The scientific potential of the post-helium data base

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Exploiting the ISO Data Archive

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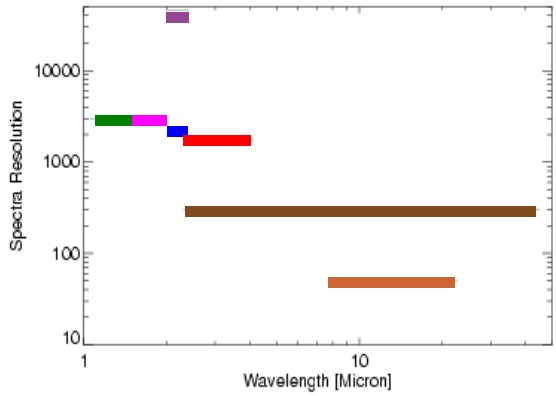
Overview

- SWS Observations after Helium boil-off
  - Rationale
  - Source selection
  - Calibration
  - The ISO post-helium atlas
- Scientific potential
  - Quantifying NIR spectral diagnostics
  - Synthetic population studies
  - Reference for ground-based L-band spectra
  - Unsupervised classification of ISO spectra

The post–Helium programme rationale

An atlas of stellar spectra at R~1800 covering 2.36-4 μm is complementary to existing atlases



Wallace et al. (2000) [88]

Meyer et al. (1998) [88]

Wallace & Hinkle (1997) [12]

Forster-Schreiber (2000) [33 late-type]

ISO-SWS Post-Helium [300]

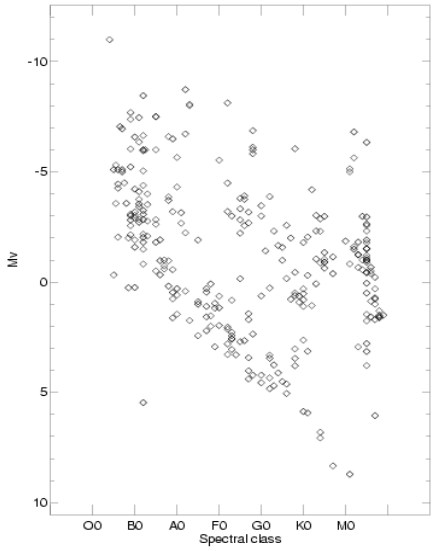
ISO STARTYPE [100]

IRAS LRS [5000]

Source selection

- Selection criteria:
  - Diversity in spectral types
  - ISO visibility after He boil-off
  - Brightness
- Input catalogues:
  - Bright Star Catalogue
  - Van der Hucht 1997 (WR stars)
- 55 programme stars discarded
  - Available as AOT1sp4 or AOT6 in nominal mission
  - Added to the sample afterwards

Observations



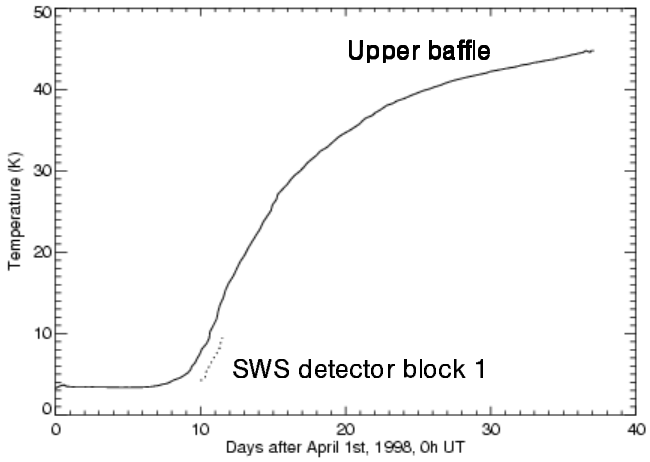
Observation mode: SWS AOT1/speed4-like

Targets selected according to priority by mission planners

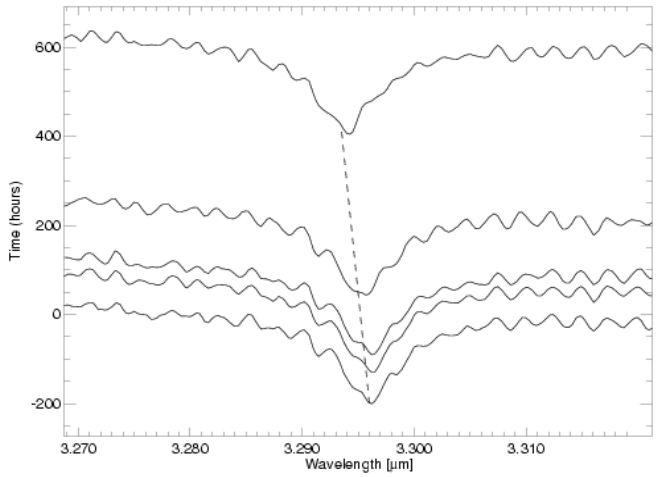
Resulting dataset :

- 55 nominal phase spectra
- 238 post-He spectra
- Covers the HR diagramme well

Temperature change after He boil–off

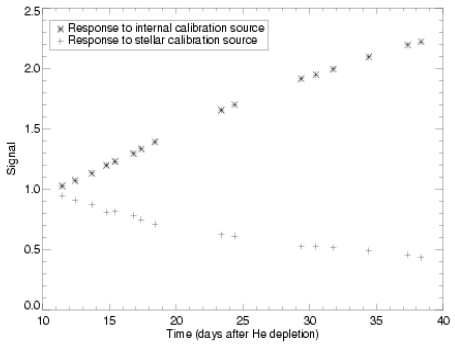


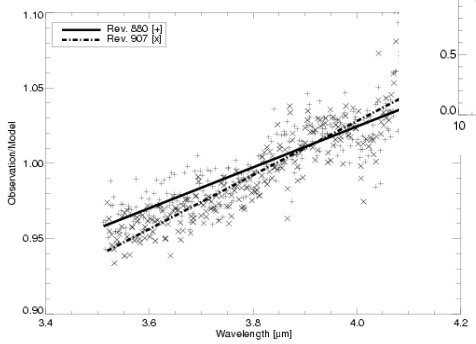
Post–Helium wavelength calibration shift



Post–Helium flux calibration change

Response change ->



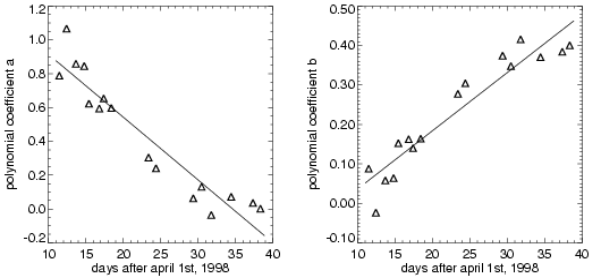


<- RSRF tilt change

Post–Helium calibration strategy

Wavelength calibration, absolute response calibration, tilt correction : characterised by polynome

Time dependent calibration : fit a polynome to the coefficients of these calibration polynomes determined at different times after helium-boil off

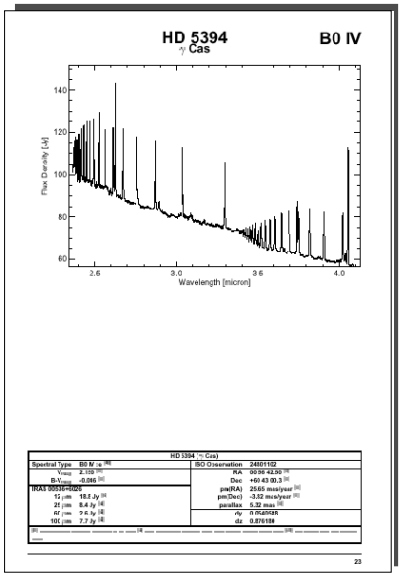


Fit to RSRF slope correction

Post–Helium flux error budget

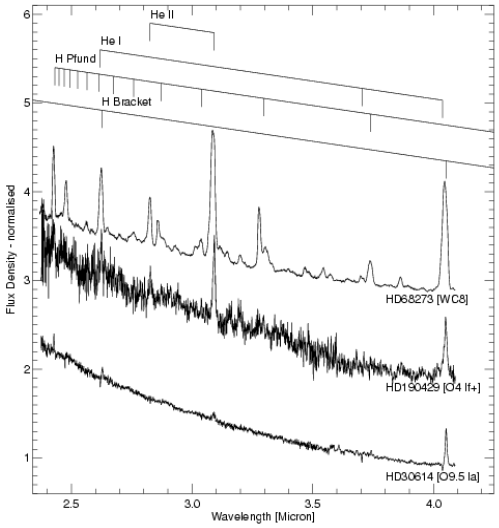
Error source	Post-He	Nominal
Absolute error on the average flux		
Absolute flux conversion	5%	2%
Absolute Pointing error	8%	4%
Relative error -- broadband		
RSRF	5%	3%
Relative errors -- small scale		
Dark noise	1Jy	1jy
RSRF	1%	1%
Pointing jitter	0-2.5%	
Line intensity of unresolved lines		
Unresolved fringes	20%	20%
Linewidth jitter	5%	5%

The ISO–SWS post–helium atlas



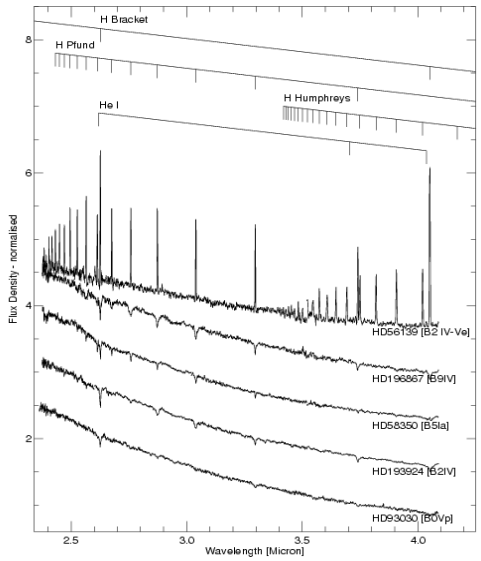
- Calibration and overview plots: accepted 15/05 A&A
- Full atlas (plots, literature data): downloadable as PDF & online available on the web
- Data (calibrated AAR, fully reduced) is in preparation for upload to the ISO Data Archive (july 2002)

O and WR stars



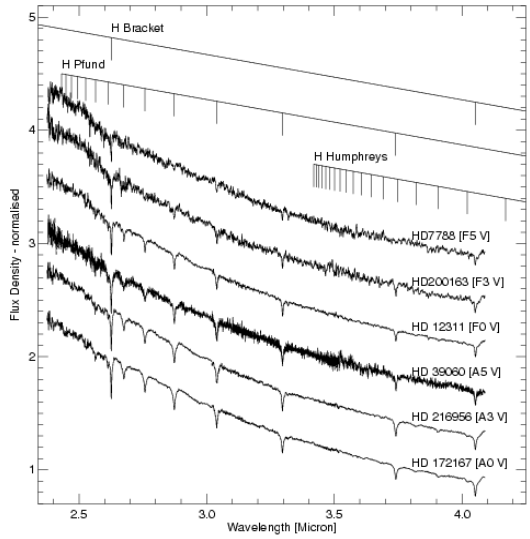
- Hydrogen lines
  - Bracket
  - Pfund
  - Humphreys
- WR : broadened lines of H, He, C and Ca originating in hot, dense winds

B stars



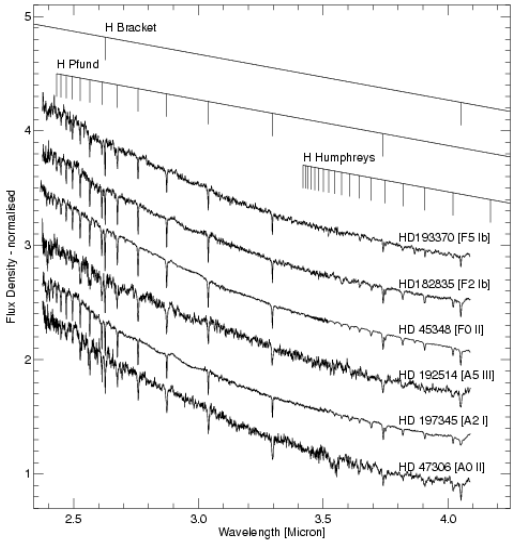
- B spectra dominated by Hydrogen lines
- Be: H in emission (gas CS disk)

A and F dwarfs

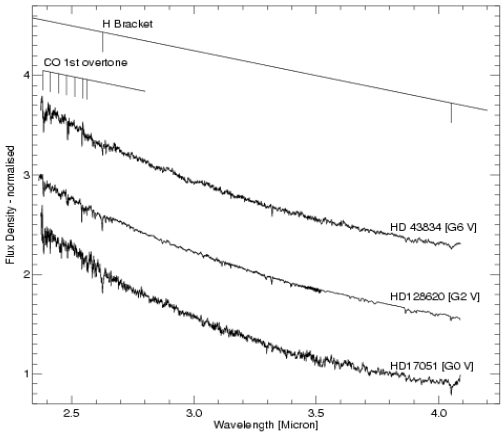


- Dominated by HI
  - Bracket
  - Pfund
  - Humpreys
- Normally in absorption
- Exception: stars with shell (eg Haebes)

A and F giants

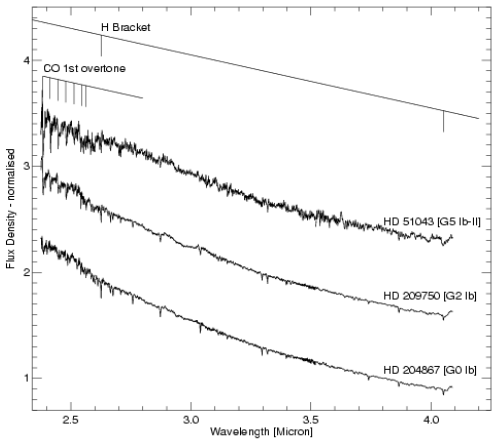


G dwarfs

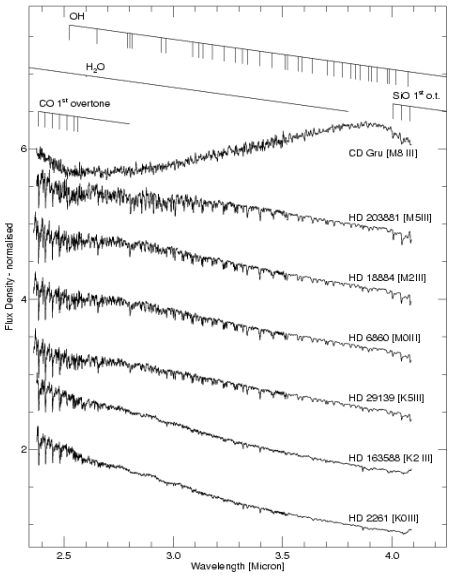


- Atomic lines
- CO towards late type

G supergiants

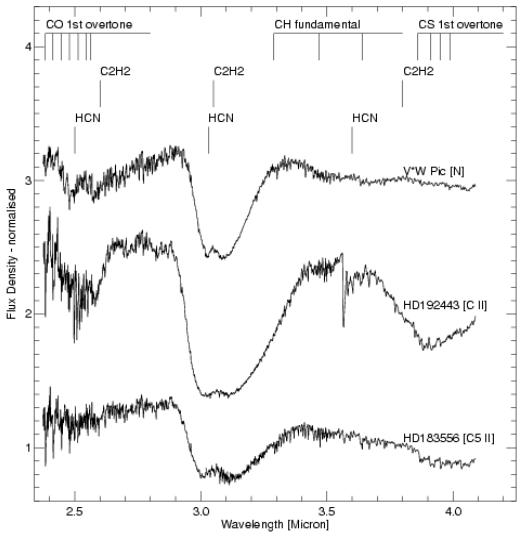


K and M giants



- CO
- OH
- H2O
- SiO

Carbon stars

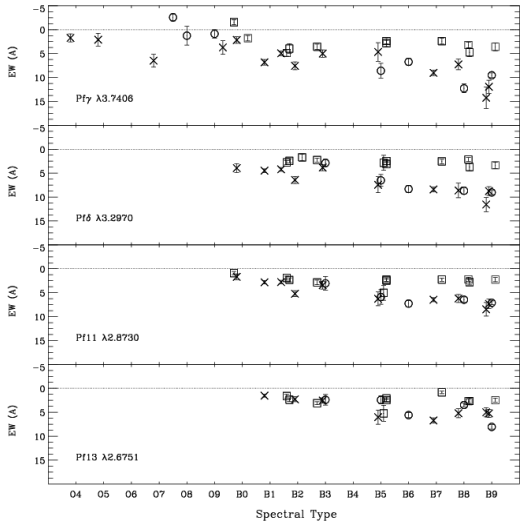


- C2H2
- HCN
- CO
- CH
- CS

The Scientific potential of the post–he atlas

- Establishing NIR diagnostics for spectral type, luminosity class, mass loss, CSM geometry : interpretation of observations of obscured stars where the NIR is the only available window
- Synthetic population studies of galaxies
- Reference spectra for the reduction of ground-based L-band spectra

NIR spectral Classification of B III–V

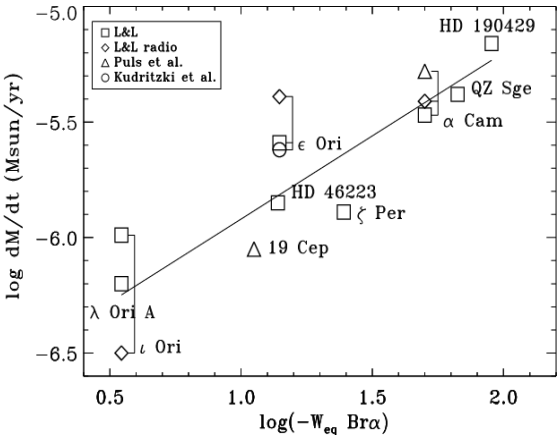


Pfund lines constrain spectral type (±2 subtypes)

Bracket-β width determines luminosity class (broader in dwarfs)

Lenorzer et al. A&A 384(2002)

Br α and mass loss in O and B I–II stars

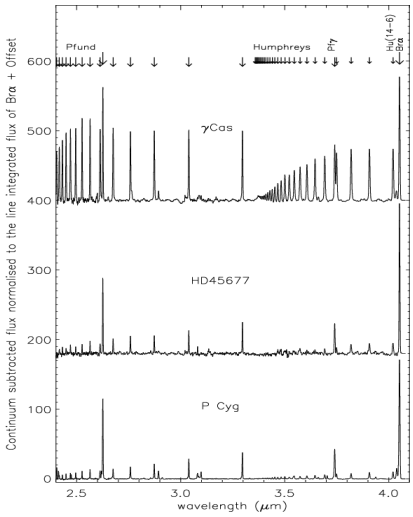


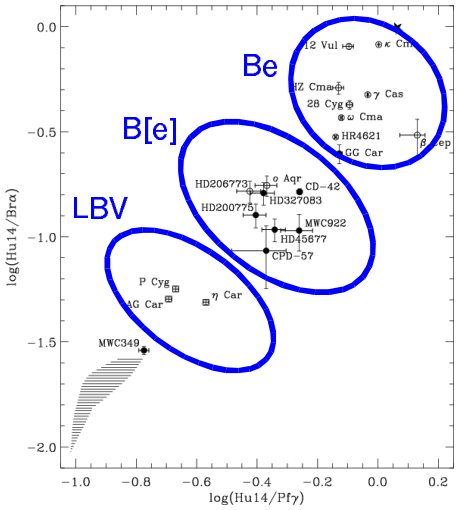
In normal O and B supergiants: Bracket-α width determines mass loss (±0.25 dex)

$$\log \dot{M} = (0.72 \pm 0.21) \log(-W_{\rm eq}{\rm Br}\alpha) - (6.64 \pm 0.28).$$

Lenorzer et al. A&A 384(2002)

Geometry of the CSM of hot stars





Lenorzer et al. A&A 384(2002)

NIR spectral diagnostics for late–type stars

Approach I : Carbon-based Brains

- Measure strengths of H lines in A, F and G dwarfs and correlate with Temperature, gravity, etc...
- KM giants: Joint Characteristics (JC) method (e.g. Cami 2002)

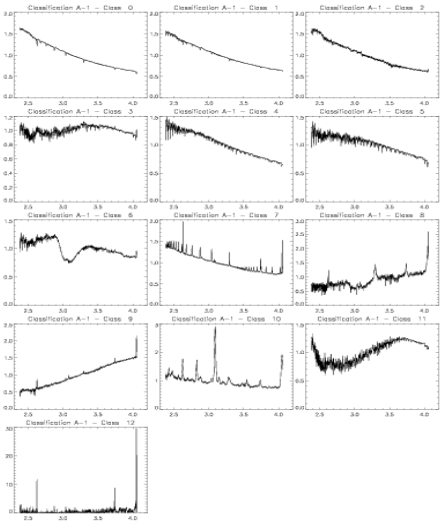
Approach II : Silicon Brains

- unsupervised Bayesian classification
  -> unbiased evidence for morphological differences
- Correlate class with Temperature, gravity, mass loss, etc...

Unsupervised Bayesian classification

- Unsupervised classification
  - Automatically 'discover' classes in sets of cases described by attributes
  - Goal: minimise surprise when seeing a new case
- Autoclass III (Cheeseman 1996)
  - Bayesian approach to unsupervised classification
  - Bayes rule : calculate the probability of a hypothesis given some additional evidence
  - Autoclass hypothesis : number of classe, class description
  - Autoclass evidence : case attributes
  - Autoclass seeks the hypothesis (classification) with the highest posterior probability given the data

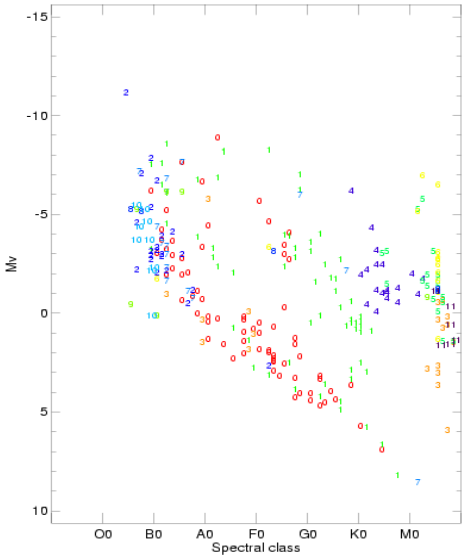
Autoclass result



Autoclass of all Post-He data

- Spectra normalised to integrated flux
- 293 cases, 2539 attributes
- 1 month of processing
- Converges (classifications found marginally different)
- Most probable classification : 13 classes

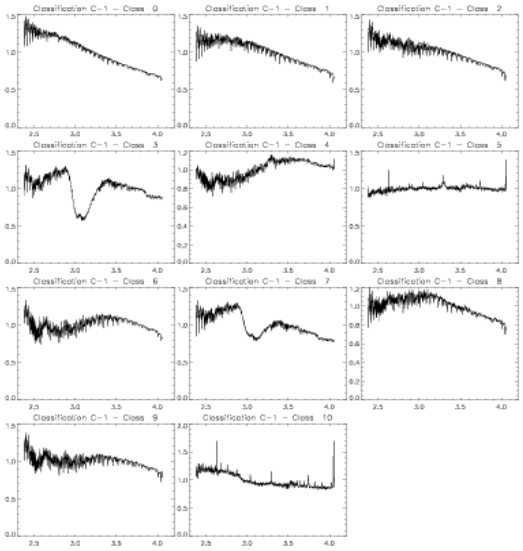
Autoclass clustering in the HR diagram



Classes found tend to cluster in the HR diagram

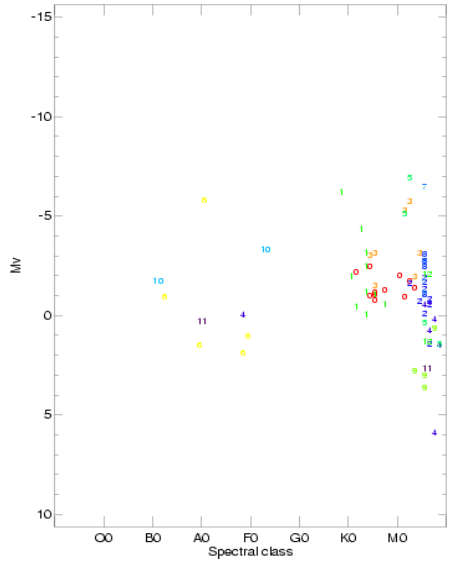
Especially good clustering in the RGB and AGB

Refinement of classification



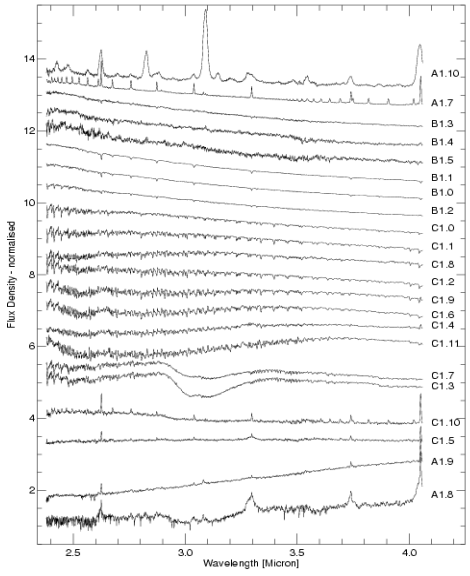
'Cool giant' classes and 'main sequence' classes pumped again into autoclass for refinement classification

Late–type refinement classification clusters in the HR diagram



- Classes well confined
  - Spectral class
  - Luminosity class
  - Carbon stars

Result of global and refined classifications



Total: 23 classes found

Can serve as a base for further correlations with properties of the stars in the class

Poor discrimination for early type stars, good discrimination between late-type stars

Autoclass beyond post–helium

- The unsupervised classification of *all* ISO spectra could reveal subtle features (e.g. solid state features) that stay hidden in the noise of individual spectra but appear in the mean of the spectra of a class
- Autoclass III robust against missing data values -> application on non-continuous SWS spectra, PHT-S and CAM-CVS spectra feasible

Library for synthetic population studies

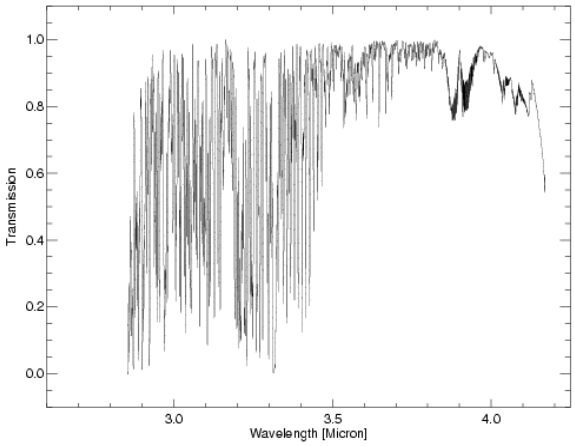
Posthe-Helium atlas spectra for synthetic population studies of external galaxies

In the NIR the integrated galaxy's spectrum is the sum of the spectra of the individual stars in the system

Reference library for telluric line standards

Post-He spectra as reference spectra for telluric standards in the L-band

(UKIRT, VLT-ISAAC)



NSO/Kitt peak FTS by NSF/NOAO

Conclusion

- Post-Helium dataset : 300 stellar spectra 2.36-4 um
- Applications
  - Quantify NIR indices of stellar properties
  - Synthetic population studies
  - Ground-based L-band spectra correction for telluric lines
- Autoclass applied successfully on Post-He data
  - Application on all ISO spectra should be initiated