes from ISO (diamonds) vs. wavelengths.

Table IV: Wavelengths ordered according to the relative errors.

	λ [μm]	$\epsilon_r (\Delta \lambda F_\lambda / \lambda F_\lambda)$
1	60	1.35E-01
6	7.7	3.19E-01
7	4.8	7.54E-01
4	12	8.13E-01
8	3.5	8.86E-01
2	20	3.43E+00
3	15	4.99E+00
5	10	5.76E+00

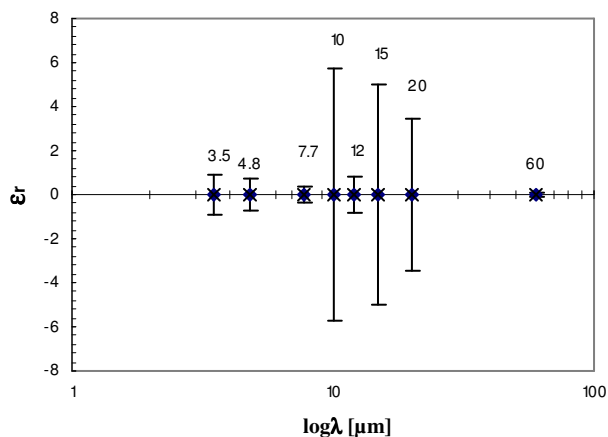


Fig. IV: Relative errors of the fluxes from the models versus wavelengths.

Why discard the models with $\epsilon_r(V) > 0.3$?

We will only consider the models that fit the black body representing the star's photosphere. Observing the models obtained with the mc code we see that only those with a relative error of the V band less than 0.3, fit the photometry at the optical wavelengths. See example in Fig. V:

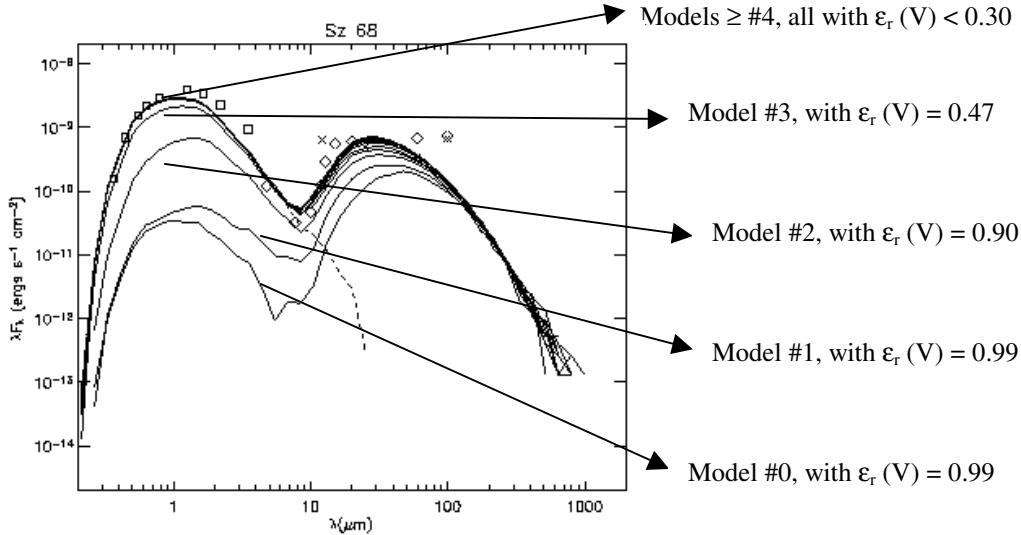


Fig. V: The 20 angle-dependent models obtained for the following combination of parameters: $M_* = 2 M_\odot$, $R_* = 3 R_\odot$, $T_* = 5000$ K, $R_a = 300$ AU, $M_{\text{disk}} = 5 \cdot 10^{-4} M_\odot$, $R_{\text{int}} = 1500 R_*$, $h_0 = 0.0075$ and using $5 \cdot 10^6$ photons.

It is important to discard the models with $\epsilon_r(V) > 0.3$ as otherwise some can appear to fit the system (star + disk) better, although they do not fit the star (photometry at the U to I bands) at all. For example, see models #2 and #3, in Fig. IV (and their corresponding relative errors in Fig. V). These models appear to fit the system better (they have a lower sum of relative errors) than models \geq #4, just because they fit the photometry of the disk better.

$\Sigma \epsilon_r$	$\epsilon_r(V)$	$\epsilon_r(4.8\mu\text{m})$	$\epsilon_r(7.7\mu\text{m})$	$\epsilon_r(10\mu\text{m})$	$\epsilon_r(12\mu\text{m})$	$\epsilon_r(15\mu\text{m})$	$\epsilon_r(20\mu\text{m})$	$\epsilon_r(60\mu\text{m})$	α
2.96197	0.165487	0.306554	0.702481	0.832209	0.0527967	0.526621	0.0889821	0.452331	#12:
2.96599	0.167462	0.319199	0.746406	0.710243	0.0441463	0.540351	0.140029	0.465614	#10:
3.02924	0.152051	0.320298	0.643928	0.610974	0.0969837	0.614315	0.243629	0.499109	#6:
3.06125	0.470858	0.175736	0.654374	0.253616	0.29435	0.70473	0.407145	0.571297	#3:
3.07648	0.217314	0.233446	0.656459	0.483348	0.166195	0.654082	0.342257	0.540689	#4:
3.09506	0.176949	0.281273	0.773585	0.925804	0.0949756	0.524137	0.0450748	0.450214	#18:
3.10299	0.165955	0.31205	0.775686	0.905942	0.102	0.52094	0.0340423	0.452331	#17:
3.10931	0.170468	0.323594	0.761038	0.959836	0.0933496	0.519756	0.0236602	0.428075	#19:
3.11964	0.15291	0.37362	0.748506	0.679047	0.0375041	0.579406	0.207073	0.494488	#7:
3.1239	0.903769	0.379978	0.0734654	0.234215	0.506314	0.769703	0.551195	0.609026	#2:
3.16889	0.171506	0.320852	0.840522	0.863403	0.153374	0.499877	0.0275528	0.463305	#15:
3.18332	0.164032	0.351628	0.880264	0.866241	0.0782114	0.509107	0.0405301	0.457336	#16:
3.18489	0.158897	0.337884	0.767321	0.954164	0.0592846	0.536443	0.0822732	0.447517	#13:
3.18914	0.158872	0.348876	0.786148	0.820866	0.00181301	0.576443	0.172249	0.482748	#8:
3.30587	0.166397	0.347231	0.75477	0.662032	0.114829	0.623665	0.290564	0.512776	#5:
3.30756	0.167147	0.332942	0.96183	0.789659	0.0500976	0.559167	0.146517	0.467347	#9:
3.31023	0.168109	0.375817	0.792399	0.979687	0.146886	0.525199	0.039452	0.450792	#14:
3.32533	0.160583	0.338983	0.832157	0.951328	0.0749675	0.539404	0.111906	0.476586	#11:
5.46208	0.989336	0.895562	0.732286	0.736232	0.781004	0.882601	0.742397	0.691996	#1:
6.35	0.991519	0.983512	0.943528	0.929094	0.925919	0.952544	0.884717	0.730689	#0:

Fig. VI: Relative errors found by the program for the models with the same combination of parameters and number of photons as the ones used for Fig. V. The sum of the relative errors does not include $\epsilon_r(V)$.

What are the results from different number of photons?

Running the program on the models for different number of photons, we realized the results were not exactly the same (see Fig. VII). The best models when 10^5 or 10^6 photons are used are not the same.

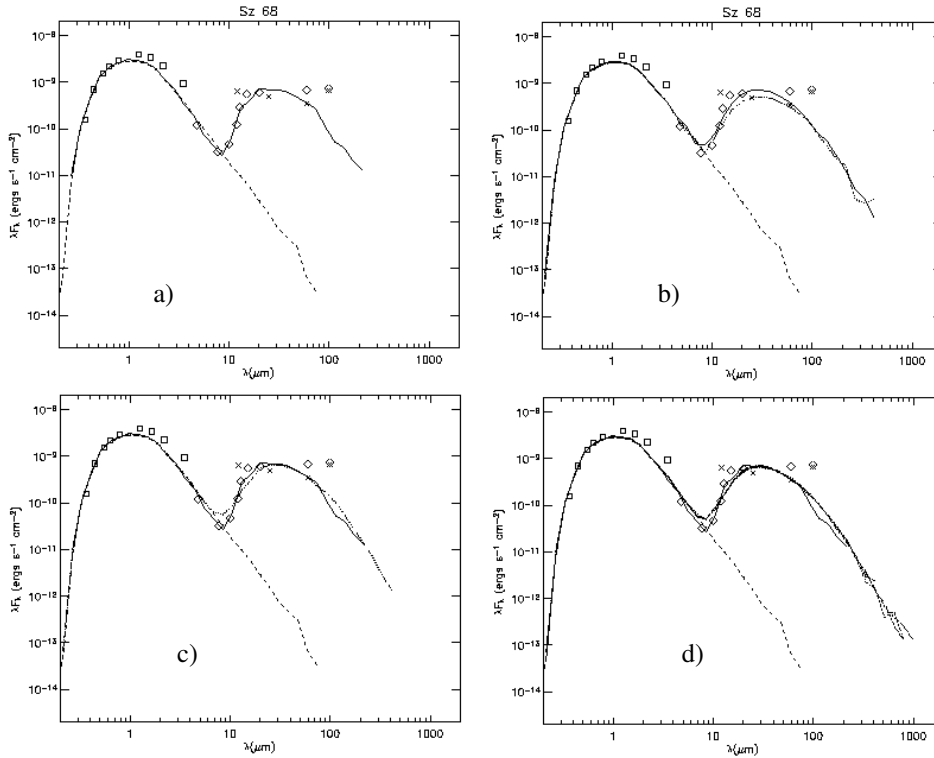


Fig. VII: All four images are models with M200R30Rin1500Md4SPT5000. **a)** Best model of the 180, using 10^5 photons. Angle: #11. **b)** Best models of the 180, when using 10^6 photons. Angles: #19 (best, continuous line) and #4 (2nd best discontinuous line). **c)** Models for angles #11, when using 10^5 photons (continuous line) and 10^6 photons (discontinuous line). **d)** The continuous line is the model for angle #11, when using 10^5 photons. The discontinuous lines are the models for the angles #10 (2nd best), #11 (worst), #12 (best) and #19 when using $5 \cdot 10^6$ photons and finding the best model only among the 20 angle-dependent models with M200R30Rin1500Md4SPT5000.

Although the same combination of parameters continued to give the best model, the best angle for the disk varied depending on the number of photons used.

Looking at the models #11 and #19 when using different number of photons (see Fig. VIII and IX), we see that the models with the same angle of inclination for the disk tend to converge as the number of photons increases.

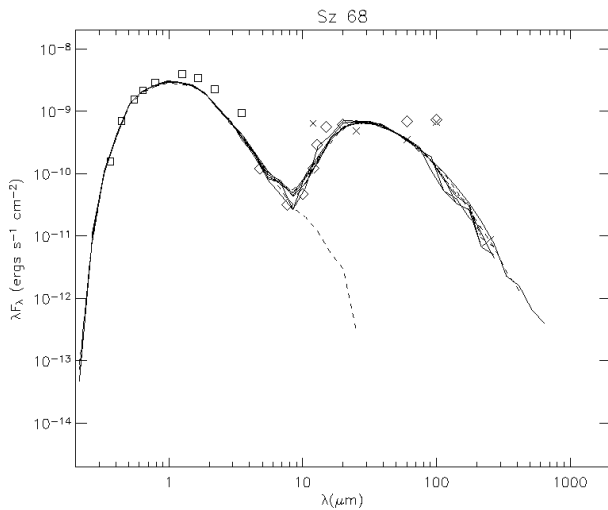


Fig. VIII: Models with 10^5 , $2 \cdot 10^5$, $3 \cdot 10^5$, $4 \cdot 10^5$, $5 \cdot 10^5$, 10^6 and $5 \cdot 10^6$ for angle #11. In the image, the models at $\sim 10\mu\text{m}$ increase as the number of photons increases.

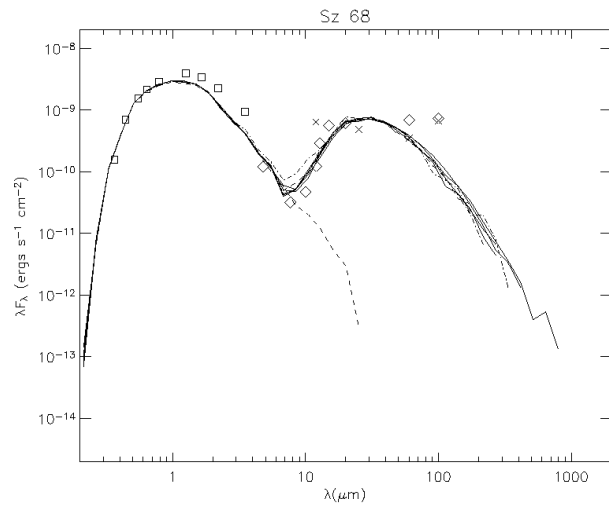


Fig. IX: Models with 10^5 , $2 \cdot 10^5$, $3 \cdot 10^5$, $4 \cdot 10^5$, $5 \cdot 10^5$, 10^6 and $5 \cdot 10^6$ for angle #19. In the image, the models at $\sim 10\mu\text{m}$ decrease as the number of photons increases.

Furthermore, all the angle-dependent models (which fit the black body) seem to converge as well (see Fig. X), when the number of photons increases (although this occurs mainly around the $10\mu\text{m}$ wavelengths).

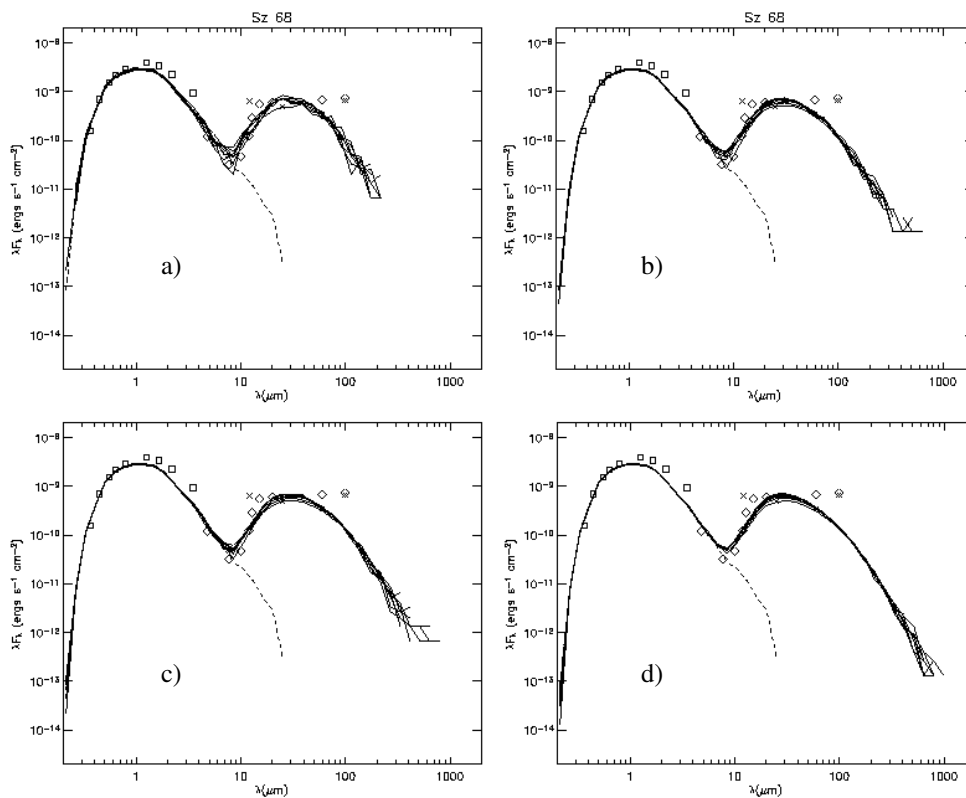


Fig. X: All for images have all the models with even angles between #4 and #19 calculated using: a) 10^5 photons, b) $5 \cdot 10^5$ photons, c) 10^6 photons and d) $5 \cdot 10^6$ photons.

Hence, the program must be applied to models obtained with $\geq 5 \cdot 10^5$ and check afterwards that models with $5 \cdot 10^6$ give the same results. I.e. the best model (combination of parameters) remains the best, when the number of photons is increased. This means the best combination of parameters will have most of its angle-dependent models among the best models, when the program is run for all the combination of parameters, for large number of photons.

Program for Finding the Best Model step by step

Programs that are going to be described:

1T8loMM.com
T8lo1.com

sed3d8loMM.pro¹
sed3d8lo1.pro

2T8loMM.com
T8lo2.com

1T8loMM.com ↵

The program starts with:

```
#!/bin/sh
#init
r=0
#loop through different
values:
for no in 10
do
for ri in 7 500 1500
do
for ms in 200
do
for rs in 30
do
for ta in 50
do
for ra in 300
do
for ha in 075
do
for ma in 2 3 4
do
for bt in 1.25
do
#for vt in 0
#do
#for lg in 35
#do
#display run numbers
r=`expr $r + 1`
```

Where the different values for the parameters have to be introduced. These must match the ones used to calculate the different models.

- no · 10⁴: number of photons
- ri: internal radius of disk (R_*)
- ms · 10⁻²: mass of star (M_\odot)
- rs · 10⁻¹: radius of star (R_\odot)
- ta · 10²: temperature of star (K)
- ra: external radius of disk (AU)
- ha: (0.0ha) disk scale-height at stellar surface (R_*)
- ma: (5·10^{-ma}) mass of disk (M_\odot)
- bt: β , disk flaring parameter [$h=h_0(r/r_*)^\beta$]

The names of the files have to be the same as the flux files obtained from mcgrid. The appropriate lines will have to be uncommented:

```
*****
#Program for 8 wavelengths*****
*****
#Choose the appropriate file_names!!*****
*****
echo "M"$ms"R"$rs"Rin"$ri"Md"$ma"SPT"$ta"00*****"
#echo "M"$ms"R"$rs"Rin"$ri"Md"$ma"SPT"$ta"00h"$ha"*****"
#echo "M"$ms"R"$rs"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00h"$ha"*****"
#echo "M"$ms"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00h"$ha"*****"
#echo "M"$ms"R"$rs"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00*****"

#hola
echo "model 8lo "$r
#run code
```

¹ Of this program only the added part that complements the other programs will be discussed.

The previous program lines show you which model is the program dealing with. The flux files `flM*.dat`, which result from `mcgrid`, have:

```

4487.97 0. 0. 0. 0.
3614.69 0. 0. 0. 0.
2911.33 0. 0. 0. 0.
2344.83 0. 0. 0. 0.
1888.57 0. 0. 0. 0.
1521.08 0. 0. 0. 0.
1225.11 0. 0. 0. 0.
986.721 0. 0. 0. 0.
794.722 0. 0. 0. 0.
640.082 1.42514E+30 0. 0. 1.42514E+30
515.533 2.85029E+30 0. 0. 2.85029E+30
415.219 1.28263E+31 0. 0. 1.28263E+31
334.424 1.14012E+31 0. 0. 1.14012E+31
263.351 3.13532E+31 0. 0. 3.13532E+31
216.940 5.98560E+31 0. 0. 5.98560E+31
174.727 7.55326E+31 0. 0. 7.55326E+31
140.728 7.41075E+31 0. 0. 7.41075E+31
113.345 1.05461E+32 0. 0. 1.05461E+32
91.2896 1.04036E+32 0. 0. 1.04036E+32
73.5261 1.35389E+32 0. 0. 1.35389E+32
59.2192 9.83349E+31 0. 0. 9.83349E+31
47.6361 1.31113E+32 0. 0. 1.31113E+32
38.4152 1.18287E+32 0. 0. 1.18287E+32
30.9403 1.15437E+32 0. 0. 1.15437E+32
24.9198 1.02610E+32 0. 0. 1.02610E+32
20.0708 9.54946E+31 1.42514E+30 0. 9.40595E+31
16.1654 8.55086E+31 0. 0. 8.55086E+31
13.0199 1.05461E+32 5.70058E+30 0. 9.97601E+31
10.48642 8.40835E+31 0. 0. 8.40835E+31
8.44594 8.12332E+31 1.28263E+31 0. 6.84069E+31
6.80250 7.98081E+31 1.14012E+31 0. 6.84069E+31
5.47884 1.12586E+32 3.27783E+31 0. 7.98081E+31
4.41275 1.02610E+32 4.70298E+31 0. 5.58086E+31
3.55411 1.45385E+32 8.25582E+31 4.27543E+30 5.84309E+31
2.86253 2.02370E+32 1.41089E+32 4.27543E+30 5.70058E+31
2.30553 2.90729E+32 2.36574E+32 1.56766E+31 3.84789E+31
1.85692 5.18752E+32 4.63172E+32 1.85269E+31 3.70537E+31
1.49559 7.06971E+32 6.48441E+32 3.42035E+31 2.42274E+31
1.20457 8.89290E+32 8.52236E+32 2.85029E+31 8.55086E+30
0.970184 9.91900E+32 9.51996E+32 3.56286E+31 4.27543E+30
0.781402 1.08453E+33 1.05033E+33 3.13532E+31 2.85029E+30
0.623354 1.20585E+33 1.15577E+33 3.84789E+31 0.
0.506892 9.27769E+32 8.89290E+32 3.84789E+31 0.
0.408259 4.21843E+32 4.13292E+32 8.55086E+30 0.
0.328819 1.39664E+32 1.35389E+32 4.27543E+30 0.
0.264836 1.42514E+31 1.42514E+31 0. 0.
0.213303 0. 0. 0. 0.

```

Fig.1: `flM*.dat`

- 10 rows with different parameters, e.g. T_{eff} , L_* , etc.
- 5 columns: λ (total flux), f_i (total flux), f_d (direct flux), f_s (scattered flux), f_t (thermal flux).
- The SED of the system, for the given input parameters, for each of the 20 possible angles of inclination of the disk, starting from 0 (90°, disk edge-on) to 19 (0°, disk face-on). For each angle, it shows the flux for 50 wavelengths.

We are only interested in the two first columns (λ , f_i) and the fluxes corresponding to 8 wavelengths we will be able to compare with the UBV, ISO, IRAS values.

To get rid of the extra information, we run the program **T8l01.com** for each flux file (model/combination of parameters).

```

T8l01.com "flM"$ms"R"$rs"Rin"$ri"Md"$ma"SPT"$ta"00"
#T8l01.com "flM"$ms"R"$rs"Rin"$ri"Md"$ma"SPT"$ta"00h"$ha"
#T8l01.com "flM"$ms"R"$rs"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00h"$ha"
#T8l01.com "flM"$ms"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00h"$ha"
#T8l01.com "flM"$ms"R"$rs"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00"

```

(Within **T8l01.com**)

It starts with:

```

cat $1.dat | awk 'NR>10{print $0}' > A.dat
cat A.dat | awk '{print $1, $2}' > B.dat

```

The first command gets rid of the 10 first lines of each `flM*.dat` file. The second one leaves only the first two columns.

Then, we will want only the rows with the fluxes corresponding to the wavelengths we are going to compare with the UBV/ISO/IRAS values. As it can be seen from Fig. 1, the possible wavelengths are the ones in Table 1:

Table 1: Wavelengths available for comparison

59.2192	—	60 μm		10.48642	—	10 μm
24.9198	—	25 μm		8.44594	}	7.7 μm
20.0708	—	20 μm		6.80250	}	
16.1654	}	15 μm		5.47884	}	4.8 μm
13.0199	}					
13.0199	—	12.8 μm		0.781402	—	I
13.0199	}	12 μm		0.629354	}	V
10.48642	}					

Depending on the star, we will have different wavelengths available. The line corresponding to the 8 wavelengths that are going to be used must be uncommented:

```

*****
#Choose the 8 wavelengths available for this star:*****
*****

#Fotometria de      60      20      10      L *****

#cat B.dat | awk '/59.2192/ /20.0708/ /10.48642/ /3.55411/' > flux.dat

#Fotometria de      60  20  15  12  10  7.7  4.8  L *****

#cat B.dat | awk '/59.2192/ /59.2192/ /20.0708/ /20.0708/ /16.1654/ /13.0199/
/13.0199/ /10.48642/ /10.48642/ /10.48642/ /8.44594/ /6.80250/ /5.47884/ /4.41275/
/3.55411/ /3.55411/' > C.dat

#Fotometria de 60  20  15  12  10  7.7  4.8  V (en compte de L!) *****

cat B.dat | awk '/59.2192/ /59.2192/ /20.0708/ /20.0708/ /16.1654/ /13.0199/ /13.0199/
/10.48642/ /10.48642/ /10.48642/ /8.44594/ /6.80250/ /5.47884/ /4.41275/ /0.629354/
/0.506892/' > C.dat

#Fotometria de 60  25  15  12  10  7.7  I  V *****

#cat B.dat | awk '/59.2192/ /59.2192/ /24.9198/ /24.9198/ /16.1654/ /13.0199/
/13.0199/ /10.48642/ /10.48642/ /10.48642/ /8.44594/ /6.80250/ /0.781402/ /0.781402/
/0.629354/ /0.506892/' > C.dat

#Fotometria de 60  25  20  12  10  4.8  I  V *****

#cat B.dat | awk '/59.2192/ /59.2192/ /24.9198/ /24.9198/ /20.0708/ /20.0708/
/13.0199/ /10.48642/ /10.48642/ /10.48642/ /5.47884/ /4.41275/ /0.781402/ /0.781402/
/0.629354/ /0.506892/' > C.dat

#Fotometria de 60  25  20  15  12  10  4.8  V *****

#cat B.dat | awk '/59.2192/ /59.2192/ /24.9198/ /24.9198/ /20.0708/ /20.0708/
/16.1654/ /13.0199/ /13.0199/ /10.48642/ /10.48642/ /10.48642/ /5.47884/ /4.41275/
/0.629354/ /0.506892/' > C.dat

#Fotometria de 25  20  15  12  10  7.7  4.8  V *****

#cat B.dat | awk '/24.9198/ /24.9198/ /20.0708/ /20.0708/ /16.1654/ /13.0199/
/13.0199/ /10.48642/ /10.48642/ /10.48642/ /8.44594/ /6.80250/ /5.47884/ /4.41275/
/0.629354/ /0.506892/' > C.dat
*****

```

Some of the wavelengths appear twice because to be able to obtain the fluxes for e.g. 15, 7.7 μm , ... we need to do averages between two values. This way, we will average all the pairs. In C.dat (Fig. 2) we will have only the wavelengths selected:

```
59.2192 3.56286E+31
59.2192 3.56286E+31
20.0708 1.56766E+31
20.0708 1.56766E+31
16.1654 8.55086E+30
13.0199 5.70058E+30
13.0199 5.70058E+30
10.48642 0.
10.48642 0.
10.48642 0.
8.44594 1.42514E+30
6.80250 0.
5.47884 0.
4.41275 2.85029E+30
0.506892 1.14012E+31
0.506892 1.14012E+31
59.2192 4.41795E+31
59.2192 4.41795E+31
20.0708 3.70537E+31
20.0708 3.70537E+31
C.dat
```

Fig. 2: C.dat

Then we pair the wavelengths, using the paste command (Fig. 3):

```
#Ordenem en files:
paste -s -d" \n \n" C.dat > D.dat
```

```
59.2192 3.56286E+31 59.2192 3.56286E+31
20.0708 1.56766E+31 20.0708 1.56766E+31
16.1654 8.55086E+30 13.0199 5.70058E+30
13.0199 5.70058E+30 10.48642 0.
10.48642 0. 10.48642 0.
8.44594 1.42514E+30 6.80250 0.
5.47884 0. 4.41275 2.85029E+30
0.506892 1.14012E+31 0.506892 1.14012E+31
59.2192 4.41795E+31 59.2192 4.41795E+31
20.0708 3.70537E+31 20.0708 3.70537E+31
D.dat
```

Fig. 3: D.dat

In Fig. 2 and 3, the first 0.50689 that appears will be in fact 0.629354, and the corresponding value of the photometry.

And we calculate the averages, both of the wavelengths and the fluxes (Fig. 4):

```
cat D.dat | awk '{print $1+$3, $2+$4}' > E.dat
cat E.dat | awk '{print $1/2, $2/2}' > F.dat
```

```
59.219 3.56286e+31
20.0708 1.56766e+31
14.5927 7.1257e+30
11.7531 2.85029e+30
10.4864 0
7.6242 7.1257e+29
4.9458 1.42515e+30
0.50689 1.14012e+31
59.219 4.41795e+31
20.0708 3.70537e+31
F.dat
```

Fig. 4: flux.dat

In Fig.4, instead of 0.50689, we will have 0.568125, and the corresponding average for the photometry.

In order to obtain a more approximate value to V (0.55 μm), it is necessary to calculate a weighted average of 0.629354 and 0.506892 μm:

$$(0.629354 + 2 \times 0.506892) / 3 = 0.547713 \mu\text{m}$$

Hence, we will calculate the weighted average indicated before of all the wavelengths (see fig. 5 and 6):

```
*****
cat D.dat | awk '{print $1+$3+$3, $2+$4+$4}' > E1.dat
cat E1.dat | awk '{print $1/3, $2/3}' > F1.dat
```

$$\bar{\lambda} \quad \overline{\lambda F_{\lambda}} \quad (\bar{\lambda})_w \quad (\overline{\lambda F_{\lambda}})_w$$

```
59.2192 4.40370E+31 59.2192 4.40370E+31
20.0708 1.63892E+31 20.0708 1.63892E+31
16.1654 8.40835E+30 13.0199 3.84789E+30
13.0199 3.84789E+30 10.48642 5.70058E+29
10.48642 5.70058E+29 10.48642 5.70058E+29
8.44594 4.27543E+29 6.80250 2.85029E+29
5.47884 0. 4.41275 8.55086E+29
0.629354 1.75293E+31 0.506892 8.55086E+30
59.2192 5.44405E+31 59.2192 5.44405E+31
D.dat
```

Fig. 5: Selected wavelengths we will be using.

```
59.219 4.4037e+31 59.2193 4.4037e+31
20.0708 1.63892e+31 20.0708 1.63892e+31
14.5927 6.1281e+30 14.0684 5.36803e+30
11.7531 2.20898e+30 11.3309 1.66267e+30
10.4864 5.7006e+29 10.4864 5.70057e+29
7.6242 3.56286e+29 7.3503 3.32534e+29
4.9458 4.27543e+29 4.7681 5.70057e+29
0.568125 1.30401e+31 0.547713 1.15437e+31
59.219 5.44405e+31 59.2193 5.44403e+31
F2.dat
```

Fig. 6: Averages and weighted averages.

And we will combine the two files, obtaining a file with both the averaged results and the weight averages:

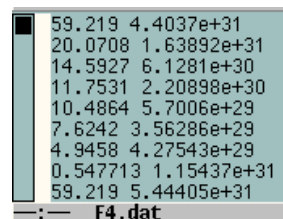
```
paste F.dat F1.dat | awk '{print $1, $2, $3, $4}' > F2.dat
```

As we will only want the weighted average, in the case of V, we change the order of the columns only in the lines that contain 0.547713 μm :

```
cat F2.dat | awk '{if ($3 ~ /0.547713/) {print $3, $4, $1, $2} if ($3 !~ /0.547713/) {print $0}}' > F3.dat
```

And we will finally remove the last two columns (see Fig. 7):

```
cat F3.dat | awk '{print $1, $2}' > F4.dat
#*****
```



59.219	4.4037e+31
20.0708	1.63892e+31
14.5927	6.1281e+30
11.7531	2.20898e+30
10.4864	5.7006e+29
7.6242	3.56286e+29
4.9458	4.27543e+29
0.547713	1.15437e+31
59.219	5.44405e+31

We copy the appropriate results to flux.dat, which will be used in the remaining 1T8loMM.com.

```
#cp F.dat flux.dat
cp F4.dat flux.dat
```

Fig. 7: Averages of all the wavelengths except 0.54..., which is the result of a weighted average.

Attention, from here onwards, in all the images where 0.506892 appears, it should read 0.547713 and its corresponding value.

(End of T8lo1.com)

(We go back to [1T8loMM.com](#))

For each model we have run T8lo1.com, we obtain a flux.dat which we copy to the corresponding file:

```
#Resultat de T8lo1.com li donem mateix nom pero amb "a" davant
#("ans" de sed3d8loMM.pro)

cp flux.dat "aflM"$ms"R"$rs"Rin"$ri"Md"$ma"SPT"$ta"00.dat"
#cp flux.dat "aflM"$ms"R"$rs"Rin"$ri"Md"$ma"SPT"$ta"00h"$ha".dat"
#cp flux.dat "aflM"$ms"R"$rs"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00h"$ha".dat"
#cp flux.dat "aflM"$ms"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00h"$ha".dat"
#cp flux.dat "aflM"$ms"R"$rs"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00.dat"

#I ac,o es el que enviarem a sed3d8loMM.pro :D

#*****
rm flux.dat
echo KONIEC*****

done
done
done
done
done
done
done
done
```

There will be one “done” per parameter that we have at the beginning of the program.

These new files “aflM*.dat” are the ones that will be used by [sed3d8loMM.pro](#) to produce the same files with (λ , f_i), but now with the total flux in the correct units ($\text{erg s}^{-1} \text{cm}^{-2}$).

(End of 1T8loMM.com)

```
IDL> .r sed3d8loMM ↵
```

(Within `sed3d8loMM.pro`)

We have added the following command lines in the `sed3d2red.pro` program written by Walker & Wood, to obtain the files `resM*.dat` with (λ, fi) , with the total flux in the correct units ($\text{erg s}^{-1} \text{cm}^{-2}$) for all the models being studied (see Fig. 8 and Fig. 9).

```

;-----
;Aco es meu: escriu en nou fitxer lambda,flux(erg/s/sqcm)
close,l
;openw,l,'resM120Rin2000Ra100Md'+ma(nma)+'SPT5750h08.dat'
openw,l,'resM120Rin'+ri(nri)+'Ra'+ra(nra)+'Md'+ma(nma)+'SPT5750h'+ha(nha)+' .dat'
;openw,l,'resM200R30Rin'+ri(nri)+'Ra'+ra(nra)+'Md'+ma(nma)+'SPT5000.dat'
;for k=0,nphi-1 do begin
  for j=0,nspec-1 do begin
    for i=0,nfreq-1 do begin
;lambda(i)=lam
printf,l,lambda(i),fluxil(i,j)
    endfor
  endfor
;endfor
close,l
;-----

```

59.2190	1.66274e-10
20.0708	7.31606e-11
14.5927	3.32547e-11
11.7531	1.33019e-11
10.4864	0.00000
7.62420	3.32547e-12
4.94580	6.65099e-12
0.506890	1.61856e-11
59.2190	2.06180e-10
20.0708	1.72925e-10

resM200R30Rin1500Md4SPT5000.dat

Fig. 8: `resM*.dat`

When working only with one model, `sed3d8lo1.pro` must be used instead, which has the same commands added and the resulting file is `res.dat`.

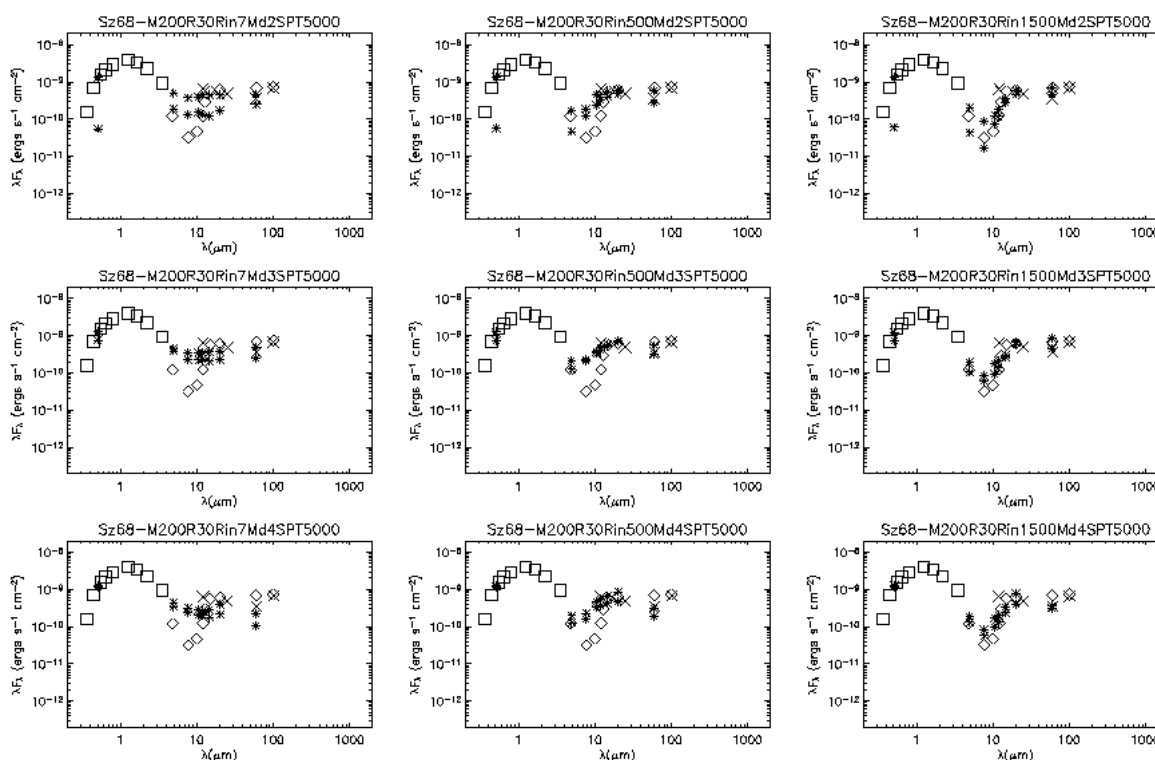


Fig. 9: Ps image with the results of `sed3d8loMM.pro`. Here we show only the models for angles 4 and 19 for the 8 wavelengths studied.

2T8loMM.com Name_of_star ↵

To run 2T8loMM.com, the name of the star we are looking the best model for must also be indicated.

As with 1T8loMM.com, we will start by introducing the different values for the parameters (which must match the ones in 1T8loMM.com and sed3d8loMM.pro). As it can be seen, the beginning is exactly the same as in 1T8loMM.com.

After the appropriate values have been introduced, we will have to uncomment the lines for the different commands that correspond to the names of the files (which depend on the parameters which will be varying).

The first command starting by “echo” displays the name of the models in the screen.

```
#!/bin/sh
#init
r=0
#loop through different
values:
for no in 10
do
for ri in 7 500 1500
do
for ms in 200
do
for rs in 30
do
for ta in 50
do
for ra in 300
do
for ha in 075
do
for ma in 2 3 4
do
for bt in 1.25
do
#for vt in 0
#do
#for lg in 35
#do
#display run numbers
r=`expr $r + 1`
```

```
*****
#Choose the appropriate file_names!!*****
*****
#echo "M"$ms"R"$rs"Rin"$ri"Md"$ma"SPT"$ta"00*****"
#echo "M"$ms"R"$rs"Rin"$ri"Md"$ma"SPT"$ta"00h"$ha"*****"
#echo "M"$ms"R"$rs"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00h"$ha"*****"
echo "M"$ms"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00h"$ha"*****"
#echo "M"$ms"R"$rs"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00*****"

#-----
#hola
echo "trobant millor model "$r
#hola2
```

We then copy each of the flux files from sed3d8loMM.pro corresponding to a combination of parameters to res.dat, which will be used in T8lo2.com. If uncommented, the files aflM*.dat used for sed3d8loMM.pro can be removed to reduce occupied space.

```
cp "resM"$ms"R"$rs"Rin"$ri"Md"$ma"SPT"$ta"00.dat" res.dat
#cp "resM"$ms"R"$rs"Rin"$ri"Md"$ma"SPT"$ta"00h"$ha".dat" res.dat
#cp "resM"$ms"R"$rs"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00h"$ha".dat" res.dat
#cp "resM"$ms"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00h"$ha".dat" res.dat
#cp "resM"$ms"R"$rs"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"00.dat" res.dat
```

```
#-----
#rm "aflM"$ms"Rin"$ri"Ra"$ra"Md"$ma"SPT"$ta"0h"$ha".dat"
```

```
#run code
```

And from within 2T8loMM.com, we run the subprogram T8lo2.com, which will need the name of the star (this is why we had to give the name of the star at the beginning of 2T8loMM.com. \$1 will be substituted automatically by the name given after 2T8loMM.com).

```
#Haurem comenc,at per cridar aquest programa fent T8lo2.com nom_estel, que
#es per 8 frequencias.

T8lo2.com $1
```

(Within **T8lo2.com**)

The program starts by removing the empty columns at the beginning of the res.dat files (see Fig. 8).

```
cat res.dat | awk '{print $1, $2}' > G.dat

#A res.dat tindrem la fotometria en les unitats correctes!!!! (erg/s/sqcm)
#Fem una copia a G.dat per llevar els espais en blanc al comenc,ament
#de cada fila.
```

Before running this program, a file called: Name_of_star_FTMM8.txt must have been created. In this file, we will have two columns ($\lambda, \lambda_{f\lambda}$) with the UBV/ISO/IRAS photometry for the 8 wavelengths we are going to use for comparison. These will be the experimental values we will be comparing the theoretical models with. The photometry in *_FTMM8.txt must be ordered from the longest wavelength to the shortest (see Fig. 10) and cannot contain any additional lines but the 8 wavelengths (the return must be under the last written line –black square in Fig. 10).

```
#Hem de fer un fitxer Star_FTMM8.txt amb la fotometria que anem a emprar per
#trobar el millor model, en ordre de MAJOR longitud d'ona a MENOR!!!!
#A aquest script se li ha d'indicar quin estel estem mirant!

cp $1_FTMM8.txt fotEXP.txt

cat fotEXP.txt > fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
cat fotEXP.txt >> fotEXP20.txt
```

60.00	6.91E-10
20.00	6.15E-10
15.00	5.62E-10
12.00	1.23E-10
10.00	4.69E-11
7.70	3.18E-11
4.80	1.21E-10
0.550	1.56E-09
	■

Fig. 10: Star_FTMM8.txt

The program will copy the file with the ISO&co fluxes to a new file called fotEXP.txt. The contents of this second file will be copied to a new file fotEXP20.txt (first cat command with only one “>”). The 19 following commands (with two “>”) will append the 8 wavelengths 19 times to the original set. This will result in a final

fotEXP20.txt file with the ISO&co photometry copied 20 times (2 columns x 160 lines).

Then, in H.dat, we will combine the photometry from the models (first two columns) with the observed photometry of the star (see Fig. 11) and we will subtract the two fluxes for each wavelength (Fig. 12).

```
#Ara fem fitxer amb la fotometria obtinguda dels models i l'experimental
paste G.dat fotEXP20.txt | awk '{print $1, $2, $3, $4}' > H.dat
#Trobem la diferència:
cat H.dat | awk '{print $2-$4}' > I.dat
```

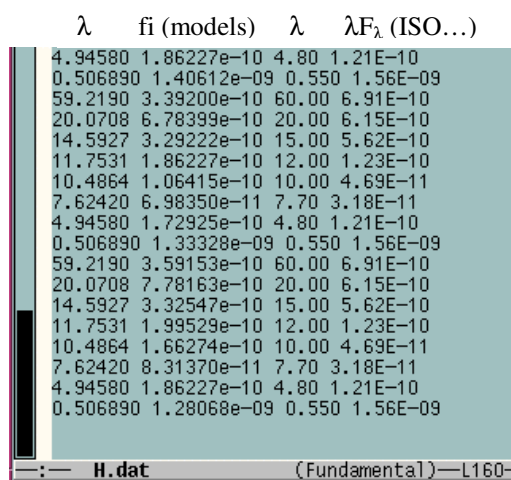


Fig. 11: Photometry from the models and the observations.

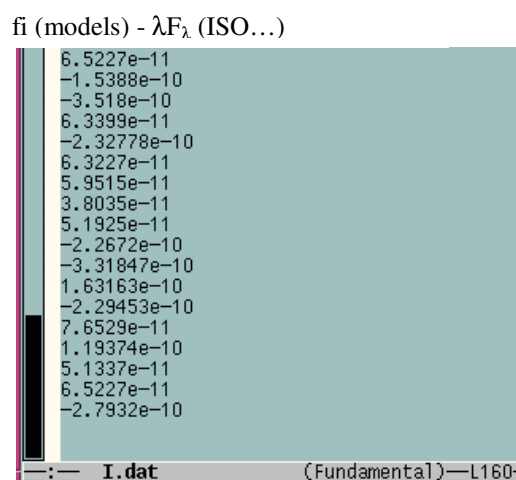


Fig. 12: Difference between the theoretical and the experimental photometry.

We will then obtain the absolute values of these differences by multiplying the numbers by themselves and then calculating the square root (see Fig. 13 and 14)

```
#Posem les sumes en valor absolut:
cat I.dat | awk '{print $1*$1}' > J.dat
cat J.dat | awk '{print sqrt($1)}' > K.dat
```

Once we have the differences we can calculate the relative errors. For this, we will first need a file with the differences, which we have in the 1st and only column of K.dat, and the observed photometry, which is the 4th column of H.dat (Fig. 15). Then we will divide the difference between the theoretical and the observed photometry by the observed photometry, obtaining the relative errors for each of the wavelengths (Fig. 16).

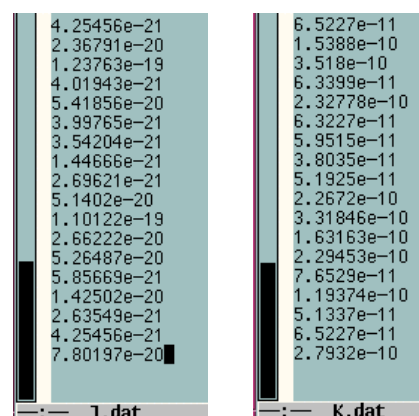


Fig. 13: (I.dat)²

Fig. 14: $\sqrt{I.dat}$ ²

```
#Troblem els errors relatius:
paste K.dat H.dat | awk '{print $1, $5}' > F2.dat
cat F2.dat | awk '{print $1/$2}' > F3.dat
```

We now need to order the results depending on the angle they belong to. For this, we will first put all 8 relative errors corresponding to one angle per row. The command we use pairs rows (as it is shown in Fig. 17, so we will have to use it three times. The first time, it will convert one column into two (compare Fig. 16 and 18). Then it will order the results in 4 columns (Fig. 19) and finally 8 (Fig. 20).

```
6.5227e-11 1.21E-10
1.5388e-10 1.56E-09
3.518e-10 6.91E-10
6.3399e-11 6.15E-10
2.32778e-10 5.62E-10
6.3227e-11 1.23E-10
5.9515e-11 4.69E-11
3.8035e-11 3.18E-11
5.1925e-11 1.21E-10
2.2672e-10 1.56E-09
3.31846e-10 6.91E-10
1.63163e-10 6.15E-10
2.29453e-10 5.62E-10
7.6529e-11 1.23E-10
1.19374e-10 4.69E-11
5.1337e-11 3.18E-11
6.5227e-11 1.21E-10
2.7932e-10 1.56E-09
```

Fig. 15: $(f_i - \lambda F_\lambda, \lambda F_\lambda)$

```
0.539066
0.098641
0.509117
0.103088
0.414196
0.514041
1.26898
1.19607
0.429132
0.145333
0.48024
0.265306
0.408279
0.622187
2.54529
1.61437
0.539066
0.179051
```

Fig. 16: (ϵ_r)

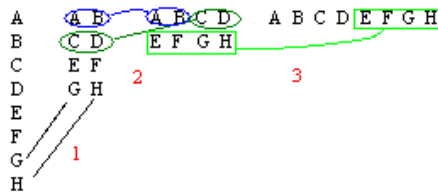


Fig. 17: `paste -s -d "\n\n" file1 > file2`

```
#Ordenem en files:
paste -s -d "\n\n" F3.dat > L.dat
paste -s -d "\n\n" L.dat > M.dat
paste -s -d "\n\n" M.dat > N.dat
```

L.dat will have 80 rows instead of the original 160 (8 wavelengths x 20 angles). M.dat will have 40 and, finally, N.dat, 20.

```
0.539066 0.098641
0.509117 0.103088
0.414196 0.514041
1.26898 1.19607
0.429132 0.145333
0.48024 0.265306
0.408279 0.622187
2.54529 1.61437
0.539066 0.179051
```

Fig. 18: File after using paste... once.

```
1.5526 1.40523 0.264231 0.15441
0.595745 0.0483154 0.591712 0.108496
1.69441 0.986912 0.401653 0.219256
0.48987 0.0158748 0.431947 0.64922
2.40348 1.40523 0.539066 0.098641
0.509117 0.103088 0.414196 0.514041
1.26898 1.19607 0.429132 0.145333
0.48024 0.265306 0.408279 0.622187
2.54529 1.61437 0.539066 0.179051
```

Fig. 19: File after using paste... a second time.

```
0.518747 0.232857 0.479283 0.351821 1.5526 1.40523 0.264231 0.15441
0.595745 0.0483154 0.591712 0.108496 1.69441 0.986912 0.401653 0.219256
0.48987 0.0158748 0.431947 0.64922 2.40348 1.40523 0.539066 0.098641
0.509117 0.103088 0.414196 0.514041 1.26898 1.19607 0.429132 0.145333
0.48024 0.265306 0.408279 0.622187 2.54529 1.61437 0.539066 0.179051
```

Fig. 20: File after using paste... a third time.

Once we have the file with 20 rows (one per angle) with the relative errors for the 8 wavelengths (from the longer to the shortest wavelength), we number each line of the file. By starting from 0 (instead of the default, 1) the numbers will match the angles of inclination of the disk (see Fig. 21).

```
#Numerem els models:
cat N.dat | awk '{print "#"NR-1 " ": " $0}' > O.dat
```

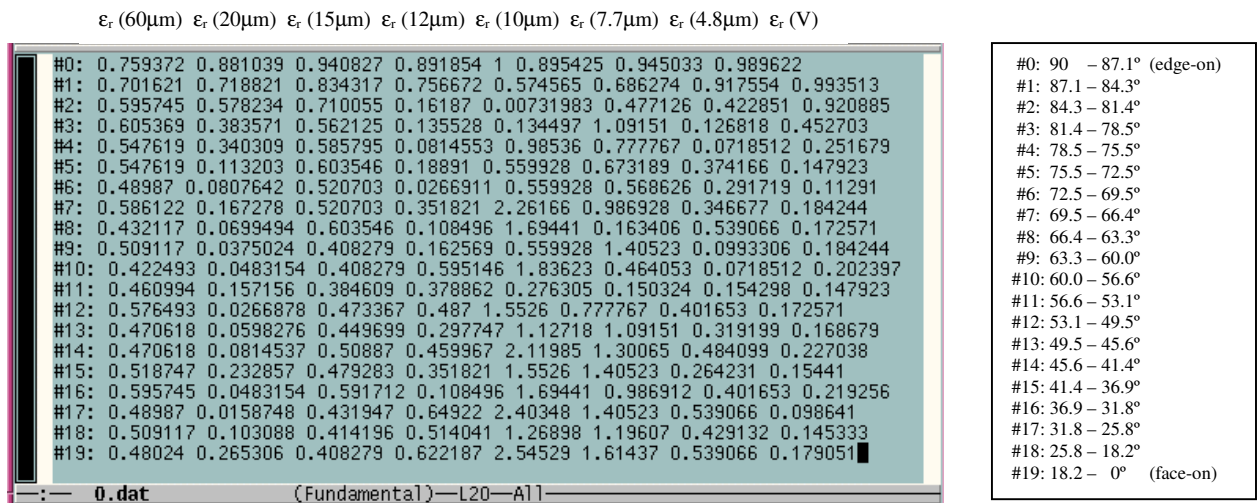


Fig. 21: Relative errors for each model

We then have to add the relative errors of the wavelengths we want to take into account for each model. We are not going to include ϵ_r (V), nor ϵ_r (I) if also present, because we are just comparing those models that fit “perfectly” the black body representing the star’s photosphere. We will not be discarding the models that do not fit V until back in 2T8loMM.com.

Hence, we will first add the relative errors (columns 2 to 8, in the general case):

```

#*****
#Addition of the relative errors of the wavelengths we want to be considered:
#*****

#Troblem la suma total per cada model i la posem com a darrera columna:*****

#cat O.dat | awk '{print $2+$3+$4+$5+$6+$7+$8+$9}' > P.dat

#Per no inclure el valor de l'error relatiu de V en la suma d'errors:*****

cat O.dat | awk '{print $2+$3+$4+$5+$6+$7+$8}' > P.dat

#Per no inclure el valor de l'error relatiu de I ni V en la suma d'errors:**

#cat O.dat | awk '{print $2+$3+$4+$5+$6+$7}' > P.dat

# NB.A la columna $1 hi ha l'angle corresponent a cada model.
#*****

```

And we will paste the sum of the relative errors in the last column (Fig. 22):

```
paste O.dat P.dat | awk '{print $1, $2, $3, $4, $5, $6, $7, $8, $9, $10 }' > Q.dat
```

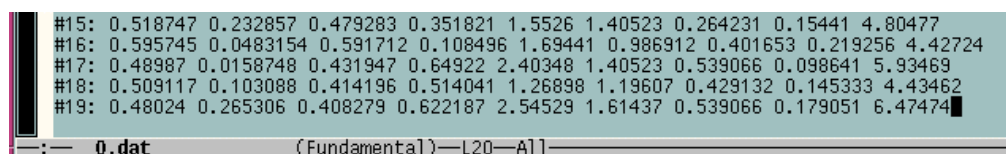


Fig. 22: Relative errors and sum of them.

Finally, we reorder the columns so we'll have the results from the shortest wavelength to the longest and we sort the models from the smallest sum of relative errors to the largest (see Fig. 23). We will send the resulting file back to 2T8loMM.com with the name: star_MM8.dat.

```
#Troblem el millor model (aquell amb la suma mes menuda) i posem les sumes
#en ordre de longitud d'ona mes MENUDA a mes GRAN:

cat Q.dat | awk '{print $10, $9, $8, $7, $6, $5, $4, $3, $2, $1}' > R.dat
sort <R.dat> S.dat -n

cp S.dat $1_MM8.dat
```

$\Sigma \epsilon_r$	$\epsilon_r(V)$	$\epsilon_r(4.8\mu\text{m})$	$\epsilon_r(7.7\mu\text{m})$	$\epsilon_r(10\mu\text{m})$	$\epsilon_r(12\mu\text{m})$	$\epsilon_r(15\mu\text{m})$	$\epsilon_r(20\mu\text{m})$	$\epsilon_r(60\mu\text{m})$	α
1.96255	0.147923	0.154298	0.150324	0.276305	0.378862	0.384609	0.157156	0.460994	#11:
2.5383	0.11291	0.291719	0.568626	0.559928	0.0266911	0.520703	0.0807642	0.48987	#6:
2.9532	0.920885	0.422851	0.477126	0.00731983	0.16187	0.710055	0.578234	0.595745	#2:
3.03942	0.452703	0.126818	1.09151	0.134497	0.135528	0.562125	0.383571	0.605369	#3:
3.06056	0.147923	0.374166	0.673189	0.559928	0.18891	0.603546	0.113203	0.547619	#5:
3.18196	0.184244	0.0993306	1.40523	0.559928	0.162569	0.408279	0.0375024	0.509117	#9:
3.39016	0.251679	0.0718512	0.777767	0.98536	0.0814553	0.585795	0.340309	0.547619	#4:
3.61099	0.172571	0.539066	0.163406	1.69441	0.108496	0.603546	0.0699494	0.432117	#8:
3.81578	0.168679	0.319199	1.09151	1.12718	0.297747	0.449699	0.0598276	0.470618	#13:
3.84637	0.202397	0.0718512	0.464053	1.83623	0.595146	0.408279	0.0483154	0.422493	#10:
4.29557	0.172571	0.401653	0.777767	1.5526	0.487	0.473367	0.0266878	0.576493	#12:
4.42724	0.219256	0.401653	0.986912	1.69441	0.108496	0.591712	0.0483154	0.595745	#16:
4.43462	0.145333	0.429132	1.19607	1.26898	0.514041	0.414196	0.103088	0.509117	#18:
4.80477	0.15441	0.264231	1.40523	1.5526	0.351821	0.479283	0.232857	0.518747	#15:
5.18982	0.993513	0.917554	0.686274	0.574565	0.756672	0.834317	0.718821	0.701621	#1:
5.22119	0.184244	0.346677	0.986928	2.26166	0.351821	0.520703	0.167278	0.586122	#7:
5.42551	0.227038	0.484099	1.30065	2.11985	0.459967	0.50887	0.0814537	0.470618	#14:
5.93469	0.098641	0.539066	1.40523	2.40348	0.64922	0.431947	0.0158748	0.48987	#17:
6.31355	0.989622	0.945033	0.895425	1	0.891854	0.940827	0.881039	0.759372	#0:
6.47474	0.179051	0.539066	1.61437	2.54529	0.622187	0.408279	0.265306	0.48024	#19:

Fig. 23: File, result of T8lo2.com, with the 20 models for a given combination of parameters, ordered from the lowest relative error to the greatest.

If the program T8lo2.com is used for only one model, the removal of the models with relative error of $V > 0.3$ must be done now. Hence, the following command must be uncommented:

```
#cat S.dat | awk '$2<0.3 {print $0}' > T.dat
```

And the best models will then be found in T.dat.

(End of T8lo2.com)

(We go back to [2T8loMM.com](#))

Back in 2T8loMM.com, we will copy the each result from T8lo2.com to a file named with the appropriate parameters of the each model. Hence, we will have as many files as combination of parameters we are studying, with the relative errors for the 20 different angles in each file.

```
#Angle que dona millor model pel cas estudiat, resultat de T8lo2.com

cp $1_MM8.dat "MM_M"$ms"$R"$rs"$Rin"$ri"$Md"$ma"$SPT"$sta"00.dat"
#cp $1_MM8.dat "MM_M"$ms"$R"$rs"$Rin"$ri"$Md"$ma"$SPT"$sta"00h"$ha".dat"
#cp $1_MM8.dat "MM_M"$ms"$R"$rs"$Rin"$ri"$Ra"$ra"$Md"$ma"$SPT"$sta"00h"$ha".dat"
#cp $1_MM8.dat "MM_M"$ms"$Rin"$ri"$Ra"$ra"$Md"$ma"$SPT"$sta"00h"$ha".dat"
#cp $1_MM8.dat "MM_M"$ms"$R"$rs"$Rin"$ri"$Ra"$ra"$Md"$ma"$SPT"$sta"00.dat"

#-----
rm res.dat
rm $1_MM8.dat
```

To be able to compare the results for different angles with all the other models, we need to make sure each line within what was S.dat (Fig. 23) has, besides the angle, already included, the corresponding combination of parameters. For this, we will create a file with all the file names (i.e. combination of parameters), copied 20 times (one per angle), and a file with all the results for all the combination of parameters and angles, in the same order as the names. To do this, as we will be appending the lines, we will need to make sure that before running this program, no files named `totsnoms_$.txt` (all the names, see Fig. 24) and `totsvalors_$.dat` (all the values, see Fig. 25) exist (`$` stands for the star being studied). Unless the lines are commented, these two files will be automatically removed at the end of the program.

The option of only keeping the best model (angle) for each combination of parameters also exists (lines with `noms_$.txt` and `valors_$.dat`) but it will not give the best model altogether as other angles, “worse” than the best model in a combination of parameters, might be better than the best angle for another combination of parameters. This option has been left in the program for illustrative purposes, but the search of the best model must comprehend the comparison of all the angles of all the models.

The following commands will create the file with all the names² (veg is the number of times we want the echo command to be repeated). The appropriate line with the name matching the name of the files must be uncommented:

```
*****ATTENTION*****ATENCIO*****UWAGA*****
#Atencio: abans d'utilitzar aquest programa, no hauria d'haver cap
#file amb el nom "totsnoms_$.txt"!!!! (20 vegades el nom)
*****

#echo "M"$ms"$Rin"$ri"$Ra"$ra"$Md"$ma"$SPT"$ta"0h"$ha" " >> noms_$.txt

#Opcio mes neta a la vista, tot i que encara podria estar millor:

for veg in 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
do

#echo $veg

echo "M"$ms"$R"$rs"$Rin"$ri"$Md"$ma"$SPT"$ta"00" >> totsnoms_$.txt
#echo "M"$ms"$R"$rs"$Rin"$ri"$Md"$ma"$SPT"$ta"00h"$ha" " >> totsnoms_$.txt
#echo "M"$ms"$R"$rs"$Rin"$ri"$Ra"$ra"$Md"$ma"$SPT"$ta"00h"$ha" " >> totsnoms_$.txt
#echo "M"$ms"$Rin"$ri"$Ra"$ra"$Md"$ma"$SPT"$ta"00h"$ha" " >> totsnoms_$.txt
#echo "M"$ms"$R"$rs"$Rin"$ri"$Ra"$ra"$Md"$ma"$SPT"$ta"00" >> totsnoms_$.txt

done
```

And the next ones will produce the file with all the results from T8lo2.com. Once again, the line with the correct name must be uncommented:

² After these commands, in the program we also have:

```
#Opcio obsoleta s'obte de copiar 20 vegades el seguent,
#echo "M"$ms"$Rin"$ri"$Ra"$ra"$Md"$ma"$SPT"$ta"0h"$ha" " >> totsnoms_$.txt
```

This is an obsolete way to produce the file with the names copied 20 times. It requires copying the line starting by “echo”, 20 times. This means that for each combination of parameters, which gave rise to a different type of name (e.g. `M#R#...dat`, `M#Ra#...dat`) we would need to copy again the 20 lines.

This last command will sort the models according to their sum of relative errors (-n indicates they are numbers).

```

5.6358 0.990923 0.917554 0.895425 0.716377 0.783707 0.863904 0.805338 0.653496 #2: M200R30Rin1500Md3SPT5000
6.07346 0.252974 0.484099 2.24182 1.97804 0.568114 0.378692 0.286933 0.135764 #14: M200R30Rin1500Md3SPT5000
6.51258 0.201096 0.594033 1.61437 2.82891 0.730333 0.461534 0.0706407 0.212764 #19: M200R30Rin1500Md3SPT5000
6.61294 0.994814 1 1 0.85819 0.945927 0.994084 0.978371 0.836373 #1: M200R30Rin1500Md3SPT5000
6.69549 0.994814 0.972521 0.895425 1 0.972967 0.994084 0.956741 0.90375 #0: M200R30Rin1500Md3SPT5000
1.96255 0.147923 0.154298 0.150324 0.276305 0.378862 0.384609 0.157156 0.460994 #11: M200R30Rin1500Md4SPT5000
2.5383 0.11291 0.291719 0.568626 0.559928 0.0266911 0.520703 0.0807642 0.48987 #6: M200R30Rin1500Md4SPT5000
2.9532 0.920885 0.422851 0.477126 0.00731983 0.16187 0.710055 0.578234 0.595745 #2: M200R30Rin1500Md4SPT5000
3.03942 0.452703 0.126818 1.09151 0.134497 0.135528 0.562125 0.383571 0.605369 #3: M200R30Rin1500Md4SPT5000
3.06056 0.147923 0.374166 0.673189 0.559928 0.18891 0.603546 0.113203 0.547619 #5: M200R30Rin1500Md4SPT5000
3.18196 0.184244 0.0993306 1.40523 0.559928 0.162569 0.408279 0.0375024 0.509117 #9: M200R30Rin1500Md4SPT5000
3.39016 0.251679 0.0718512 0.777767 0.98536 0.0814553 0.585795 0.340309 0.547619 #4: M200R30Rin1500Md4SPT5000
3.61099 0.172571 0.539066 0.163406 1.69441 0.108496 0.603546 0.0699494 0.432117 #8: M200R30Rin1500Md4SPT5000
3.81578 0.168679 0.319199 1.09151 1.12718 0.297747 0.449699 0.0598276 0.470618 #13: M200R30Rin1500Md4SPT5000
3.84637 0.202397 0.0718512 0.464053 1.83623 0.595146 0.408279 0.0483154 0.422493 #10: M200R30Rin1500Md4SPT5000
4.29557 0.172571 0.401653 0.777767 1.5526 0.487 0.473367 0.0266878 0.576493 #12: M200R30Rin1500Md4SPT5000
4.42724 0.219256 0.401653 0.986912 1.69441 0.108496 0.591712 0.0483154 0.595745 #16: M200R30Rin1500Md4SPT5000
4.43462 0.145333 0.429132 1.19607 1.26898 0.514041 0.414196 0.103088 0.509117 #18: M200R30Rin1500Md4SPT5000
4.80477 0.15441 0.264231 1.40523 1.5526 0.351821 0.479283 0.232857 0.518747 #15: M200R30Rin1500Md4SPT5000
5.18982 0.993513 0.917554 0.686274 0.574565 0.756672 0.834317 0.718821 0.701621 #1: M200R30Rin1500Md4SPT5000
5.22119 0.184244 0.346677 0.986928 2.26166 0.351821 0.520703 0.167278 0.586122 #7: M200R30Rin1500Md4SPT5000
5.42551 0.227038 0.484099 1.30065 2.11985 0.459967 0.50887 0.0814537 0.470618 #14: M200R30Rin1500Md4SPT5000
5.93469 0.098641 0.539066 1.40523 2.40348 0.64922 0.431947 0.0158748 0.48987 #17: M200R30Rin1500Md4SPT5000
6.31355 0.989622 0.945033 0.895425 1 0.891854 0.940827 0.881039 0.759372 #0: M200R30Rin1500Md4SPT5000
6.47474 0.179051 0.539066 1.61437 2.54529 0.622187 0.408279 0.265306 0.48024 #19: M200R30Rin1500Md4SPT5000

```

Fig. 26: Every model with its relative errors.

We are then going to remove the models with a relative error of V larger than 0.3, as these will not fit the black body of the star. For this, we will first rearrange the columns so the first column will have the relative errors of V .

```

#*****
# Sols vaig a tenir en compte els models amb l'error relatiu de  $V < 0.3$ :
# The rest will not fit the black body representing the star.
#*****

# Posem la columna amb l'error relatiu de  $V$  primer per poder veure'l millor.

cat BestModels8lo_$1.dat | awk '{print $2, $1, $3, $4, $5, $6, $7, $8, $9, $10, $11}'
> mes1.dat

cat mes1.dat | awk '$1<0.3 {print $0}' > mes2.dat

cat mes1.dat | awk '$1>0.3 {print $0}' > mes3.dat

```

In mes2.dat we will have only the models with $\epsilon_r(V) < 0.3$, which are the ones of interest for us. In mes3.dat we will have the models with $\epsilon_r(V) > 0.3$, not necessary but interesting in case of wanting to check the results. We will then rearrange the columns of mes2.dat, to have the sum of the relative errors back in the first column³.

```

#*****
# Tornem a posar les columnes tal que:
# $1: suma dels errors relatius (sols dels fluxos d'ISO/IRAS)
# $2 - $9: errors relatius de la lo menor a major ( $V$  a 25/60 segons el cas)
# $10: # angle
# $11: model
#*****

```

³ The rearrangement of the columns back and forth can actually be avoided by using

```
cat BestModels8lo_$1.dat | awk '$2<0.3 {print $0}' > BM8lo_$1.dat
```

Which will remove the models with $\epsilon_r(V) < 0.3$, directly (in BestModels8lo_\$1.dat, the relative error of V is in column 2).

```

cat mes2.dat | awk '{print $2, $1, $3, $4, $5, $6, $7, $8, $9, $10, $11}' >
BM8lo_$1.dat

emacs BM8lo_$1.dat &

rm mes1.dat
rm mes2.dat
#-----
#rm noms_$1.txt
#rm valors_$1.dat
rm totsnums_$1.txt
rm totsvalars_$1.dat

```

This program ends here by producing the file **BM8lo_\$1.dat** with the models ordered as to give the best fit to the experimental data (see Fig. 27).

$\Sigma \epsilon_r$	ϵ_r (V)	ϵ_r (4.8 μm)	ϵ_r (7.7 μm)	ϵ_r (10 μm)	ϵ_r (12 μm)	ϵ_r (15 μm)	ϵ_r (20 μm)	ϵ_r (60 μm)	α	combination of parameters
1.96255	0.147923	0.154298	0.150324	0.276305	0.378862	0.384609	0.157156	0.460994	#11:	M200R30Rin1500Md4SPT5000
2.5383	0.11291	0.291719	0.568626	0.559928	0.0266911	0.520703	0.0807642	0.48987	#6:	M200R30Rin1500Md4SPT5000
3.05875	0.127179	0.401653	0.254896	1.26898	0.568114	0.331354	0.0807642	0.152987	#6:	M200R30Rin1500Md3SPT5000
3.06056	0.147923	0.374166	0.673189	0.559928	0.18891	0.603546	0.113203	0.547619	#5:	M200R30Rin1500Md4SPT5000
3.18196	0.184244	0.0993306	1.40523	0.559928	0.162569	0.408279	0.0375024	0.509117	#9:	M200R30Rin1500Md4SPT5000
3.39016	0.251679	0.0718512	0.777767	0.98536	0.0814553	0.585795	0.340309	0.547619	#4:	M200R30Rin1500Md4SPT5000
3.61099	0.172571	0.539066	0.163406	1.69441	0.108496	0.603546	0.0699494	0.432117	#8:	M200R30Rin1500Md4SPT5000
3.68663	0.153115	0.264231	0.986928	1.12718	0.595146	0.301767	0.027387	0.383994	#5:	M200R30Rin1500Md3SPT5000
3.7472	0.134962	0.126818	0.163406	2.11985	0.784407	0.366859	0.146343	0.0395166	#11:	M200R30Rin1500Md3SPT5000
3.81578	0.168679	0.319199	1.09151	1.12718	0.297747	0.449699	0.0598276	0.470618	#13:	M200R30Rin1500Md4SPT5000
3.84637	0.202397	0.0718512	0.464053	1.83623	0.595146	0.408279	0.0483154	0.422493	#10:	M200R30Rin1500Md4SPT5000
4.09103	0.180353	0.401653	0.673189	1.69441	0.784407	0.307685	0.0382	0.191491	#12:	M200R30Rin1500Md3SPT5000
4.15406	0.189429	0.0443719	0.359475	2.40348	0.730333	0.313601	0.265306	0.0374906	#10:	M200R30Rin1500Md3SPT5000
4.29557	0.172571	0.401653	0.777767	1.5526	0.487	0.473367	0.0266878	0.576493	#12:	M200R30Rin1500Md4SPT5000
4.41763	0.150519	0.401653	1.61437	1.41079	0.487	0.349105	0.0382	0.116517	#18:	M200R30Rin1500Md2SPT5000
4.42724	0.219256	0.401653	0.986912	1.69441	0.108496	0.591712	0.0483154	0.595745	#16:	M200R30Rin1500Md4SPT5000
4.43462	0.145333	0.429132	1.19607	1.26898	0.514041	0.414196	0.103088	0.509117	#18:	M200R30Rin1500Md4SPT5000
4.46661	0.153115	0.181785	1.40523	1.83623	0.297747	0.414196	0.157156	0.174268	#15:	M200R30Rin1500Md3SPT5000
4.53555	0.127179	0.181785	0.254896	1.83623	1.24402	0.0946601	0.64382	0.28014	#11:	M200R30Rin1500Md2SPT5000
4.53572	0.153115	0.319199	1.61437	1.41079	0.32478	0.479283	0.145652	0.241644	#18:	M200R30Rin1500Md3SPT5000

Fig. 27: Best Model for the star studied.

All the programs will remove the intermediate files, unless the corresponding commands are commented.

End of program to find best model for 8 wavelengths.

The program in case of having only 4 wavelengths is basically the same. Slight variations take into account having only half of the number of wavelengths. Furthermore, TMM2.com will need *_FTMM4.txt with the 4 photometric values to compare the models with, also ordered from the longest wavelength to the shortest, and the final results will be found in BM4lo_\$1.dat.

anemaveure.com Best_Models_file.dat ↵

With this script we find which combinations of parameters appear more often among the best 30 models obtained, which can be found in BM8lo_\$.dat, BM4lo_\$.dat, BestModels8lo_\$.dat or T.dat. This additional script does not belong to the program for finding the best model but helps to see the results obtained from FBM better.

We first obtain a file with only the first (best) 30 models.

```
cat $1 | awk 'NR<31{print $0}' > AAV1.dat
```

And we number them (the number will appear at the end of each line, as shown in Fig. 28).

```
cat AAV1.dat | awk '{print $0, NR}' > AAV2.dat
```

```
2.06591 0.0991005 0.478249 0.78144 0.806217 #10: M70Rin300Ra100Md2SPT4000h13 1
2.07024 0.0311323 0.475803 0.784267 0.810174 #9: M70Rin300Ra100Md2SPT4000h13 2
2.08671 0.0772751 0.490467 0.790257 0.805989 #11: M70Rin300Ra100Md2SPT4000h13 3
2.10584 0.0750476 0.513274 0.781937 0.810626 #12: M70Rin300Ra100Md2SPT4000h13 4
2.11058 0.0768571 0.511646 0.788759 0.810174 #13: M70Rin300Ra100Md2SPT4000h13 5
2.11142 0.0792222 0.508387 0.790257 0.812776 #10: M70Rin300Ra200Md2SPT4000h13 6
2.1132 0.096873 0.503908 0.790754 0.818541 #11: M70Rin300Ra200Md2SPT4000h13 7
2.13062 0.0870053 0.524272 0.788262 0.818089 #9: M70Rin300Ra200Md2SPT4000h13 8
2.13243 0.107439 0.517349 0.792586 0.822498 #12: M70Rin300Ra200Md2SPT4000h13 9
2.13622 0.0640741 0.522644 0.791419 0.822157 #10: M70Rin300Ra300Md2SPT4000h13 10
2.1455 0.0408624 0.534862 0.803063 0.807573 #14: M70Rin300Ra100Md2SPT4000h13 11
2.1479 0.0961746 0.523864 0.800403 0.82363 #12: M70Rin300Ra300Md2SPT4000h13 12
2.14966 0.0885344 0.536492 0.798241 0.814922 #11: M70Rin300Ra300Md2SPT4000h13 13
2.15178 0.0692116 0.390677 0.867602 0.893498 #14: M70Rin7Ra100Md2SPT4000h13 14
2.15382 0.0682434 0.533638 0.812377 0.807801 #14: M70Rin300Ra200Md2SPT4000h13 15
2.15437 0.0574021 0.545859 0.802063 0.806445 #15: M70Rin300Ra100Md2SPT4000h13 16
2.16158 0.082418 0.3976 0.864607 0.899377 #16: M70Rin7Ra100Md2SPT4000h13 17
2.16277 0.0797778 0.409821 0.861942 0.891011 #15: M70Rin7Ra100Md2SPT4000h13 18
2.16941 0.174285 0.536897 0.80323 0.829281 #9: M70Rin300Ra300Md2SPT4000h13 19
2.1711 0.0839471 0.549118 0.800733 0.821253 #13: M70Rin300Ra200Md2SPT4000h13 20
2.17839 0.0831164 0.543008 0.818534 0.816847 #14: M70Rin300Ra300Md2SPT4000h13 21
2.18082 0.0840847 0.414708 0.871592 0.894516 #17: M70Rin7Ra100Md2SPT4000h13 22
2.18161 0.0936772 0.413487 0.869764 0.898359 #15: M70Rin7Ra200Md2SPT4000h13 23
2.18308 0.0840847 0.405749 0.876251 0.901075 #14: M70Rin7Ra200Md2SPT4000h13 24
2.18589 0.104656 0.55441 0.80356 0.827925 # 13: M70Rin300Ra300Md2SPT4000h13 25
2.18591 0.118413 0.402082 0.878576 0.905256 #13: M70Rin7Ra200Md2SPT4000h13 26
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2.18944 0.114106 0.398826 0.878911 0.911701 #13: M70Rin7Ra300Md2SPT4000h13 28
2.19149 0.10855 0.416744 0.874916 0.899829 #13: M70Rin7Ra100Md2SPT4000h13 29
2.19742 0.128836 0.415523 0.873921 0.907972 #11: M70Rin7Ra100Md2SPT4000h13 30
```

Fig. 28: Best 30 models obtained by 1T4loMM.com and 2T4loMM.com for CoKu Ser G7.

Then we must indicate all the possible values of the parameters that appear indicated in the names of the files of the models.

```
*****
for ri in 200 300 400
do
for ms in 70
do
for rs in 16 21
do
for ta in 40
do
for ra in 100 200 300
do
for ha in 13
do
for ma in 2 3 4
do
```

Depending on whether we have compared the models with 4 or 8 wavelengths, the commands to be uncommented will be from the set of commands for 4 wavelengths or 8, indicated before the actual commands in the script. Within the appropriate set of commands, the actual lines to be uncommented will depend on the names of the files. One line per “paragraph” will have to be uncommented (none if the commands are in the set of commands corresponding to the number of wavelengths not being used).

```
***** Attention: *****
# Depending on the names of the files and the number wavelengths (4 or 8),
# the appropriate lines in each paragraph must be uncommented!!
*****
```

Within the following set of commands, we are first putting together all the models with the same combination of parameters (AAV5.dat) and then showing the original order of the models in the same file with the results in AAV5.dat (AAV6.dat).

```
# When using FBM4 uncomment from: *****

#cat AAV2.dat | awk '$7 ~ /M'$ms'$rin'$ri'$ra'$ra'$md'$ma'$spt'$ta'$00h'$ha/' {print $6,
$7, $8}' >> AAV5.dat
cat AAV2.dat | awk '$7 ~ /M'$ms'$rs'$rin'$ri'$ra'$ra'$md'$ma'$spt'$ta'$00h'$ha/' {print
$6, $7, $8}' >> AAV5.dat

paste AAV2.dat AAV5.dat | awk '{print $6, $7, $8 " | " $9, $10, $11}' > AAV6.dat

*****
```

The resulting AAV6.dat can be seen in Fig. 29:

```
#10: M70Rin300Ra100Md2SPT4000h13 1 | #14: M70Rin7Ra100Md2SPT4000h13 14
#9: M70Rin300Ra100Md2SPT4000h13 2 | #16: M70Rin7Ra100Md2SPT4000h13 17
#11: M70Rin300Ra100Md2SPT4000h13 3 | #15: M70Rin7Ra100Md2SPT4000h13 18
#12: M70Rin300Ra100Md2SPT4000h13 4 | #17: M70Rin7Ra100Md2SPT4000h13 22
#13: M70Rin300Ra100Md2SPT4000h13 5 | #13: M70Rin7Ra100Md2SPT4000h13 29
#10: M70Rin300Ra200Md2SPT4000h13 6 | #11: M70Rin7Ra100Md2SPT4000h13 30
#11: M70Rin300Ra200Md2SPT4000h13 7 | #15: M70Rin7Ra200Md2SPT4000h13 23
#9: M70Rin300Ra200Md2SPT4000h13 8 | #14: M70Rin7Ra200Md2SPT4000h13 24
#12: M70Rin300Ra200Md2SPT4000h13 9 | #13: M70Rin7Ra200Md2SPT4000h13 26
#10: M70Rin300Ra300Md2SPT4000h13 10 | #16: M70Rin7Ra200Md2SPT4000h13 27
#14: M70Rin300Ra100Md2SPT4000h13 11 | #13: M70Rin7Ra300Md2SPT4000h13 28
#12: M70Rin300Ra300Md2SPT4000h13 12 | #10: M70Rin300Ra100Md2SPT4000h13 1
#11: M70Rin300Ra300Md2SPT4000h13 13 | #9: M70Rin300Ra100Md2SPT4000h13 2
#14: M70Rin7Ra100Md2SPT4000h13 14 | #11: M70Rin300Ra100Md2SPT4000h13 3
#14: M70Rin300Ra200Md2SPT4000h13 15 | #12: M70Rin300Ra100Md2SPT4000h13 4
#15: M70Rin300Ra100Md2SPT4000h13 16 | #13: M70Rin300Ra100Md2SPT4000h13 5
#16: M70Rin7Ra100Md2SPT4000h13 17 | #14: M70Rin300Ra100Md2SPT4000h13 11
#15: M70Rin7Ra100Md2SPT4000h13 18 | #15: M70Rin300Ra100Md2SPT4000h13 16
#9: M70Rin300Ra300Md2SPT4000h13 19 | #10: M70Rin300Ra200Md2SPT4000h13 6
#13: M70Rin300Ra200Md2SPT4000h13 20 | #11: M70Rin300Ra200Md2SPT4000h13 7
#14: M70Rin300Ra300Md2SPT4000h13 21 | #9: M70Rin300Ra200Md2SPT4000h13 8
#17: M70Rin7Ra100Md2SPT4000h13 22 | #12: M70Rin300Ra200Md2SPT4000h13 9
#15: M70Rin7Ra200Md2SPT4000h13 23 | #14: M70Rin300Ra200Md2SPT4000h13 15
#14: M70Rin7Ra200Md2SPT4000h13 24 | #13: M70Rin300Ra200Md2SPT4000h13 20
#13: M70Rin300Ra300Md2SPT4000h13 25 | #10: M70Rin300Ra300Md2SPT4000h13 10
#13: M70Rin7Ra200Md2SPT4000h13 26 | #12: M70Rin300Ra300Md2SPT4000h13 12
#16: M70Rin7Ra200Md2SPT4000h13 27 | #11: M70Rin300Ra300Md2SPT4000h13 13
#13: M70Rin7Ra300Md2SPT4000h13 28 | #9: M70Rin300Ra300Md2SPT4000h13 19
#13: M70Rin7Ra100Md2SPT4000h13 29 | #14: M70Rin300Ra300Md2SPT4000h13 21
#11: M70Rin7Ra100Md2SPT4000h13 30 | #13: M70Rin300Ra300Md2SPT4000h13 25
```

Fig. 29: AAV2 | AAV5. The first three columns are the original order of the models and the other three have the models grouped according to the combination of parameters.

The same commands if 8 wavelengths have been used, can be found in the next set of commands:

```
# When using FBM8 uncomment from: *****

#cat AAV2.dat | awk '$11 ~ /M'$ms'Rin'$ri'Ra'$ra'Md'$ma'SPT'$ta'00h'$ha'/ {print $10, $11, $12}' >> AAV5.dat
#cat AAV2.dat | awk '$11 ~ /M'$ms'R'$rs'Rin'$ri'Ra'$ra'Md'$ma'SPT'$ta'00h'$ha'/ {print $10, $11, $12}' >> AAV5.dat

#paste AAV2.dat AAV5.dat | awk '{print $10, $11, $12 " | " $13, $14, $15}' > AAV6.dat

#*****
```

For each combination of parameters, we then add the position of all its models (combination of parameters plus angle number) by adding to each position, the positions in the previous lines, which belong to the same combination of parameters.

```
#cat AAV5.dat | awk '$2 ~ /M'$ms'Rin'$ri'Ra'$ra'Md'$ma'SPT'$ta'00h'$ha'/ {print s +=$3}' >> AAV7.dat
cat AAV5.dat | awk '$2 ~ /M'$ms'R'$rs'Rin'$ri'Ra'$ra'Md'$ma'SPT'$ta'00h'$ha'/ {print s +=$3}' >> AAV7.dat
```

And we create a file that will have models with their position within the best 30 models, and the sum of the positions for each combination of parameters.

```
paste AAV5.dat AAV7.dat | awk '{print $1, $2, $3, $4}' > AAV8.dat
```

We also number the models for each combination of parameters.

```
#cat AAV8.dat | awk '$2 ~ /M'$ms'Rin'$ri'Ra'$ra'Md'$ma'SPT'$ta'00h'$ha'/ {print $0, s +=1}' >> AAV9.dat
cat AAV8.dat | awk '$2 ~ /M'$ms'R'$rs'Rin'$ri'Ra'$ra'Md'$ma'SPT'$ta'00h'$ha'/ {print $0, s +=1}' >> AAV9.dat
```

The result of AAV7, AAV8 and AAV9 can be seen in Fig. 30:

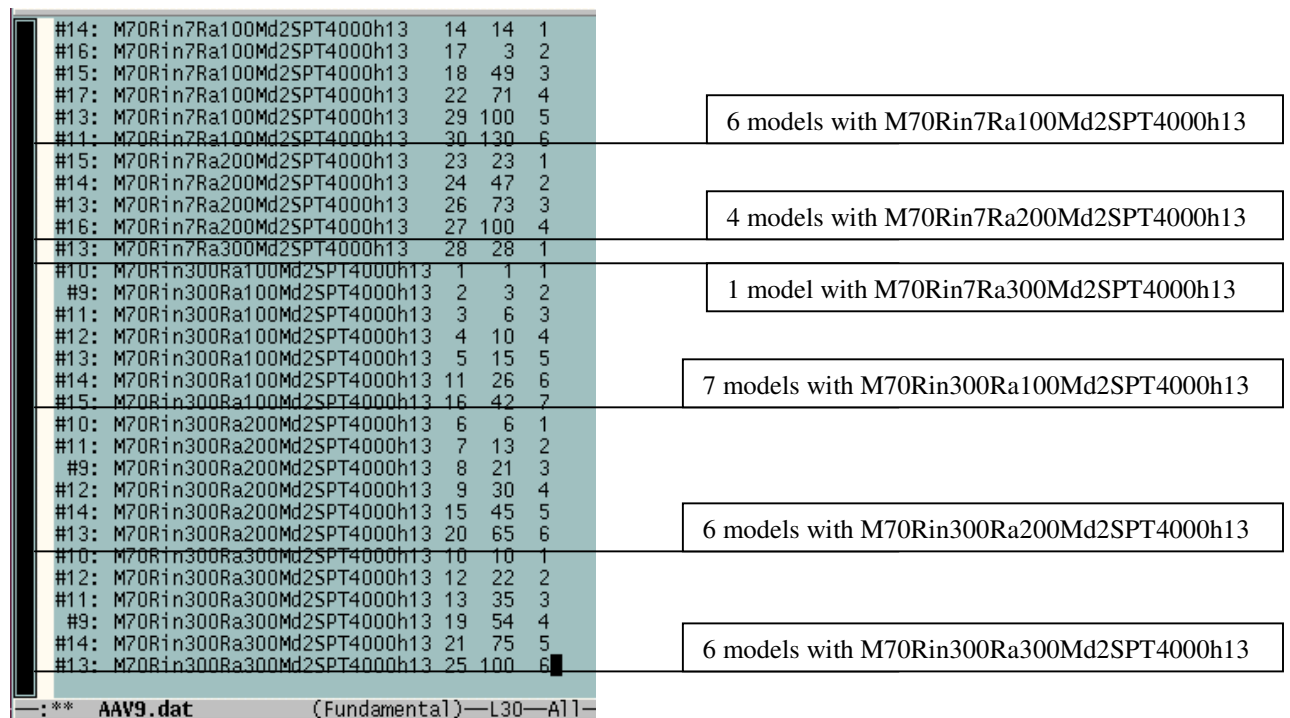


Fig. 30: File with the angle+combination of parameters, position among the best 30 models, sum of the positions for each combination of parameters, and number of models.

\$1	\$2	\$3	\$4	\$5	\$6	\$7	\$8
#10: M70Rin300Ra100Md2SPT4000h13	1	#14: M70Rin7Ra100Md2SPT4000h13	14	1	14		
#9: M70Rin300Ra100Md2SPT4000h13	2	#16: M70Rin7Ra100Md2SPT4000h13	17	2	15.5		
#11: M70Rin300Ra100Md2SPT4000h13	3	#15: M70Rin7Ra100Md2SPT4000h13	18	3	16.3333		
#12: M70Rin300Ra100Md2SPT4000h13	4	#17: M70Rin7Ra100Md2SPT4000h13	22	4	17.75		
#13: M70Rin300Ra100Md2SPT4000h13	5	#13: M70Rin7Ra100Md2SPT4000h13	29	5	20		
#10: M70Rin300Ra200Md2SPT4000h13	6	#11: M70Rin7Ra100Md2SPT4000h13	30	6	21.6667		
#11: M70Rin300Ra200Md2SPT4000h13	7	#15: M70Rin7Ra200Md2SPT4000h13	23	1	23		
#9: M70Rin300Ra200Md2SPT4000h13	8	#14: M70Rin7Ra200Md2SPT4000h13	24	2	23.5		
#12: M70Rin300Ra200Md2SPT4000h13	9	#13: M70Rin7Ra200Md2SPT4000h13	26	3	24.3333		
#10: M70Rin300Ra300Md2SPT4000h13	10	#16: M70Rin7Ra200Md2SPT4000h13	27	4	25		
#14: M70Rin300Ra100Md2SPT4000h13	11	#13: M70Rin7Ra300Md2SPT4000h13	28	1	28		
#12: M70Rin300Ra300Md2SPT4000h13	12	#10: M70Rin300Ra100Md2SPT4000h13	1	1	1		
#11: M70Rin300Ra300Md2SPT4000h13	13	#9: M70Rin300Ra100Md2SPT4000h13	2	2	1.5		
#14: M70Rin7Ra100Md2SPT4000h13	14	#11: M70Rin300Ra100Md2SPT4000h13	3	3	2		
#14: M70Rin300Ra200Md2SPT4000h13	15	#12: M70Rin300Ra100Md2SPT4000h13	4	4	2.5		
#15: M70Rin300Ra100Md2SPT4000h13	16	#13: M70Rin300Ra100Md2SPT4000h13	5	5	3		
#16: M70Rin7Ra100Md2SPT4000h13	17	#14: M70Rin300Ra100Md2SPT4000h13	11	6	4.33333		
#15: M70Rin7Ra100Md2SPT4000h13	18	#15: M70Rin300Ra100Md2SPT4000h13	16	7	6		
#9: M70Rin300Ra300Md2SPT4000h13	19	#10: M70Rin300Ra200Md2SPT4000h13	6	1	6		
#13: M70Rin300Ra200Md2SPT4000h13	20	#11: M70Rin300Ra200Md2SPT4000h13	7	2	6.5		
#14: M70Rin300Ra300Md2SPT4000h13	21	#9: M70Rin300Ra200Md2SPT4000h13	8	3	7		
#17: M70Rin7Ra100Md2SPT4000h13	22	#12: M70Rin300Ra200Md2SPT4000h13	9	4	7.5		
#15: M70Rin7Ra200Md2SPT4000h13	23	#14: M70Rin300Ra200Md2SPT4000h13	15	5	9		
#14: M70Rin7Ra200Md2SPT4000h13	24	#13: M70Rin300Ra200Md2SPT4000h13	20	6	10.8333		
#13: M70Rin300Ra300Md2SPT4000h13	25	#10: M70Rin300Ra300Md2SPT4000h13	10	1	10		
#13: M70Rin7Ra200Md2SPT4000h13	26	#12: M70Rin300Ra300Md2SPT4000h13	12	2	11		
#16: M70Rin7Ra200Md2SPT4000h13	27	#11: M70Rin300Ra300Md2SPT4000h13	13	3	11.6667		
#13: M70Rin7Ra300Md2SPT4000h13	28	#9: M70Rin300Ra300Md2SPT4000h13	19	4	13.5		
#13: M70Rin7Ra100Md2SPT4000h13	29	#14: M70Rin300Ra300Md2SPT4000h13	21	5	15		
#11: M70Rin7Ra100Md2SPT4000h13	30	#13: M70Rin300Ra300Md2SPT4000h13	25	6	16.6667		

Fig. 31: Resulting file from running the script anemaveure.com on the file with the best models obtained from the program to find the best model.

The lines highlighted show:

- Column \$5: the combination of parameters present among the 30 best models (from all the combinations possible given at the beginning of the script).
- Column \$7: the number of models with the corresponding combination of parameters within the best 30 models.
- Column \$8: the average position of the corresponding combination of parameters within the best 30 models.

End of script to find the best model.

Troubleshooting

- Error that appears after running 2T8loMM.com or 2T4loMM.com:

**awk: division by zero
record number 2**

Make sure *_FTMM#.txt does not contain ^M (from Windows). It can be removed by:

- In vi entering the following command
:1,\$s/^M//g (^M = Ctr+v and then ctr+M)
- In unix entering the command
dos2unix oldfile.* newfile.* (newfile won't have ^M)

- Error that appears after running 2T8loMM.com or 2T4loMM.com:

**awk: division by zero
record number 4**

Make sure in *_FTMM#.txt the return is under the last written line. See page 19, especially Fig. 10.

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