Recent Researches concerning Semi-Regular Variables

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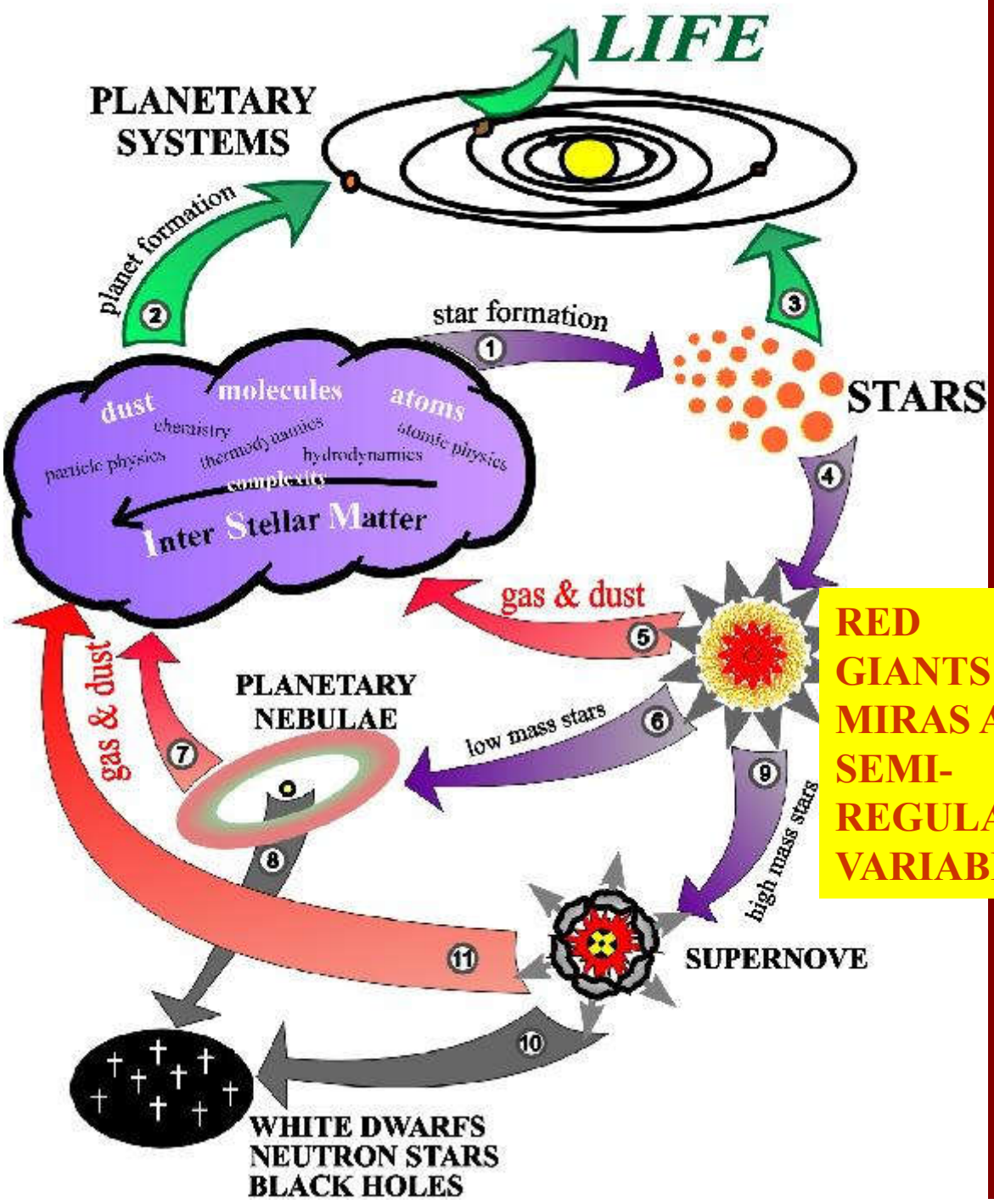
Distances in the Universe - the distance ladder – a summary

- *Trig parallaxes* – only direct method
- *Variable stars as standard candles* – period-luminosity relations – Cepheids, RR Lyraes, Miras etc – problem of calibration.
- *Redshift – distance relation* – calibrated from galaxies containing variable stars
- *Supernovae* of type Ia

Outline

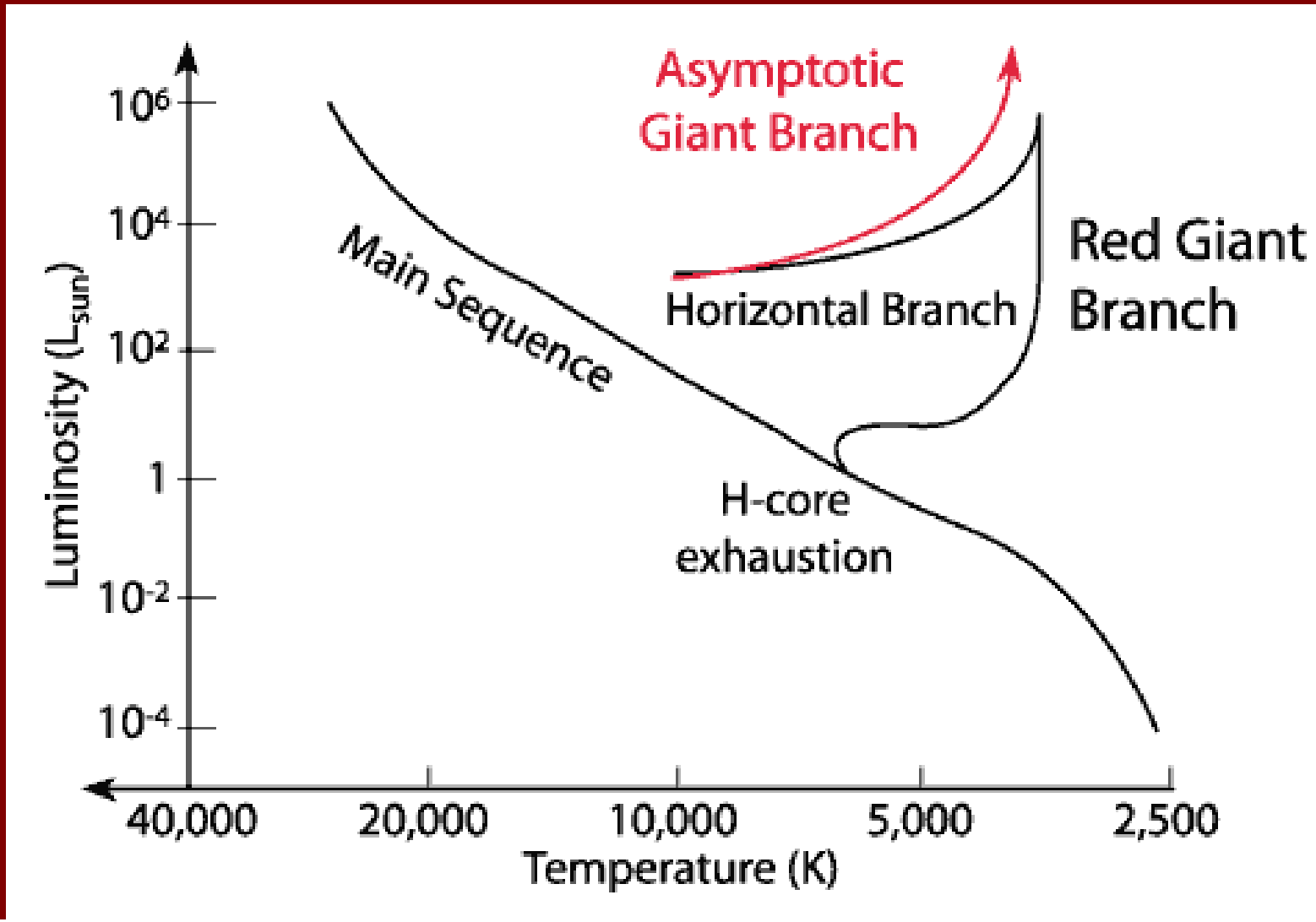
- Place of SRVs in the evolutionary scheme
- Relation to Miras
- How common they are
- Studies in the Magellanic Clouds and Galactic Centre
- Their use as distance indicators
- Local examples - Hipparcos - Calibration
- Need for more data



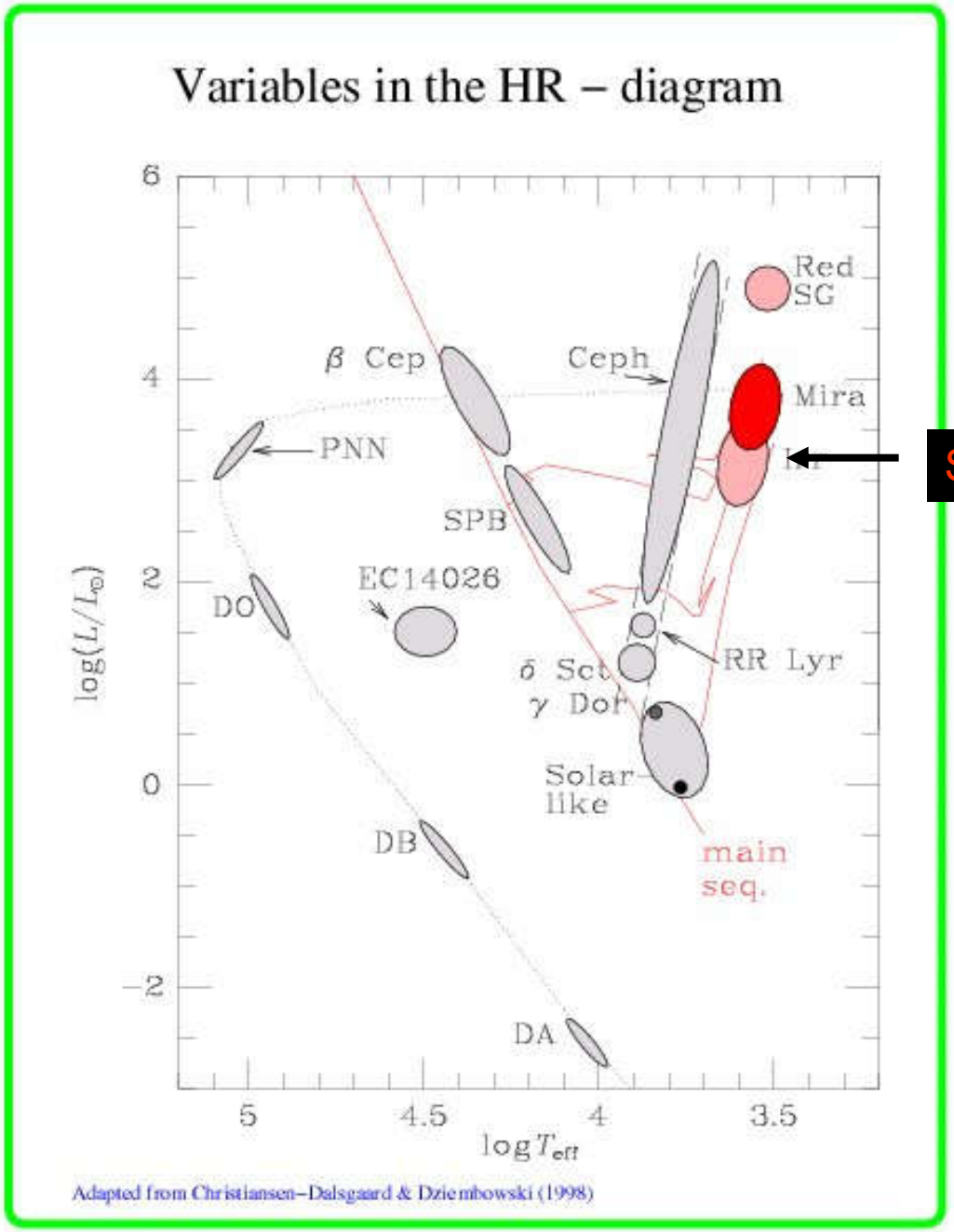
The matter cycle.

All heavy elements such as C, N and O (from which you and I are made up) arose from processing of H and He in stars!

Low- to medium- mass stars evolve into SRVs (AGB)
Path in the Hertzsprung-Russell diagram



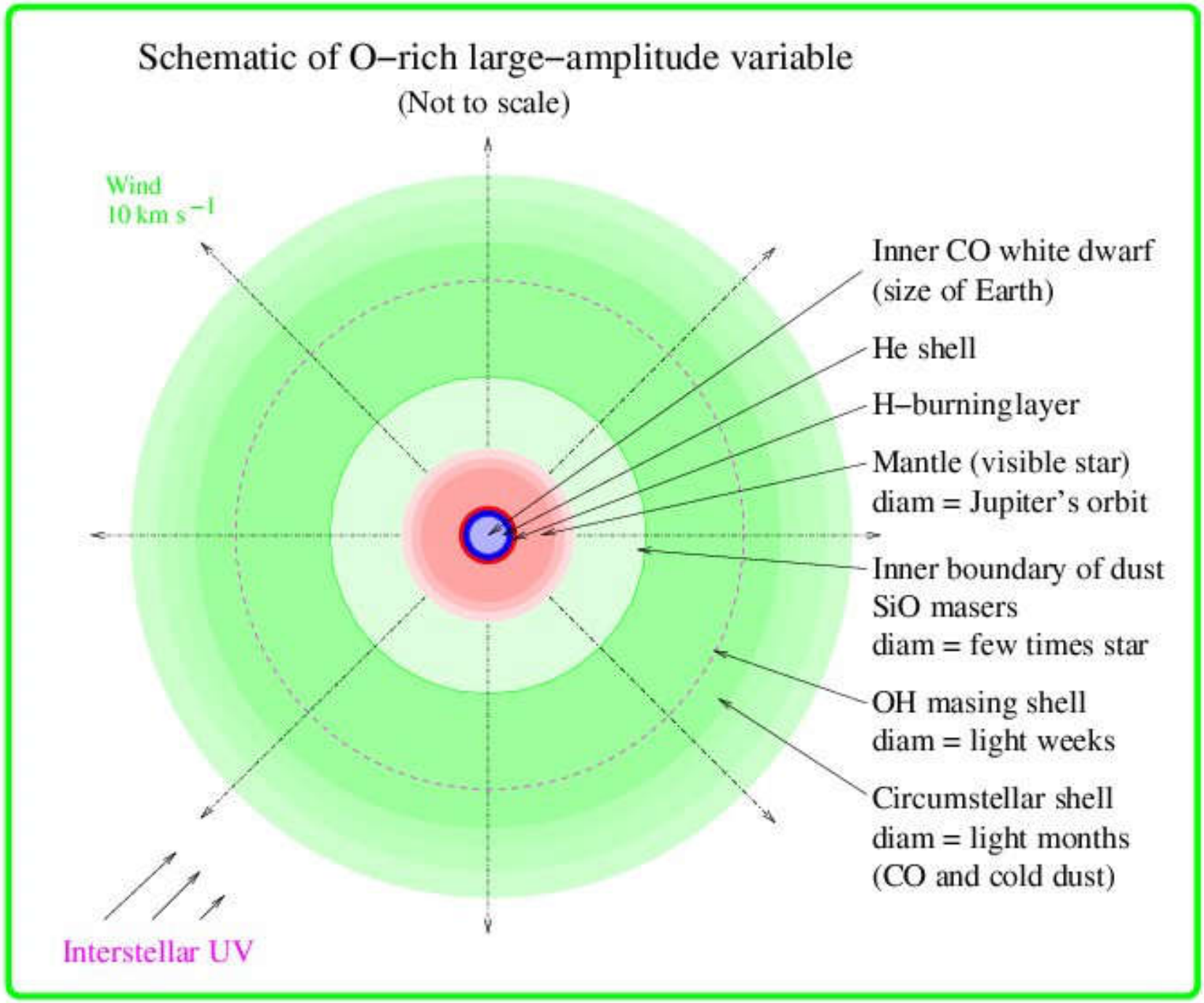
Variables in the HR diagram – the complete “zoo”



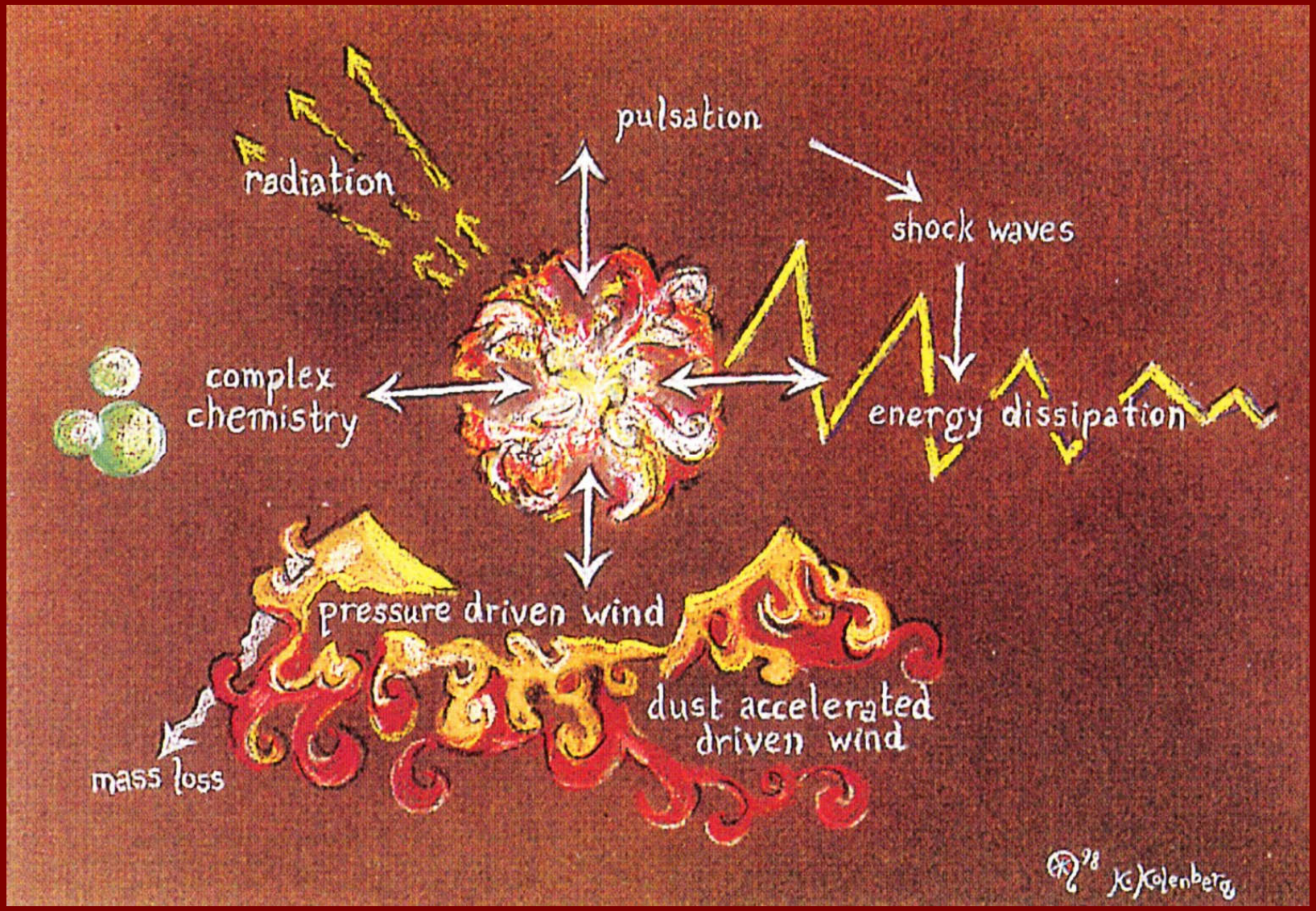
Semi-regular Variables

Properties of late-M type giants

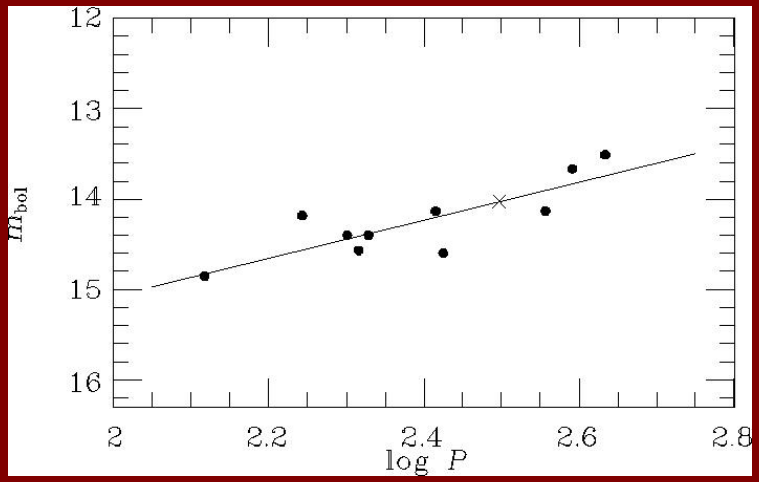
- They are among the coolest M stars : M4III to M8III
- Light is mainly infrared
- They are all variable – from just a few hundredths of a mag at M4 to many mags at M8 (Mira variables)
- They all lose mass copiously


Schematic of O–rich large–amplitude variable
(Not to scale)
Wind
10 km s^{-1}
Inner CO white dwarf
(size of Earth)
He shell
H–burning layer
Mantle (visible star)
diam = Jupiter's orbit
Inner boundary of dust
SiO masers
diam = few times star
OH masing shell
diam = light weeks
Circumstellar shell
diam = light months
(CO and cold dust)
Interstellar UV

The processes going on in a red giant variable

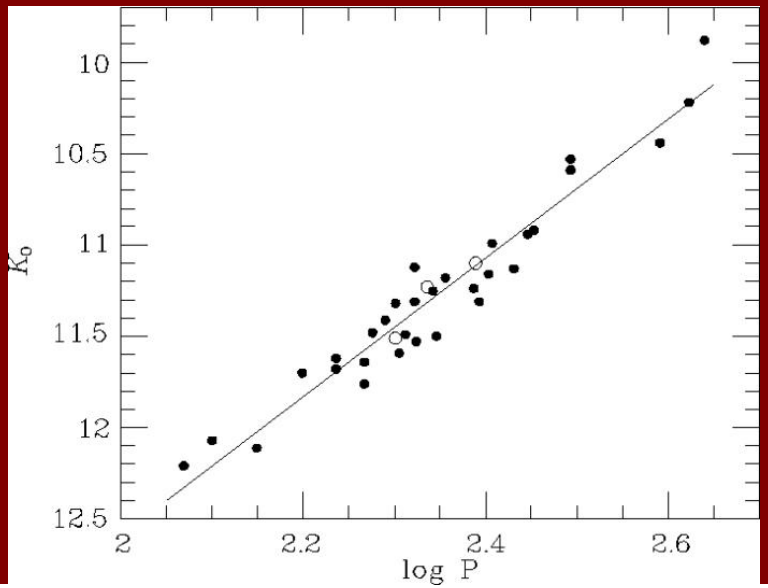


Period-magnitude relation for Miras



(LMC)

- First period-luminosity relation (Glass and Lloyd Evans 1979)

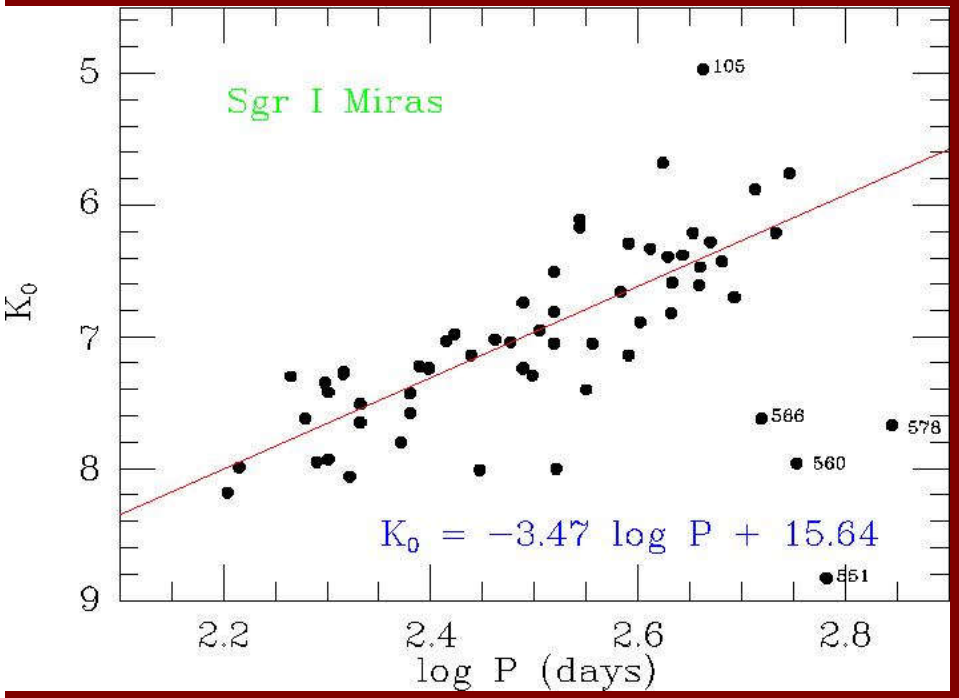


- Refined period-luminosity relation (Glass, Whitelock, Catchpole, Feast, Reid, 1987)

Baade's "Windows" - I

- There are two regions near the Galactic Centre where we can see the Inner Bulge through "windows" in the obscuring dust. These are around the globular cluster NGC6522 and, even closer to the Centre, the region called Sgr I.
- These have been studied at many wavelengths.
- Because the stars are so concentrated near the Centre, their distance spread is relatively small.
- The windows are therefore ideal for calibrating surveys of obscured regions nearer to the galactic centre.

Miras near the Galactic Centre

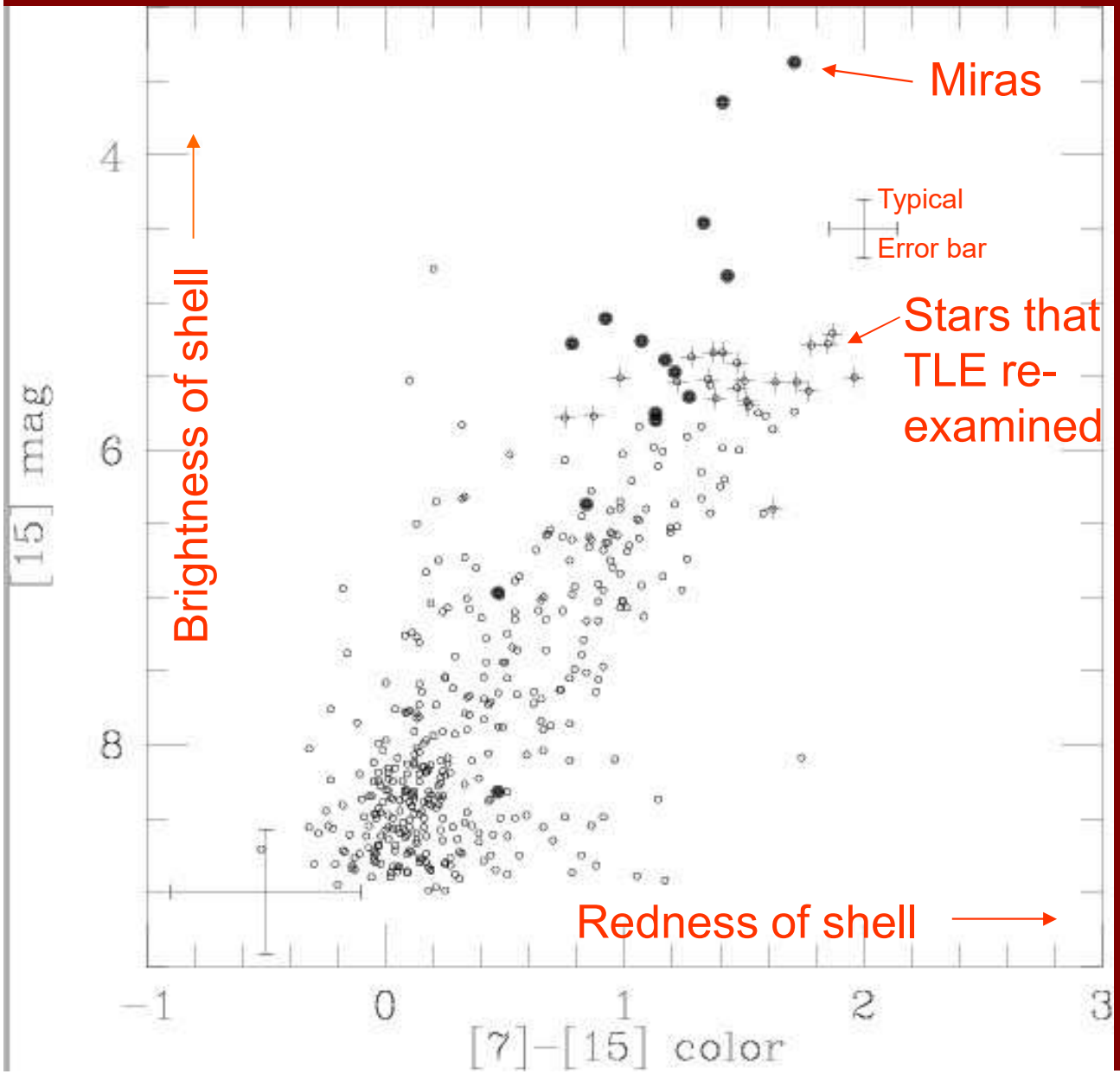


- Glass, Whitelock, Catchpole and Feast (1995) showed that Miras near the centre of the Milky Way galaxy obey the same K mag, log P relation as those in the LMC

Baade's Windows - II

- Lloyd Evans had already identified many Miras there using photography.
- But a survey by the ISO satellite showed that many other stars had abnormally strong infrared radiation, indicating they were losing mass.
- They did not show up as variable on Lloyd Evans's plates.
- But photography not very quantitative!

ISO satellite revealed vast numbers of dust shells!

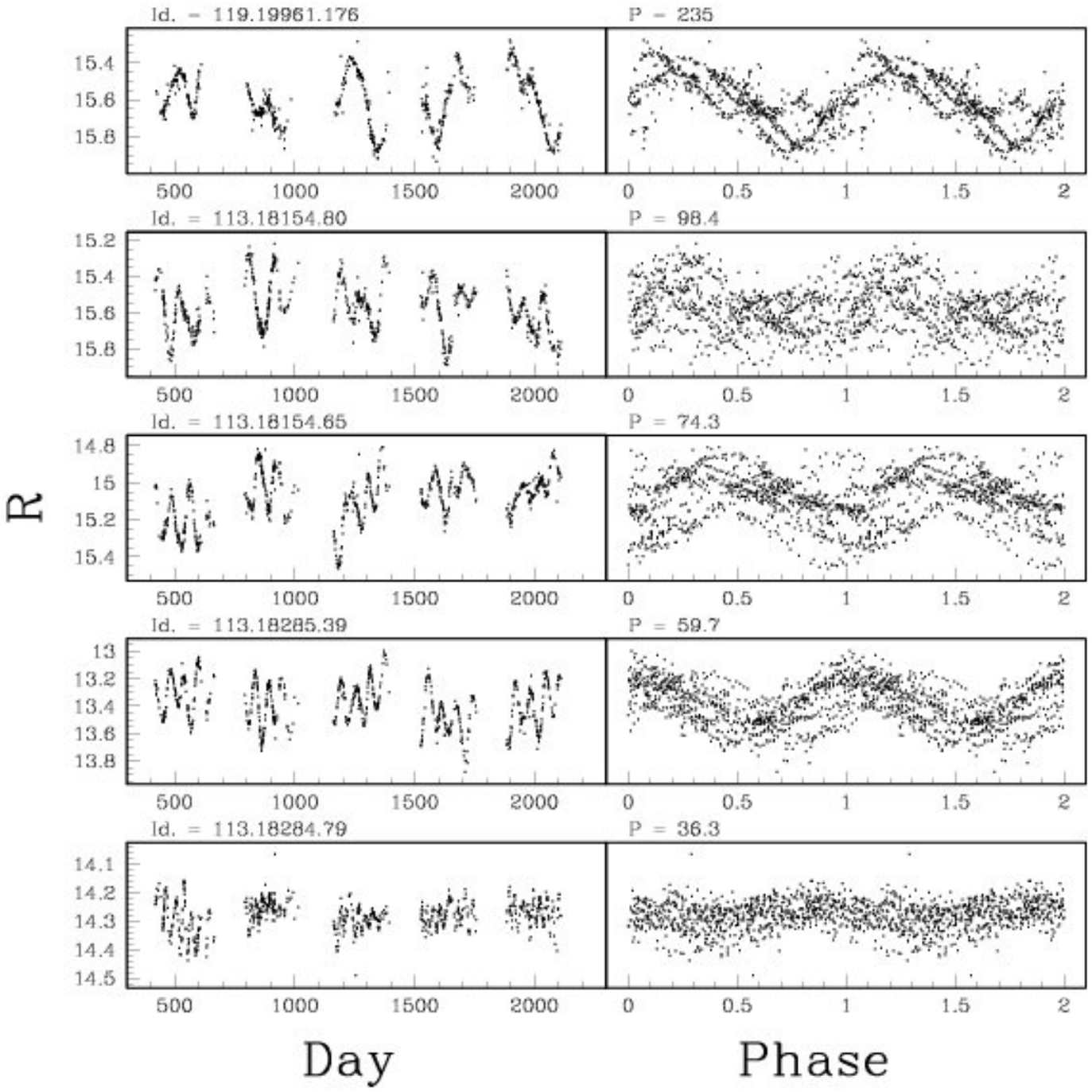


Infrared view of stars in Baade's Windows

(ISOGAL survey 1999 – et al and Glass)

Baade's Window - III

- But …. Baade's Windows were being surveyed for MACHO – millions of stars observed >1000 times over 5 years!
- Many stars turned out to be variable, but at a lower level than Miras
- There already existed a spectroscopic survey of red giant stars in part of Baade's Window by Blanco et al
- There were 1:1 correspondences between late M-type giants, variables and mass-loss (Alves, Glass et al, 1991).



The MACHO treasure trove!

In Baade's Windows, just about all objects bright at K (2.2μm) turned out to be small-amplitude variables

(Alves, Glass & others, 2001)

Meanwhile - Discovery by Wood

- Peter Wood (Mount Stromlo, Australia) looked at MACHO results from Large Magellanic Cloud.
- Cloud is like a face-on plate, so stars are at same distance.
- Found several distinct sequences of variables in a visual magnitude vs period diagram – first indication of systematic behaviour in SRVs
- They were even “better behaved” in a diagram based on infrared magnitudes.

Wood's dramatic Montpellier announcement: near-IR magnitudes vs log P for LMC stars

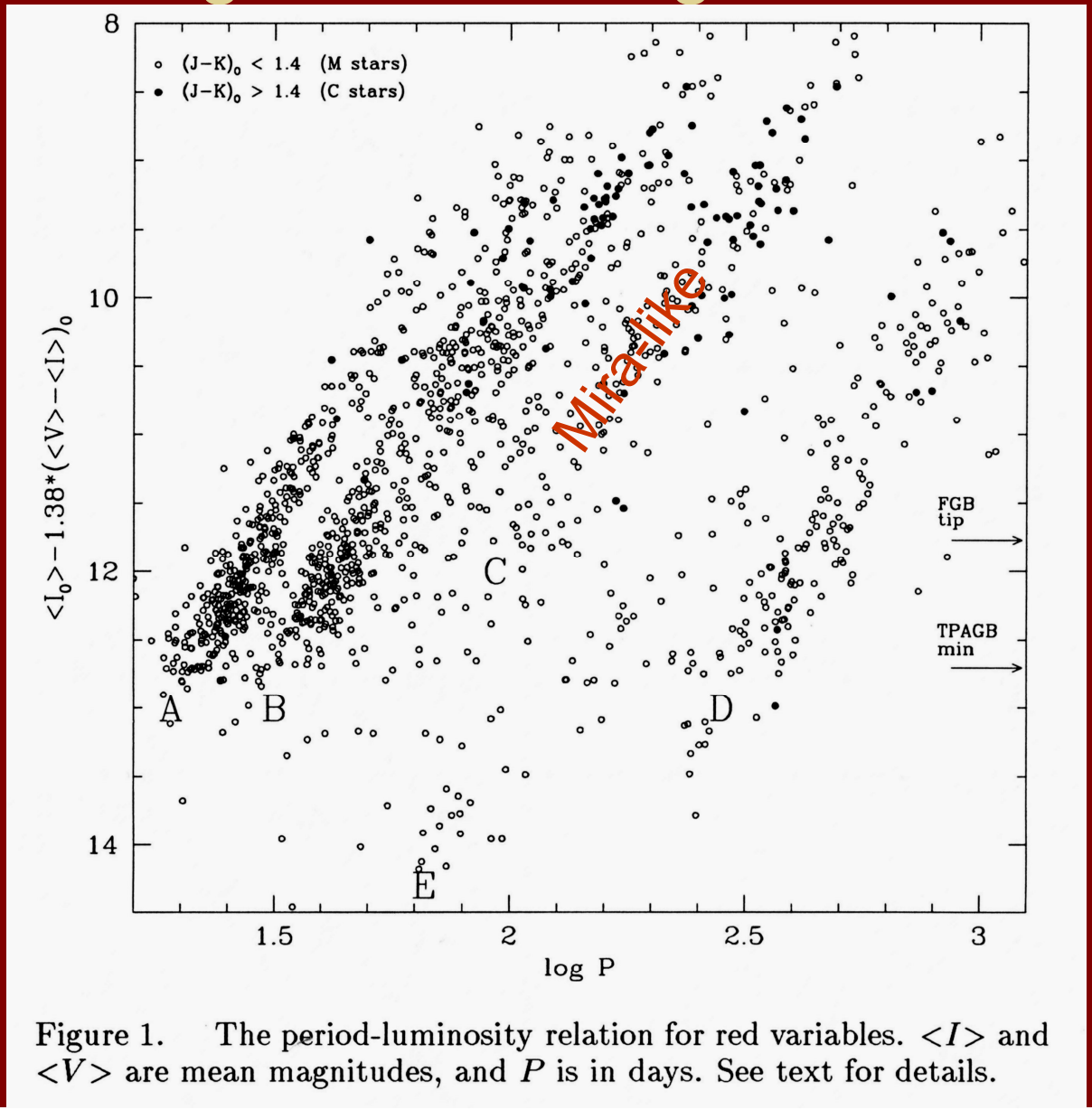


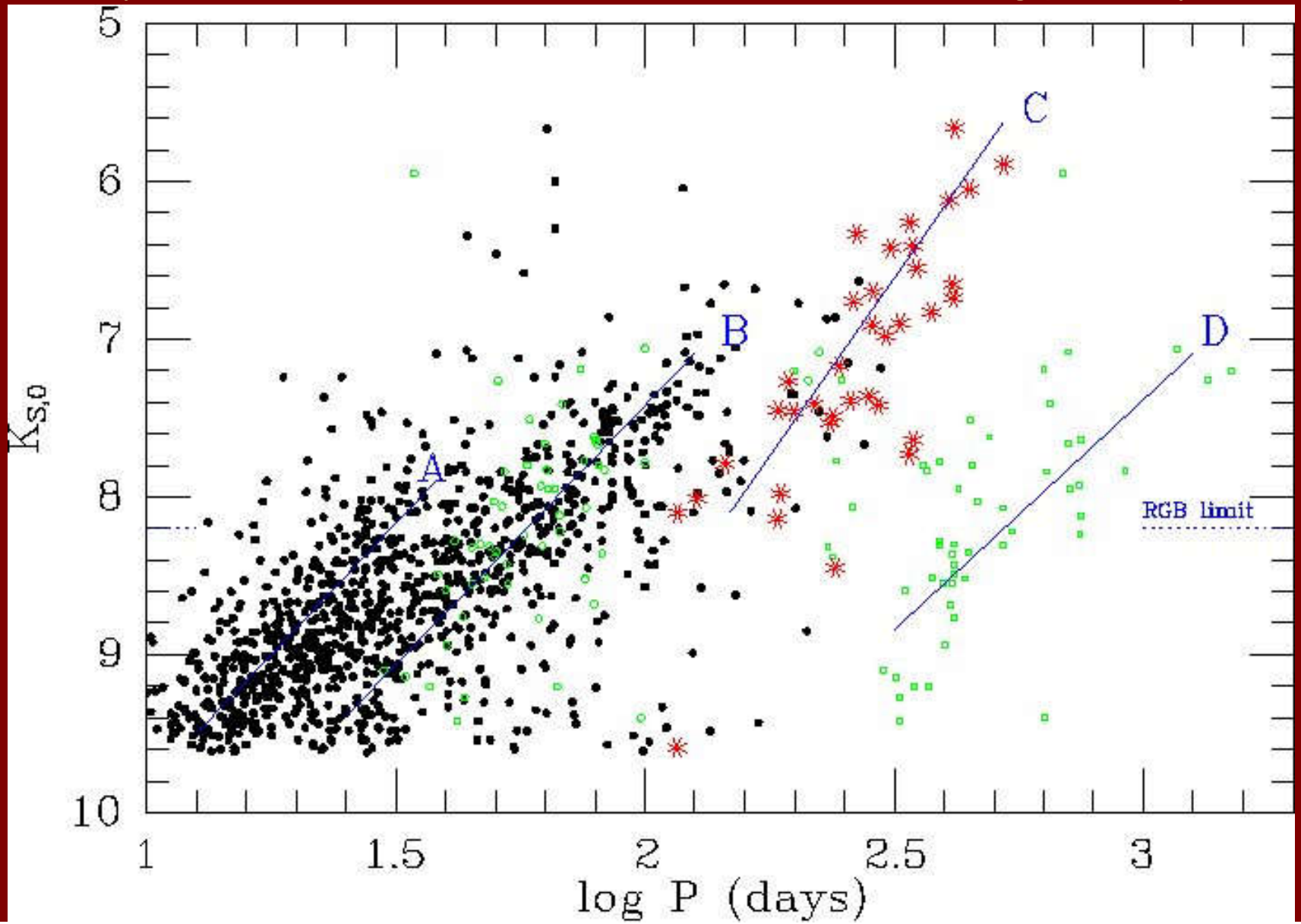
Figure 1. The period-luminosity relation for red variables. $<I>$ and $<V>$ are mean magnitudes, and P is in days. See text for details.

Baade's Window - IV

- By this time, 2MASS had surveyed Baade's Window, so we had a complete catalogue of infrared measurements.
- We searched for objects in MACHO corresponding to all the bright IR sources.
- We analysed all their periods.
- Found that there is are good period-K mag relations in the Milky Way galaxy also.

K vs log P diagram, Baade's Window
Glass and Schultheis (2003)

(Red = Miras, Green = SRVs with both short & long periods)



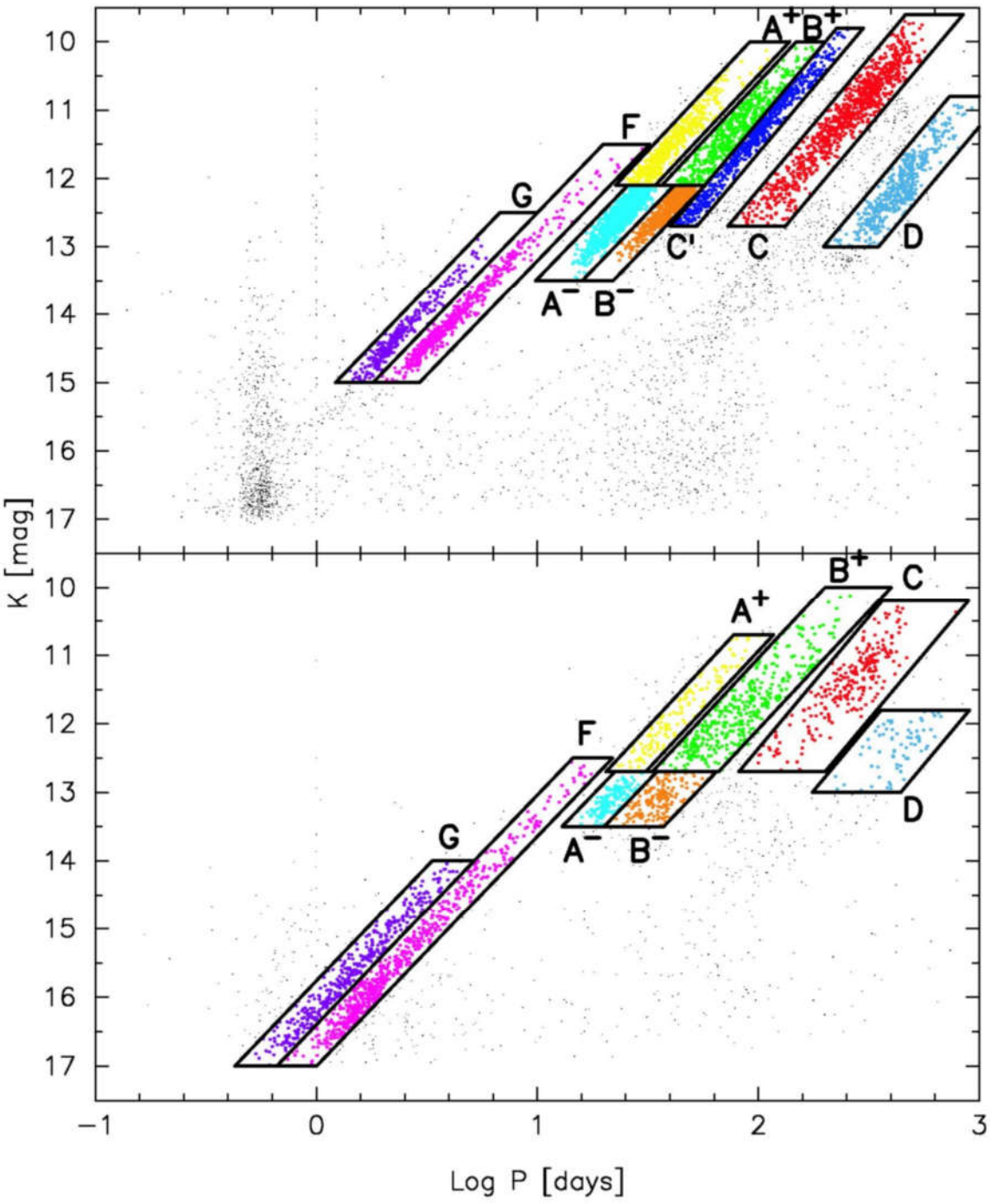
IRSF Japan/SA Telescope

1.4m f/10 telescope

SIRIUS camera

(simultaneous JHK filters)

1024 x 1024 pixels



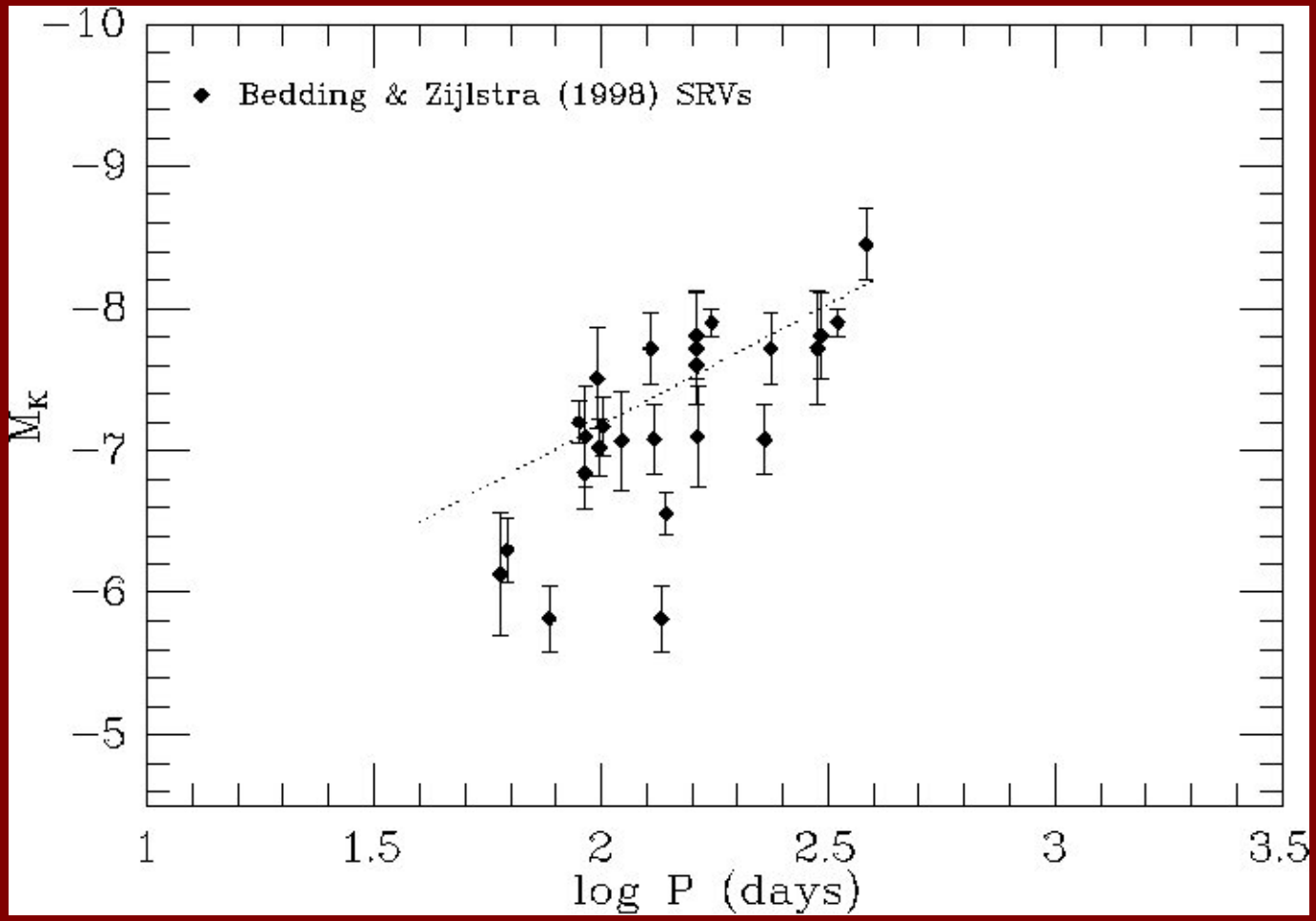
More precise sequences in the Magellanic Clouds (Ita et al (2004)

Photometry from IRSF

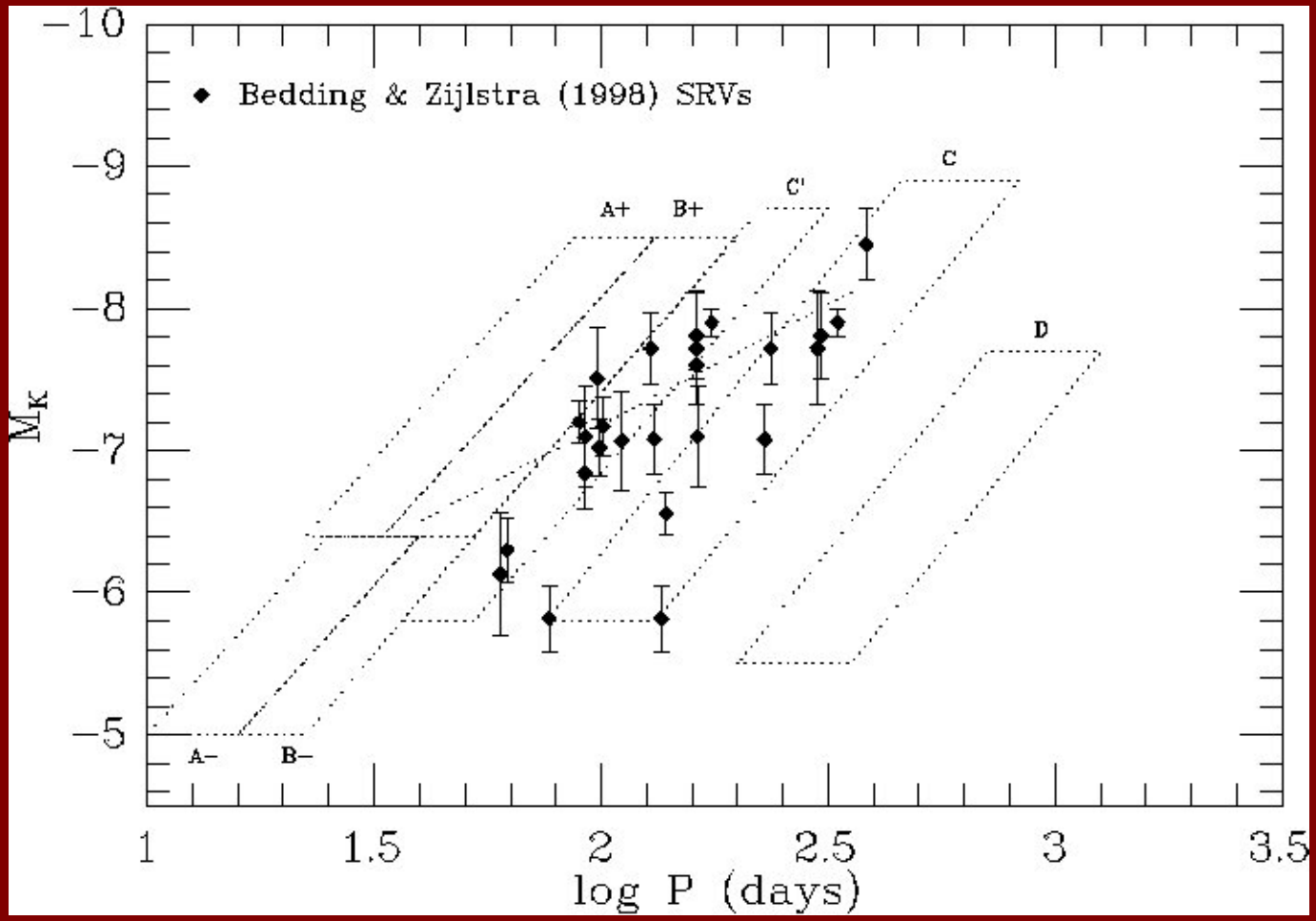
The nearby semi-regulars

- We need a way to absolutely calibrate the K, log P relations.
- Distances known from Hipparcos
- Too bright to be in 2MASS infrared survey
- K mag known from IRC Catalog or from recent photometry
- Some periods known from frequent photometry - preferably over a few years. Usually too bright to be in surveys like Superwasp!

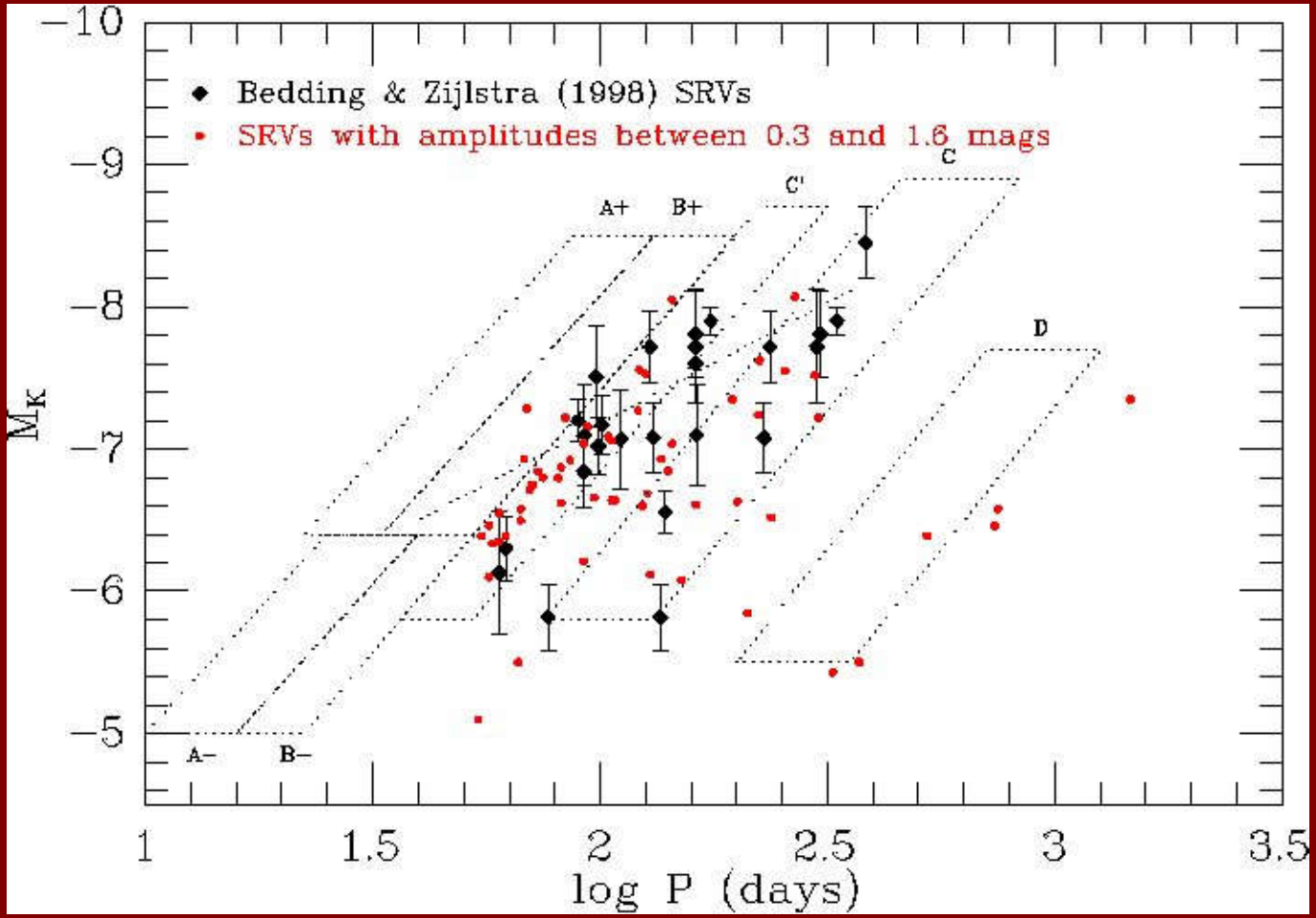
First attempt for local SRVs (Bedding & Zijlstra (1998)



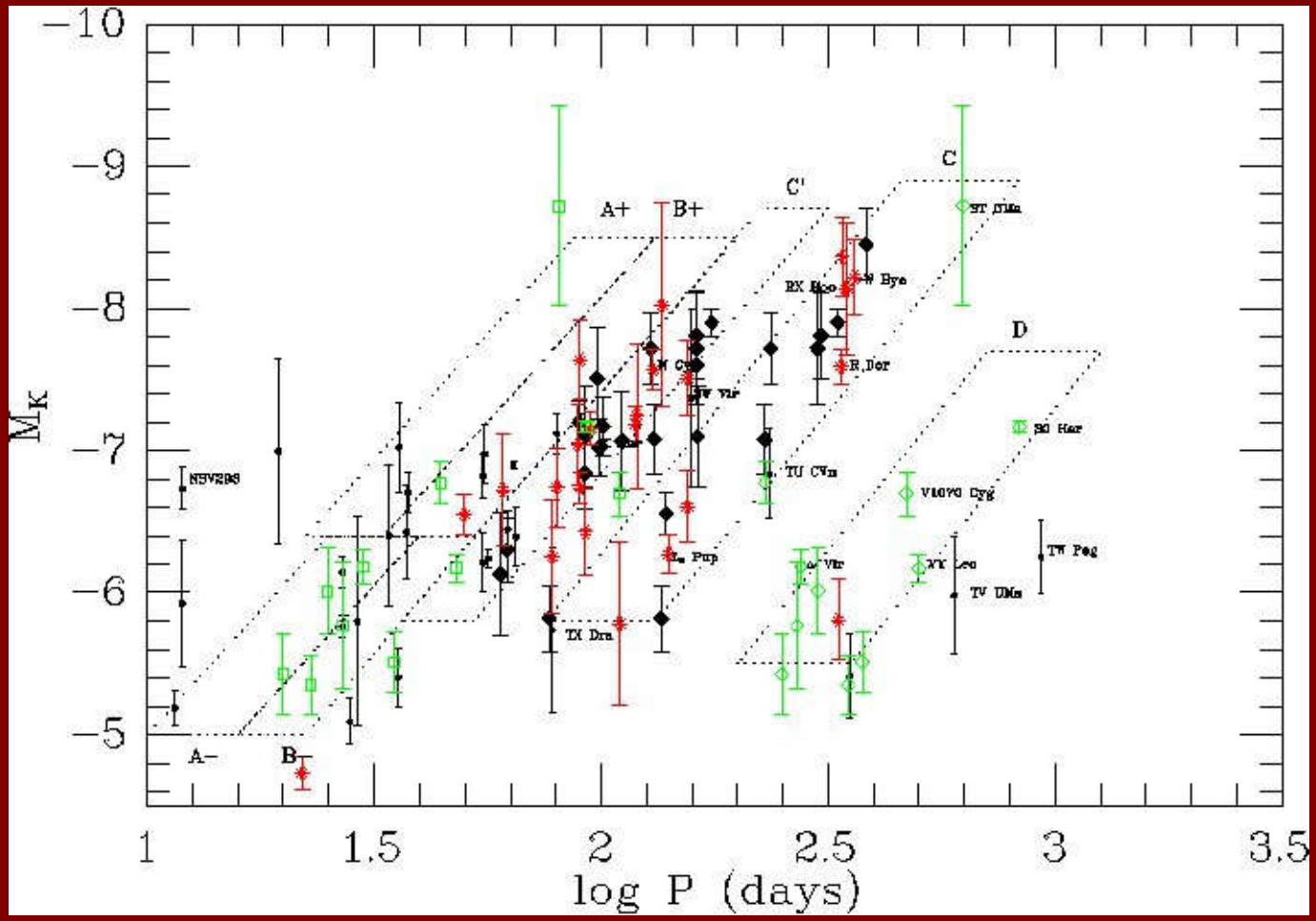
Ita's boxes added



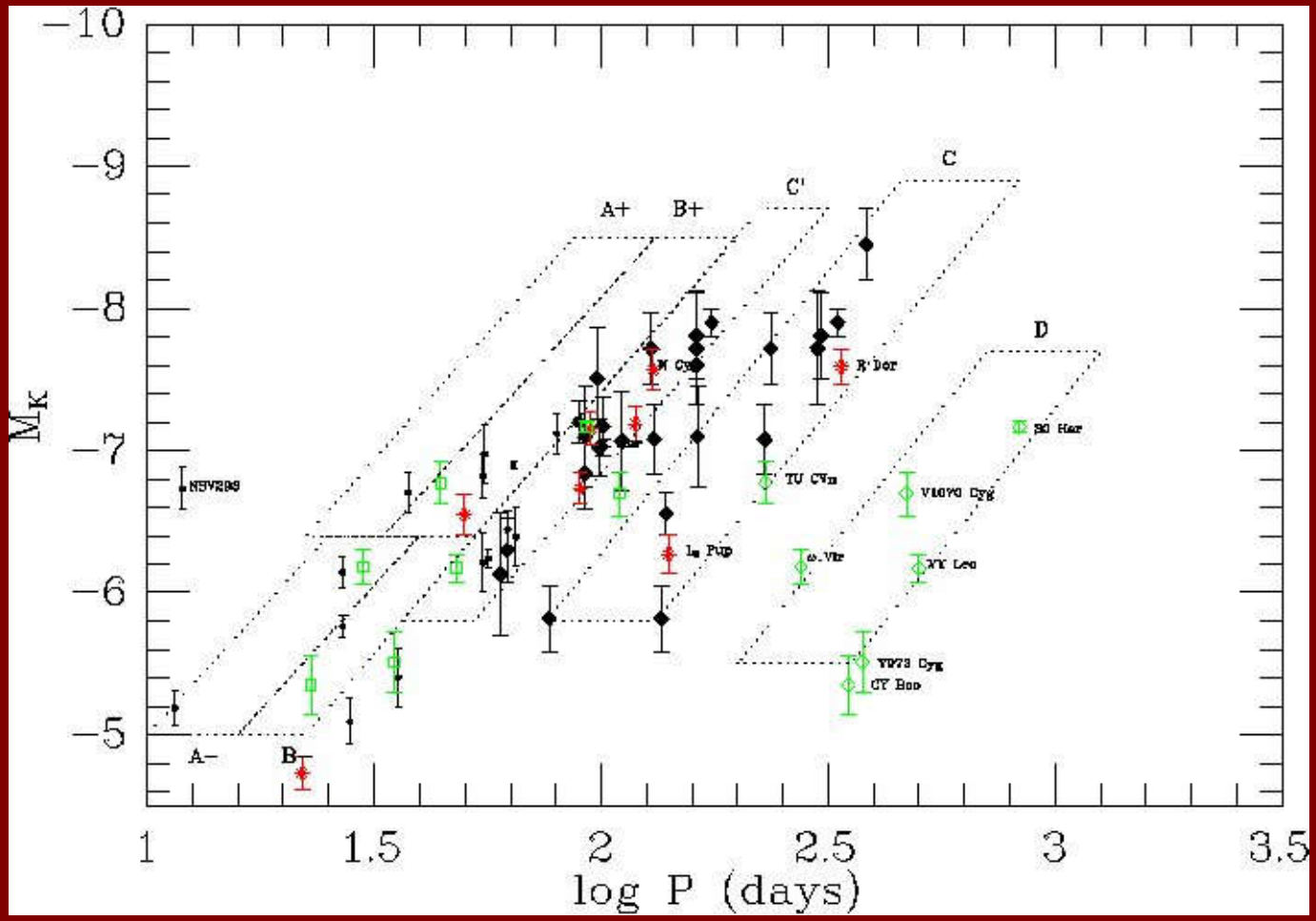
Putting in only large amplitude SRVs from Baade's Window gives same general distribution



Glass and van Leeuwen (2007)



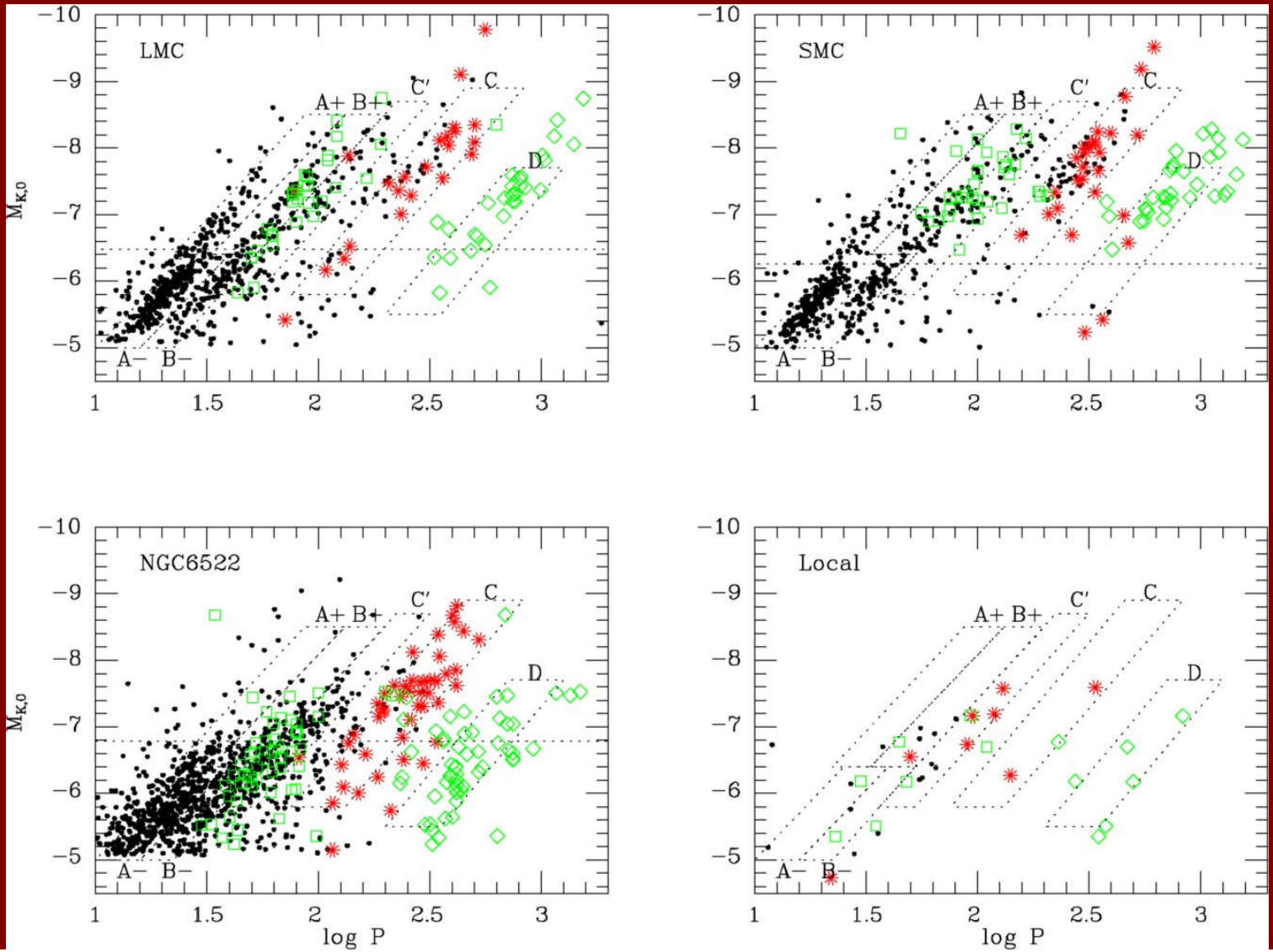
All parallaxes better than 3 x probable error



All parallaxes better than 10 times probable error

Comparison of fields from Magellanic Clouds and our galaxy

(Schultheis, Glass, Cioni, 2004) [absolute magnitudes – i.e., as if all stars were at the same distance of 10 parsecs (30 light years)]



Still needed!

- More semi-regular variables with known periods.
- Periods can be got from good photometry carried out many times over 2 or 3 years.
- Must have known distances from Hipparcos.
- Need K-band infrared photometry.
- They are bright, late-type M stars.

The End