AGB star winds as constrained by PACS and SPIRE spectra

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Overview Talk

- Introduction:
  Understanding the mass-loss process and the structure of the circumstellar envelope around AGB stars
- Infrared work: PACS and SPIRE spectroscopy
- Infrared work: 3D RT models, first attempts
- Molecular work: CO/H_2 abundance in AGB stars

MESS

MESS (Mass-loss of Evolved StarS), a Herschel key program
Groenewegen, Waelkens, Barlow, Kerschbaum, Garcia-Lario et al.
2011 A&A 526, A126

Observed 150 objects in imaging and about 50 objects in spectroscopy (AGB, RSG, post-AGB, PN, WR, SN)

Many results on the imaging part (AGB overview: Cox et al. 2012) but limited results on the spectroscopic part, mostly on line-emission.

PACS-SPIRE spectroscopy

PACS & SPIRE range spectroscopy of cool evolved stars
Nicolaes, Gr., Royer, Lombaert, Danilovich, Decin
2018, A&A 618, A143

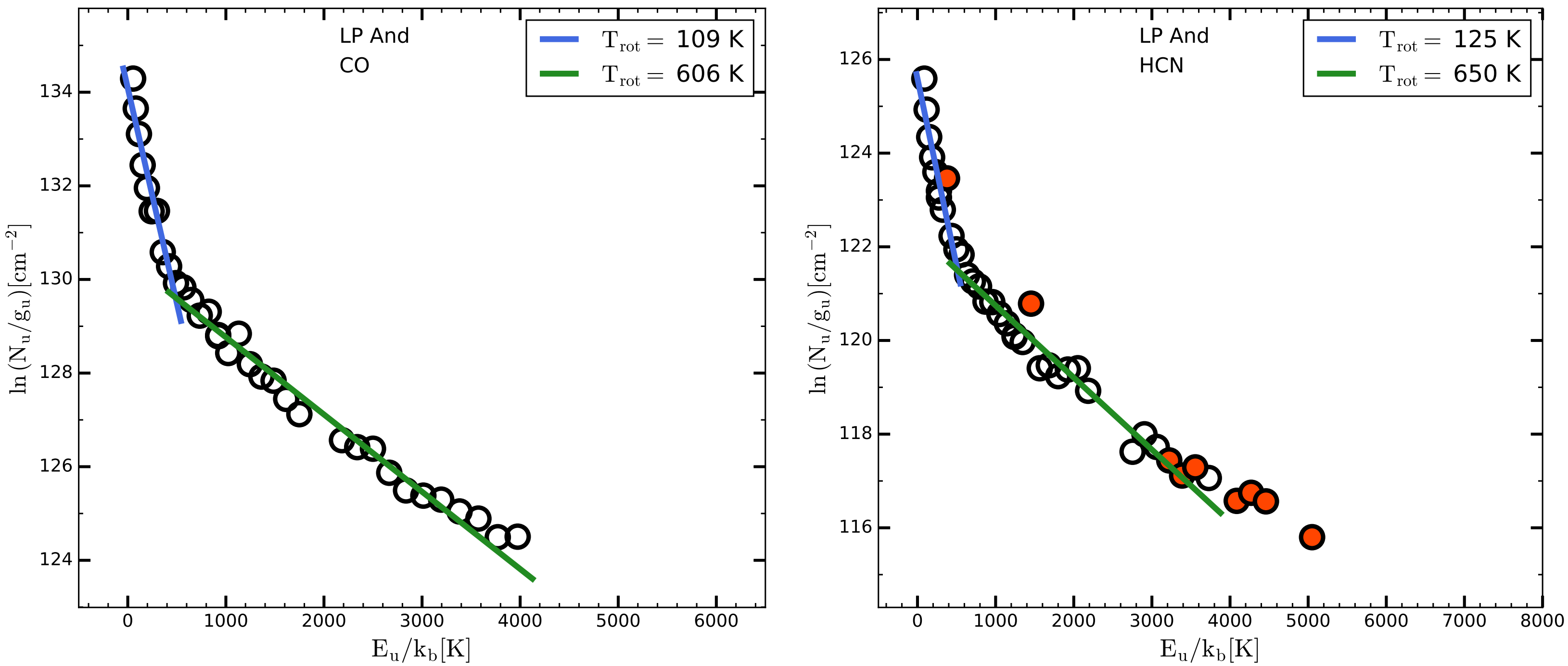
The HIPE software + latest calibration was used to process PACS and SPIRE spectra of 40 AGB/RSG stars (also non-MESS).

PACS/SPIRE imaging data was retrieved to get photometry (compare bolometer values to synthetic fluxes from the spectra)

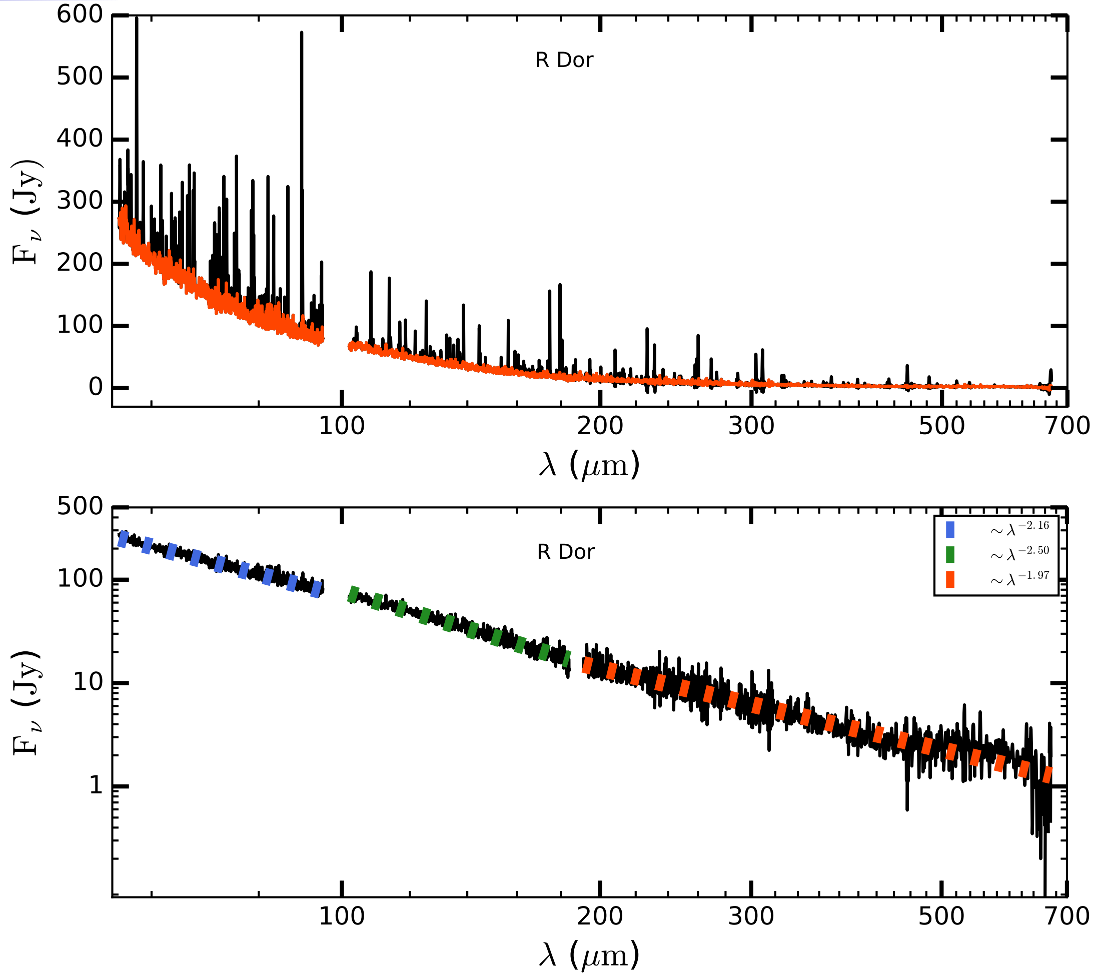
Lines

band	λ_{obs} (μm)	ν_{obs} (GHz)	F_{int} 10^{-17} (W/m^2)	$\sigma(F_{int})$ 10^{-17} (W/m^2)	Spec.	Transition	λ_0 (μm)	ν_0 (GHz)	75K (%)	300K (%)	500K (%)
SSW	191.33	1566.91	3.31	0.349	SO_2	$48_{5,43} \rightarrow 48_{2,46}$	191.27	1567.38	0.14	1.37	1.15
					SO_2	$84_{5,79} \rightarrow 83_{6,78}$	191.30	1567.11	< 0.01	0.17	2.61
					SO_2	$85_{5,81} \rightarrow 84_{4,80}$	191.33	1566.88	< 0.01	0.18	2.93
					^{13}CS	$34 \rightarrow 33$	191.34	1566.81	0.10	10.81	16.02
					SO_2	$44_{5,39} \rightarrow 43_{4,40}$	191.34	1566.77	17.05	29.04	19.38
					SO_2	$25_{11,15} \rightarrow 24_{10,14}$	191.35	1566.74	0.53	33.71	36.42
					SO_2	$40_{4,36} \rightarrow 39_{3,37}$	191.37	1566.56	82.18	23.97	12.65
					SO_2	$86_{3,83} \rightarrow 85_{4,82}$	191.38	1566.47	< 0.01	0.20	3.23
					SO_2	$87_{3,85} \rightarrow 86_{2,84}$	191.40	1566.29	< 0.01	0.21	3.52
SSW	194.47	1541.60	8.11	0.319	H_2O	$6_{3,3} \rightarrow 5_{4,2}$	194.42	1541.96	15.33	82.84	85.96
					^{13}CO	$14 \rightarrow 13$	194.55	1540.98	84.67	16.77	13.35
SSW	216.95	1381.85	7.12	0.304	CO	$12 \rightarrow 11$	216.93	1381.99	100.00	99.82	99.56
SSW	226.80	1321.85	12.2	0.324	H_2O	$6_{2,5} \rightarrow 5_{3,2}$	226.76	1322.06	43.26	94.77	95.81
					^{13}CO	$12 \rightarrow 11$	226.90	1321.26	56.64	5.22	4.12
SLW	294.89	1016.61	3.29	0.270	SO_2	$47_{5,43} \rightarrow 46_{4,42}$	294.92	1016.51	0.71	46.00	53.66
					SO_2	$32_{17,15} \rightarrow 33_{16,18}$	294.98	1016.30	0.03	4.63	6.03
					SO_2	$27_{16,12} \rightarrow 28_{15,13}$	295.01	1016.19	0.38	6.46	6.30
					^{13}CS	$22 \rightarrow 21$	295.09	1015.92	65.54	40.94	33.00
					SO_2	$28_{3,25} \rightarrow 28_{0,28}$	295.10	1015.89	33.34	1.98	0.91

Rotational diagrams



Full & Continuum spectra

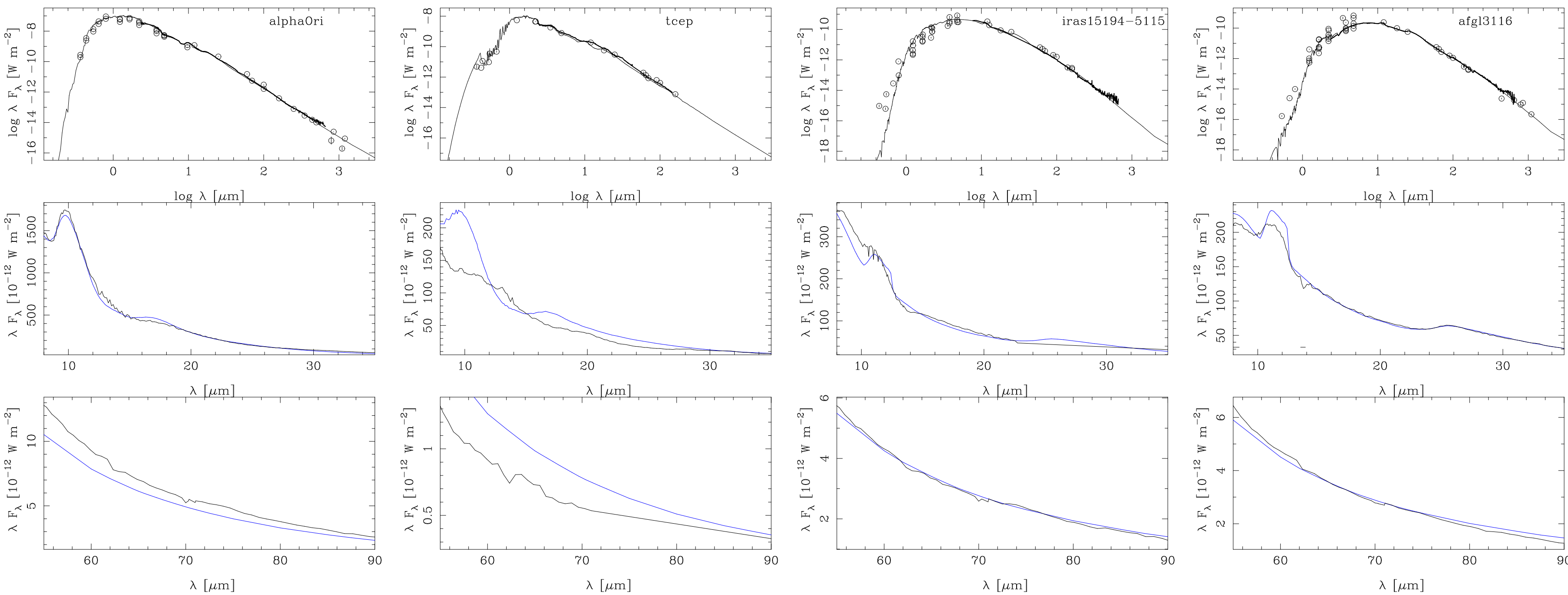


all data publically available.

THROES (A caTalogue of HeRschel Observations of Evolved Stars)
Ramos Medina et al. (2018)

Also PN (22%), P-AGB (25%). PACS-only. CO lines for 26 O-rich stars

Example SEDs

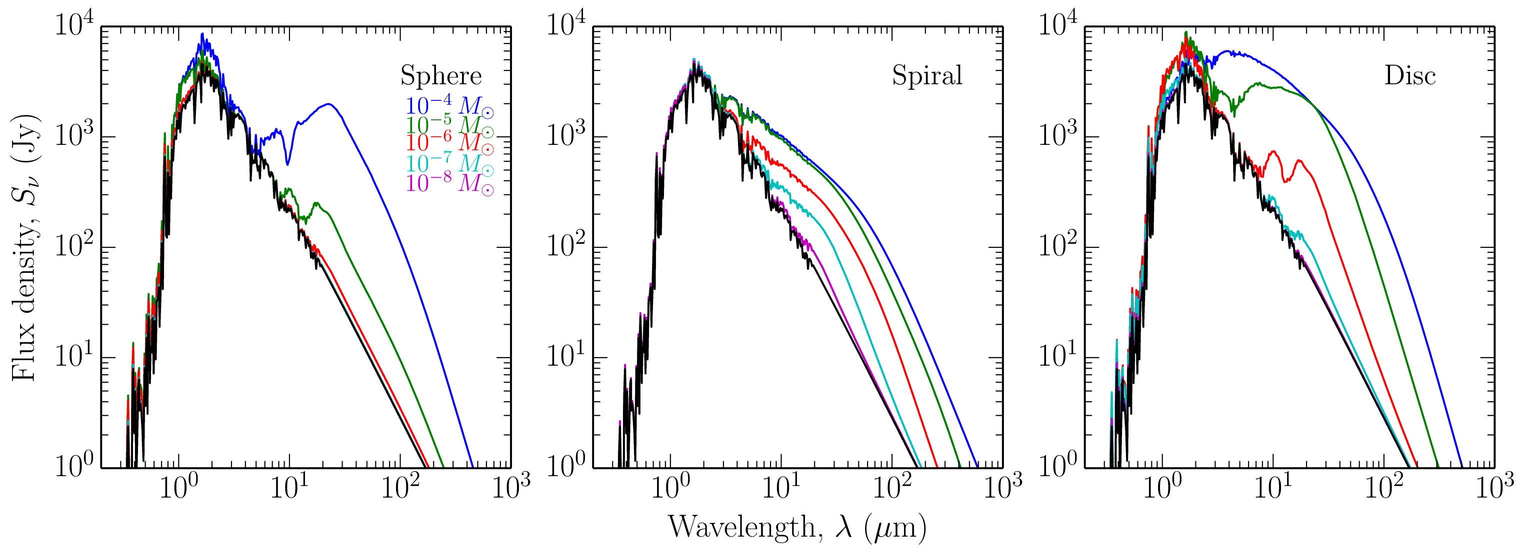


DEATHSTAR - NESS - ATOMIUM initiatives

3D RT modelling

"Morphological effects on dust SEDs of O-rich AGB stars with EP Aqr as a template"
Wiegert, Groenewegen, Jorissen, Decin, in prep.

RADMC-3D
Example: EP Aqr (ALMA: Homan et al. 2018, Hoai et al. 2019, Tuan-Anh et al. 2019)



1-2 orders of magnitude difference

CO abundance in AGB stars

(Work with Paola Marigo)

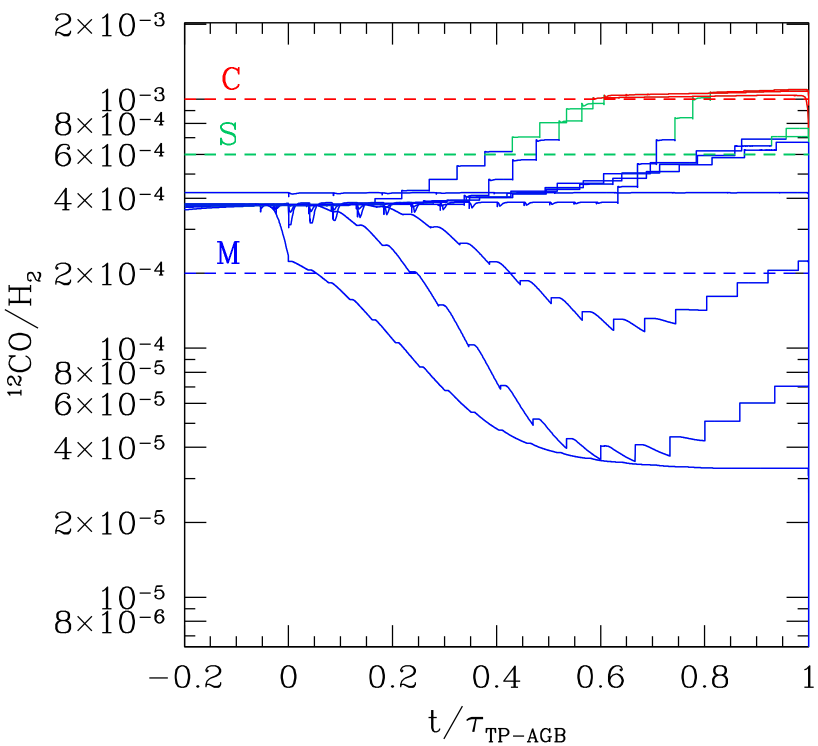
DTG ratio in dust modelling $\Longleftrightarrow$ CO/H_2 ratio in CO modelling

Solar abundance + first dredge-up:

$(2-5) \cdot 10^{-4}$ for M-stars, $6 \cdot 10^{-4}$ for S-stars

$(9-10) \cdot 10^{-4}$ for C-stars

(Olofsson, Danilovich, De Beck, Ramstedt, Schoier, ...)



$Z = 0.014$

1.4, 2.0, 2.4, 3.0, 3.4, 4.0, 4.4, 5.0, 5.4, 6.0 $M_\odot$

Effect HBB

THE END