

A large, luminous, multi-colored nebula or galaxy cluster against a dark background. The central region is bright yellow and orange, transitioning into darker red and brown hues towards the edges. The overall shape is irregular and somewhat elongated vertically.

Observational constraints on dust production

Jacco van Loon, Keele University (UK)

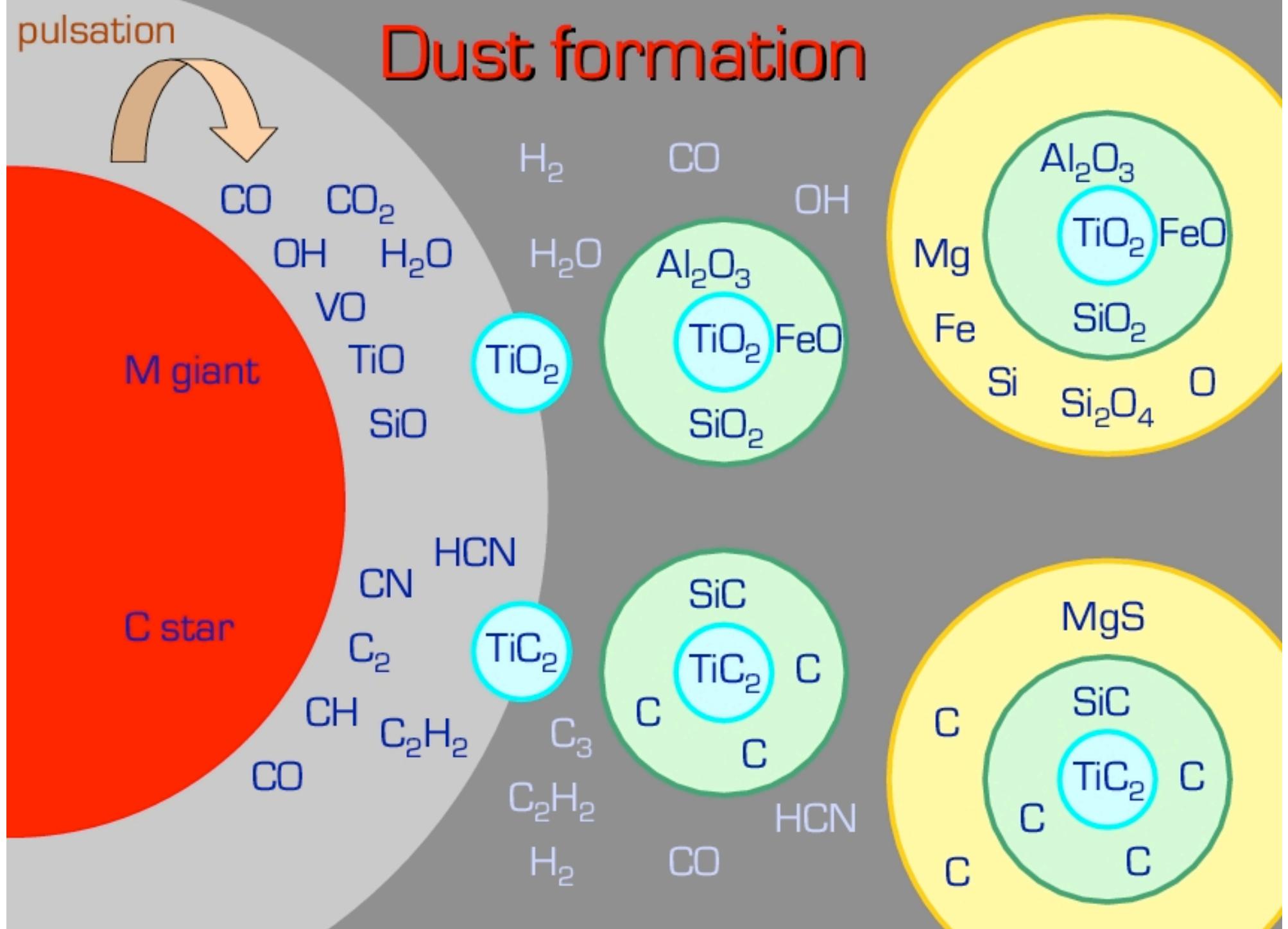
Dust factories

- AGB stars (M-type, carbon stars, VLTP, RCB)
- first ascent RGB stars
- red supergiants
- (some?) supernovae
- some novae
- some WR stars, LBVs, wind-colliding binaries
- slow shocks in molecular clouds?

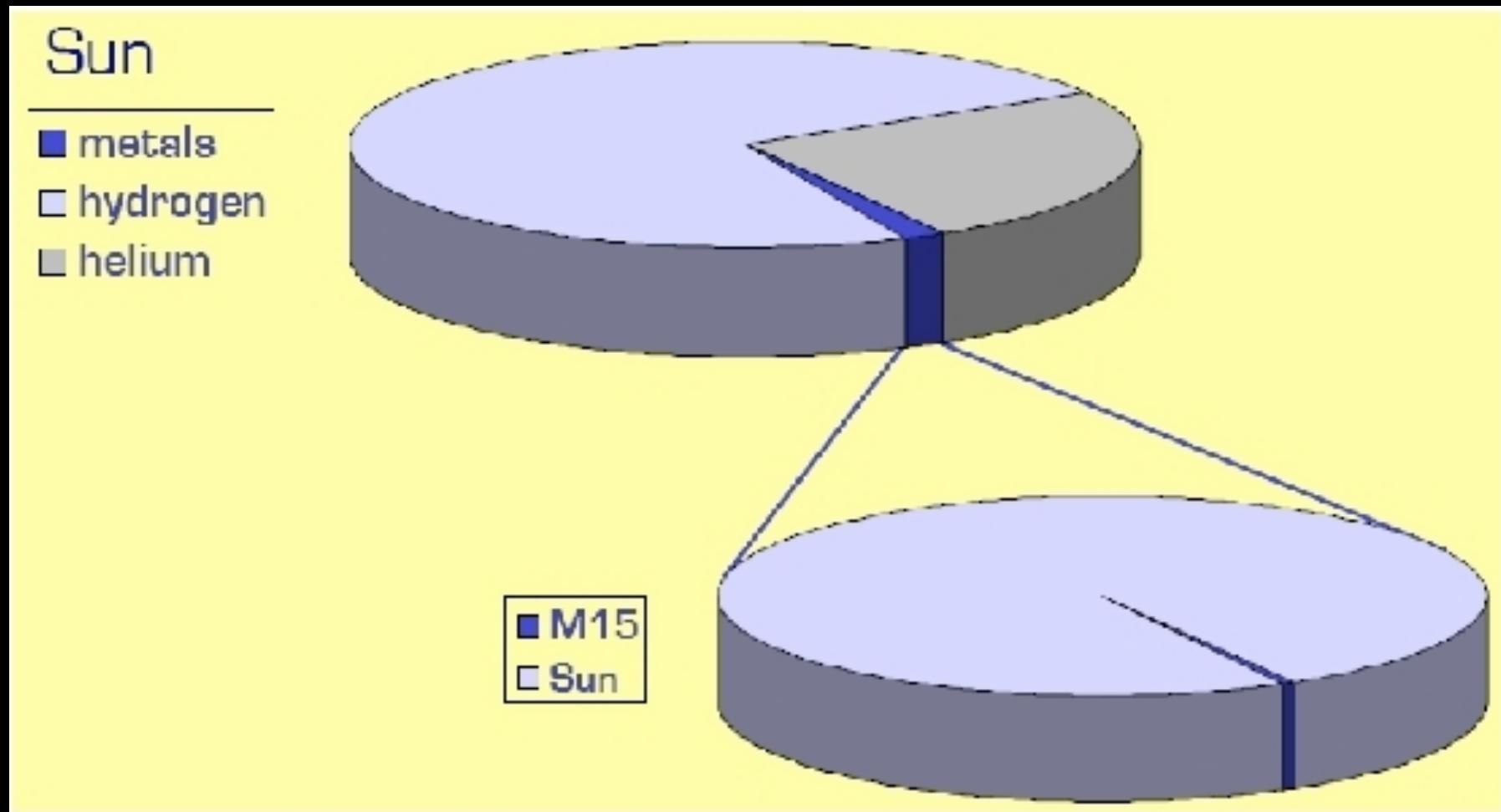
Dust formation in red (super)giants

see also talks by Henkel, Zhukovska
(and others) and the poster by Woods

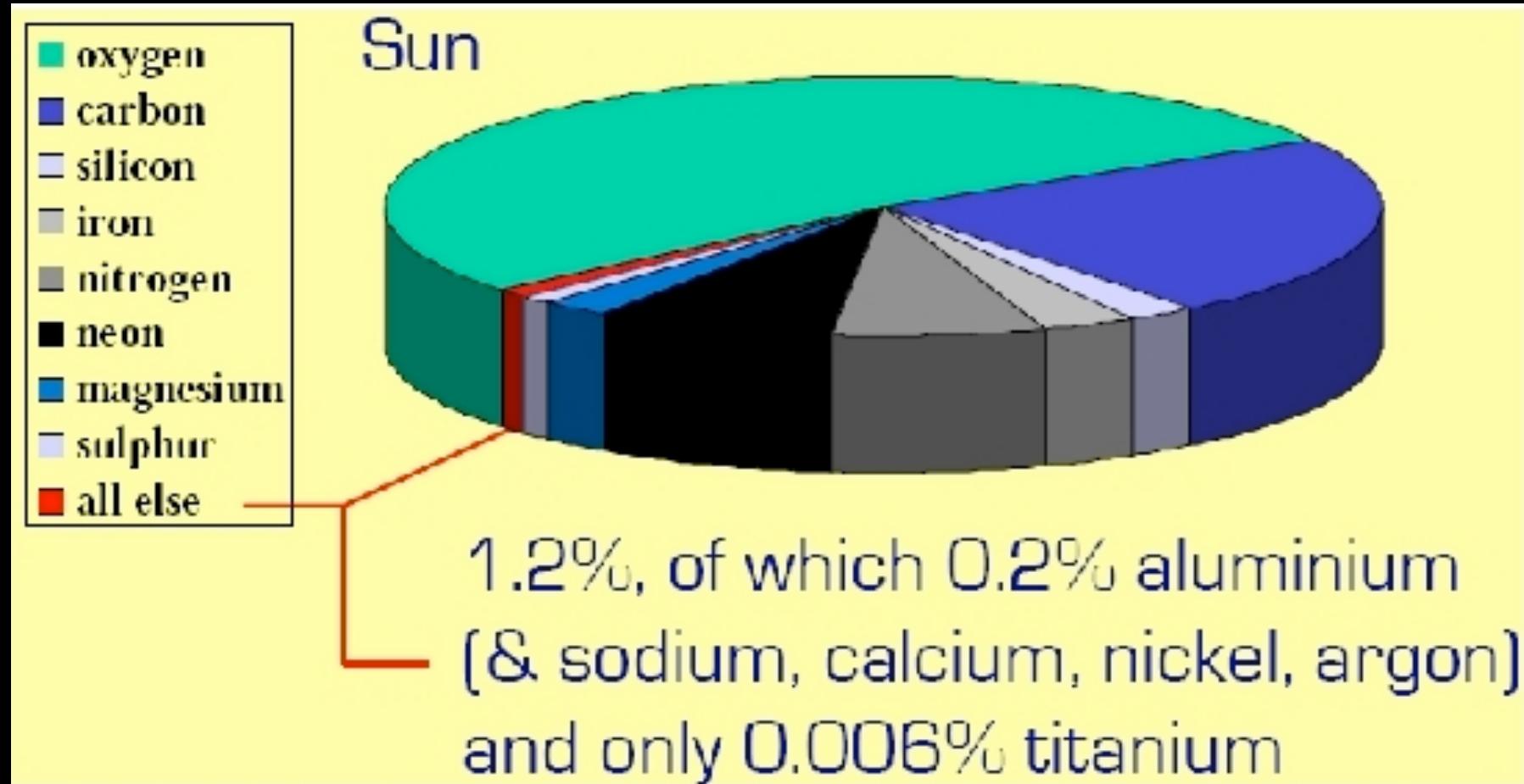
Blommaert et al. (2006), Sloan et al. (2006, 2008),
Zijlstra et al. (2006), Lagadec et al. (2007), et cetera



Possible condensates: metals



Trace elements may be key

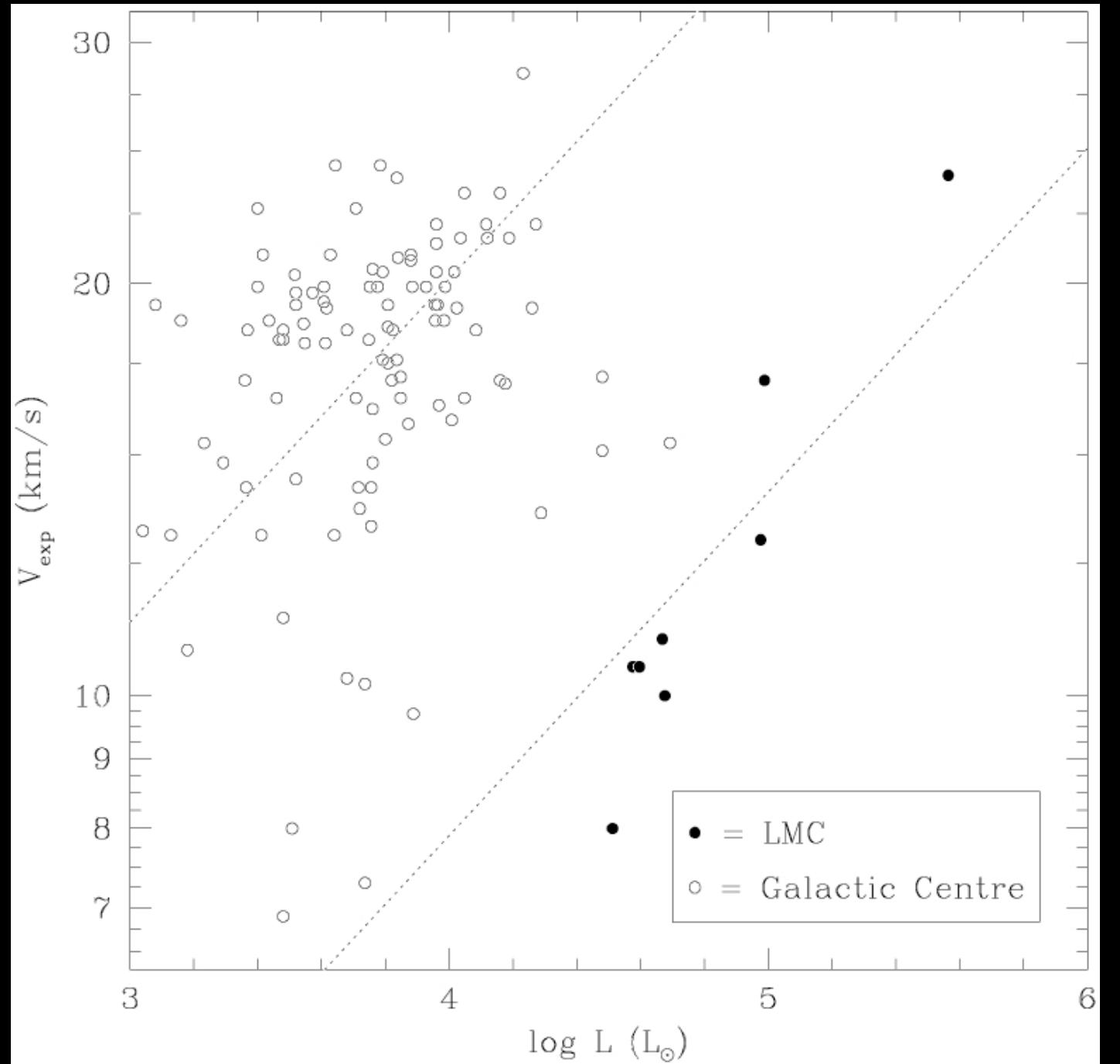


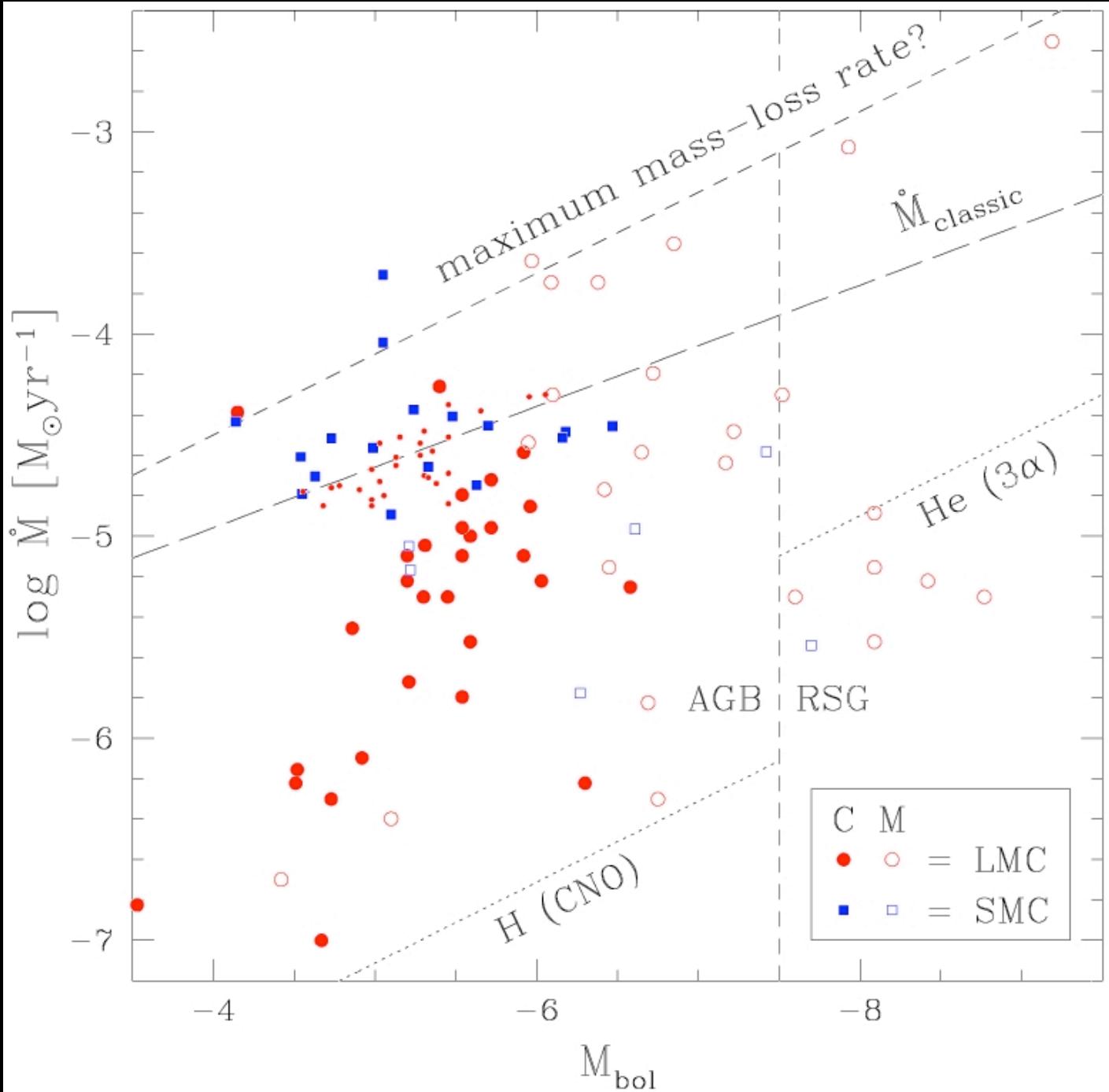
Test 1

do
(luminous)
cool star
winds
behave like
dust-driven
winds?

YES

Marshall et al.
(2004)





Test 2

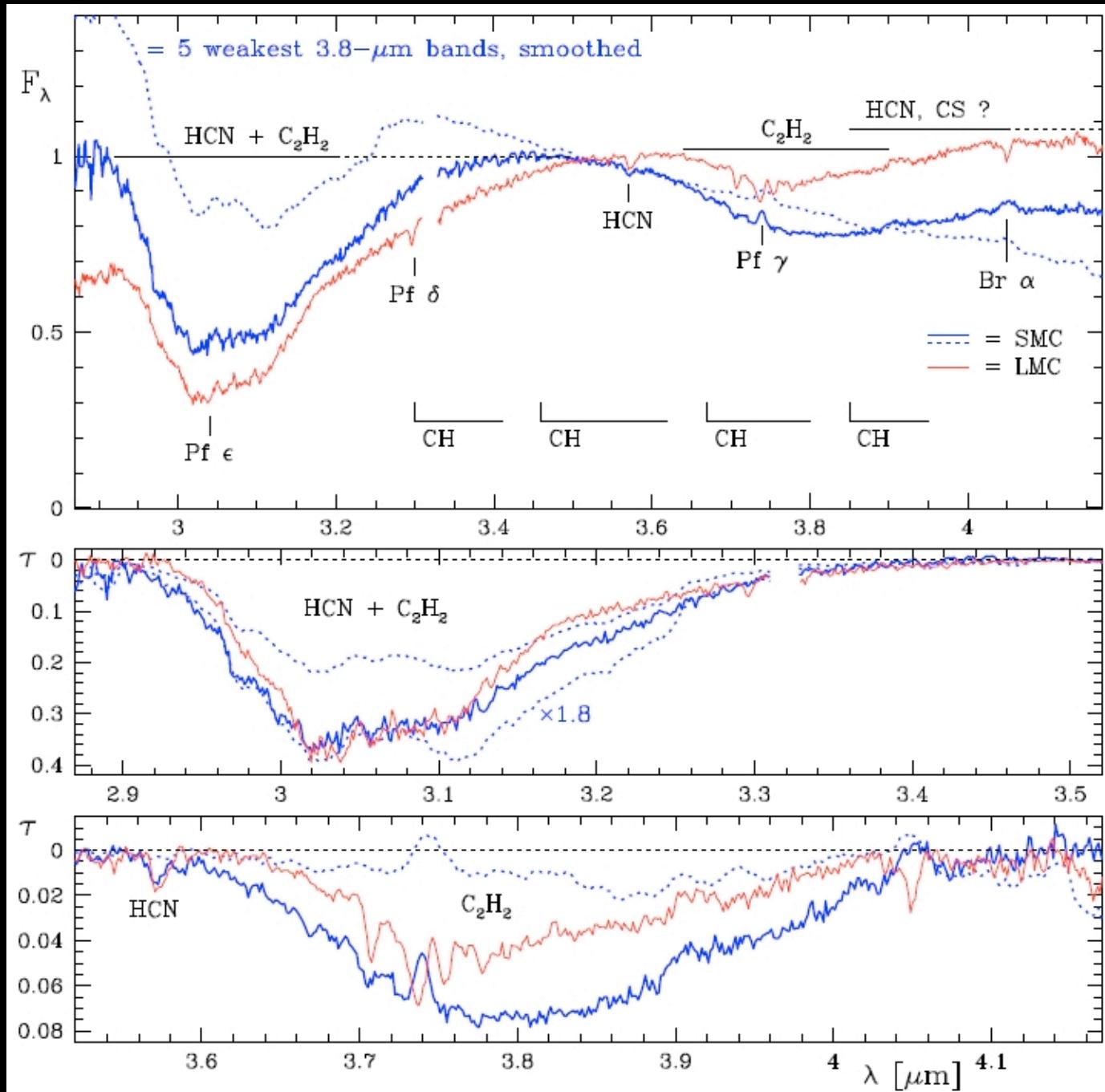
does dust
content scale
with
(primordial)
metal
content?

YES

van Loon (2006)

Chemistry of carbon stars

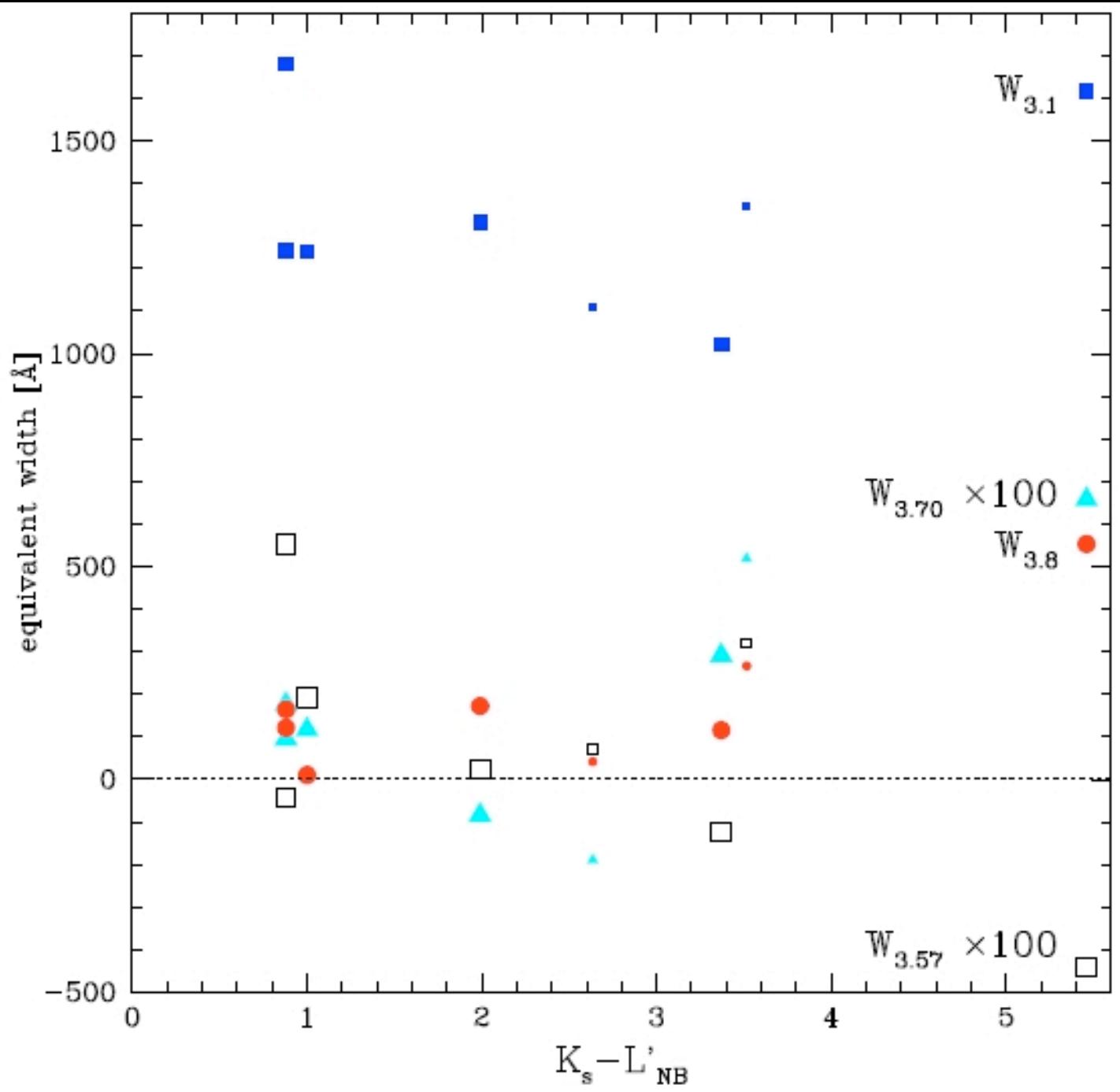
carbon is produced by the star



Less metals,
but more
free carbon?

Stronger
acetylene
bands, but
less dust !?

van Loon et al. (2008)

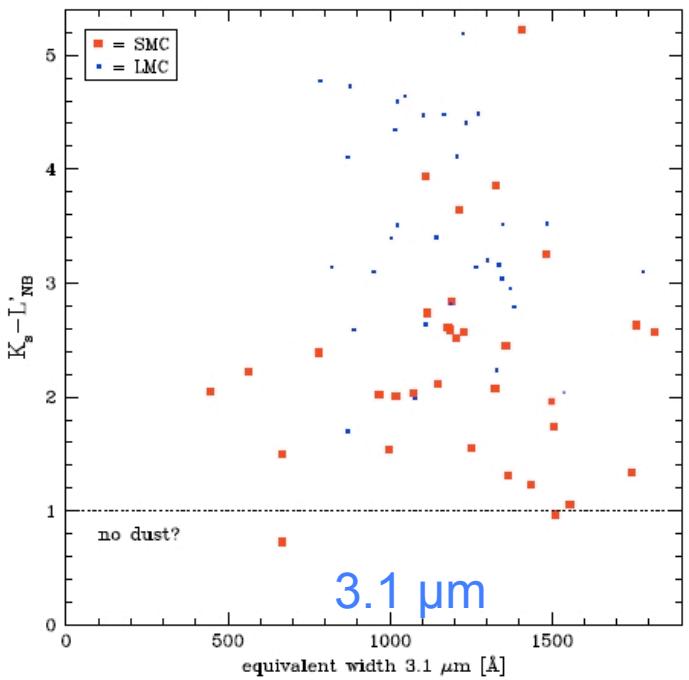


more evolved,
dustier, stronger
acetylene bands

NGC419 (SMC) +
NGC1978 (LMC),
same metallicity

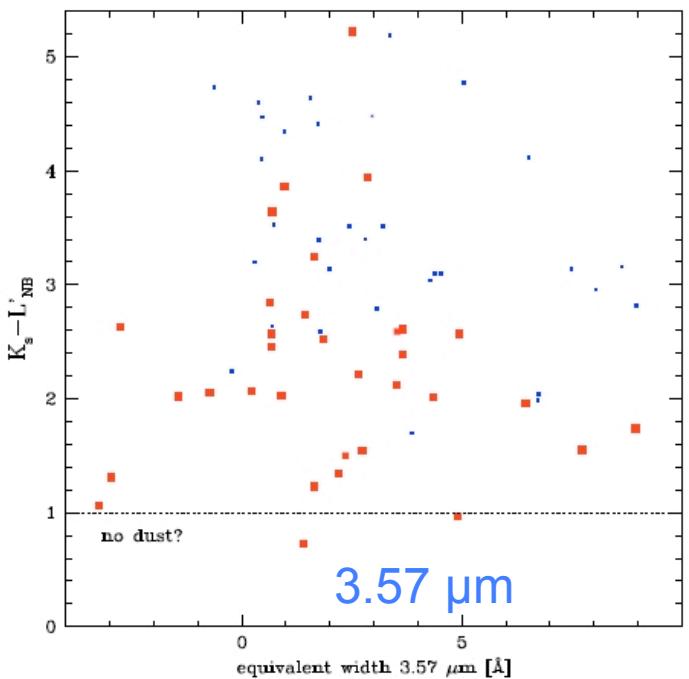
van Loon et al.
(2008)

K-L

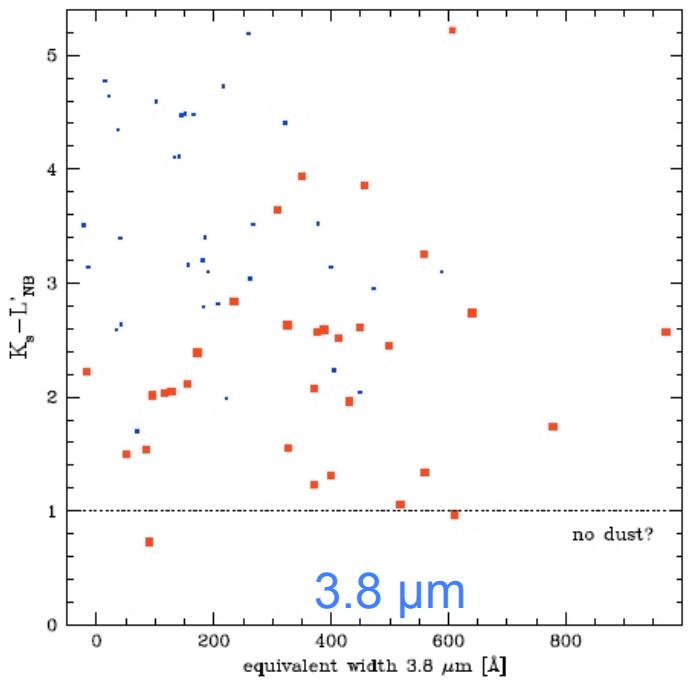


$3.1 \mu\text{m}$

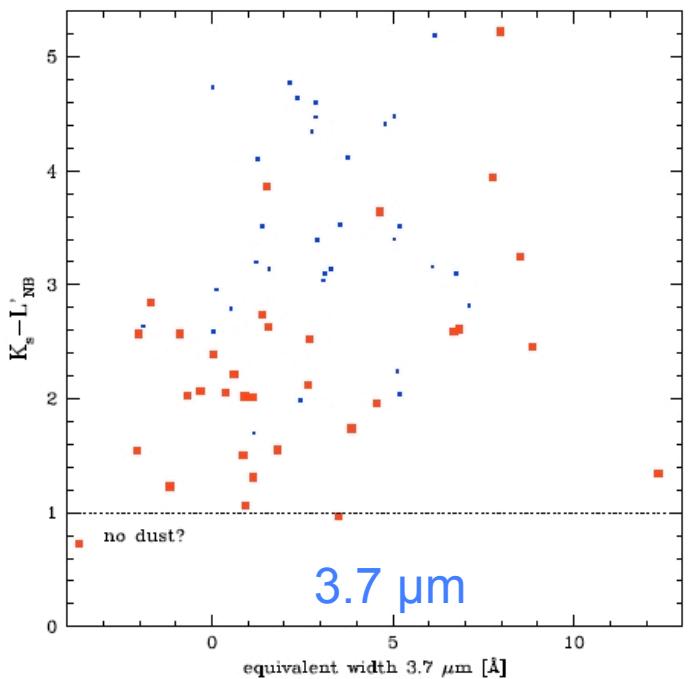
K-L



$3.57 \mu\text{m}$



$3.8 \mu\text{m}$



$3.7 \mu\text{m}$

More metals,
but less free
carbon?

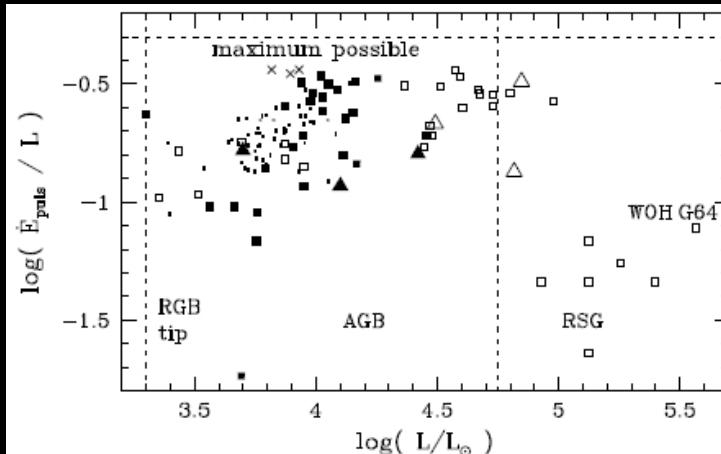
Weaker
acetylene
bands, but
more dust !?

van Loon et
al. (2008)

The rôle of pulsation

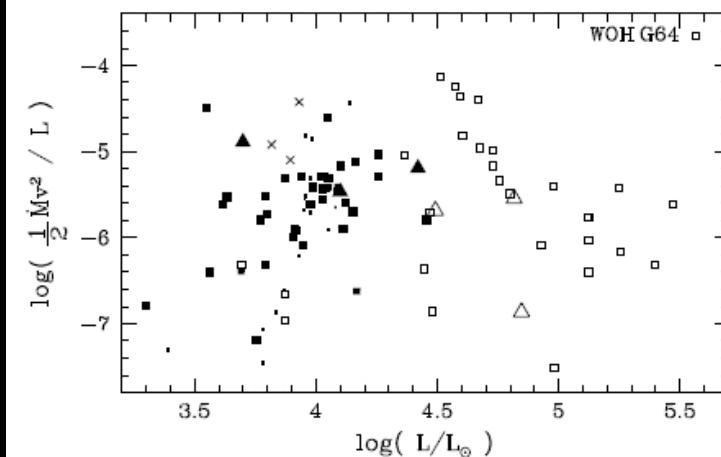
dust does not form in photospheres, but in an extended atmosphere possibly due to strong radial pulsation with periods ~200-1200 days

pulsation power / L



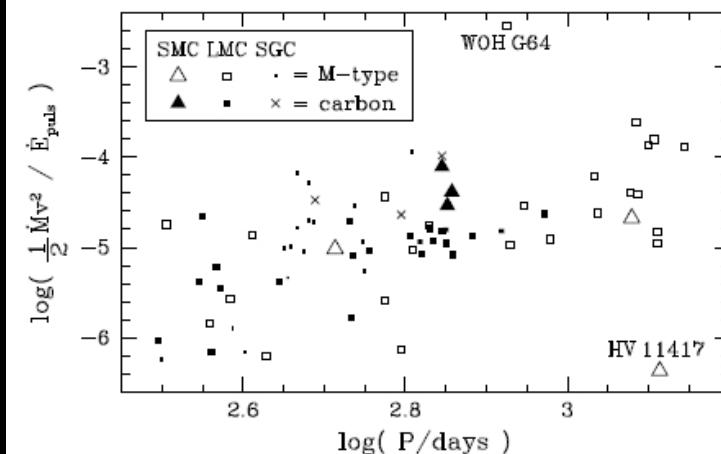
red supergiants
relatively weaker,
but as strong as
typical AGB stars !

wind power / L



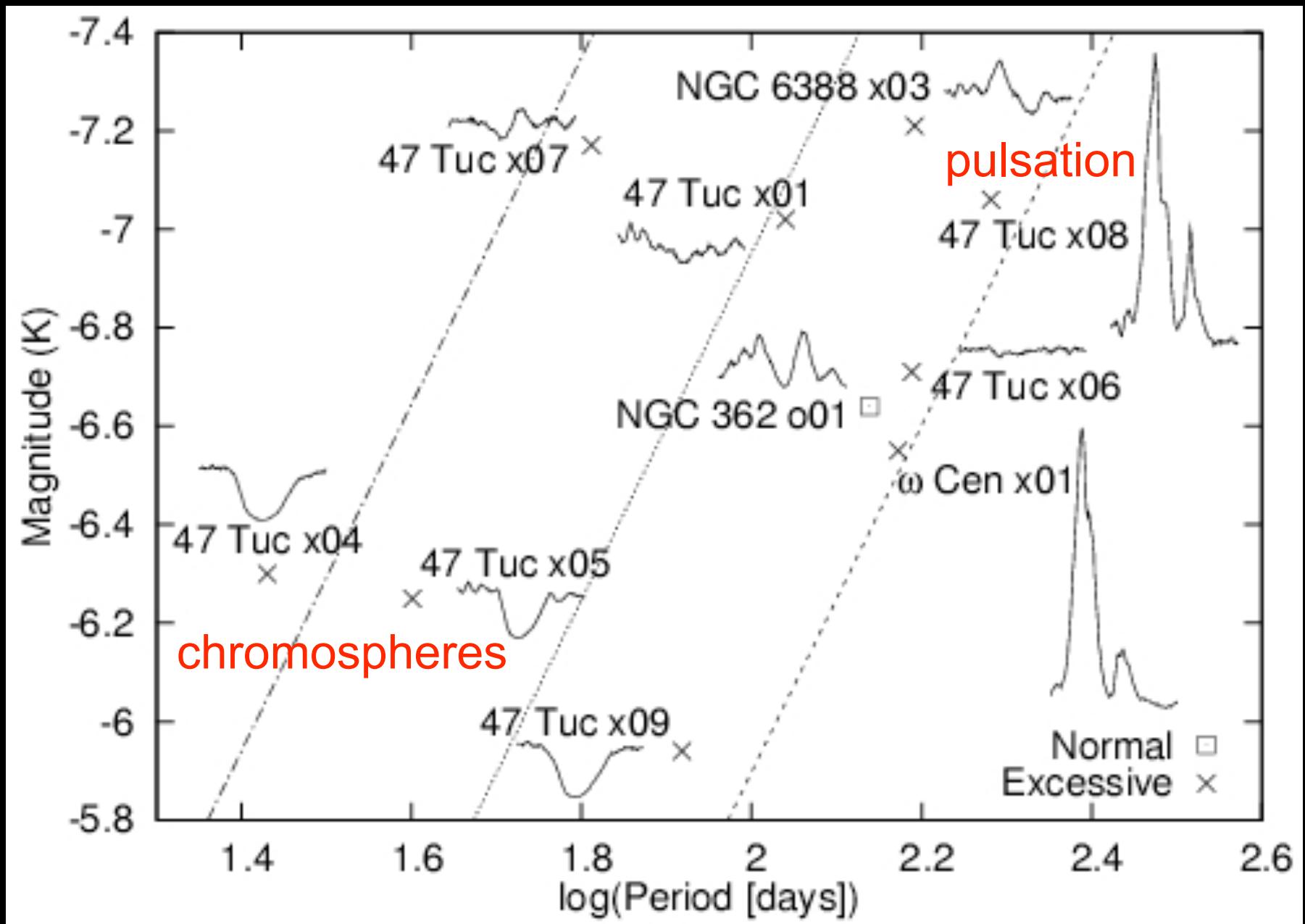
tip-AGB stars
most effective?

wind power /
pulsation power



slower pulsation
more effective

van Loon et al. (2008)

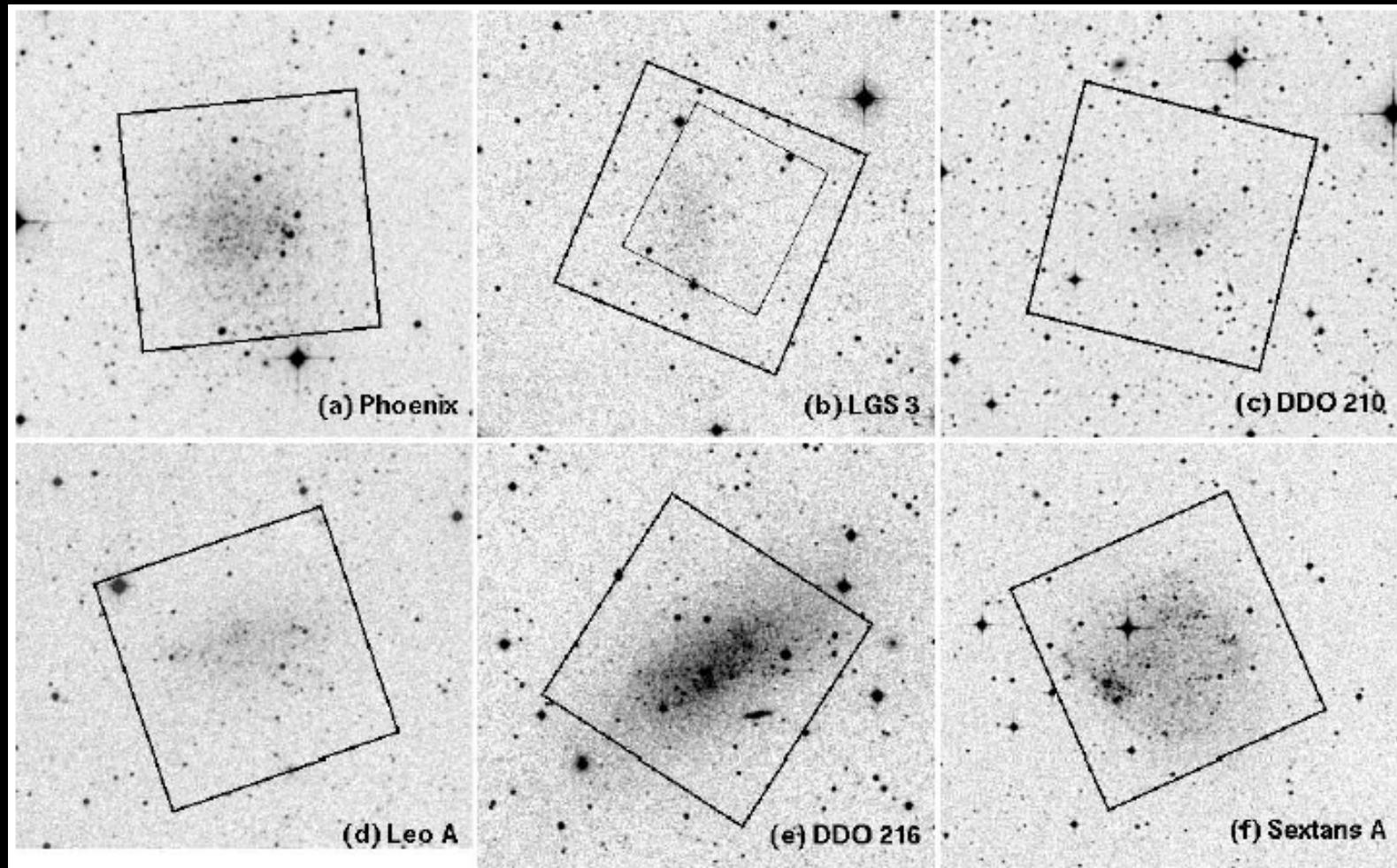


McDonald & van Loon (2007)

(other) Local Group dwarf galaxies

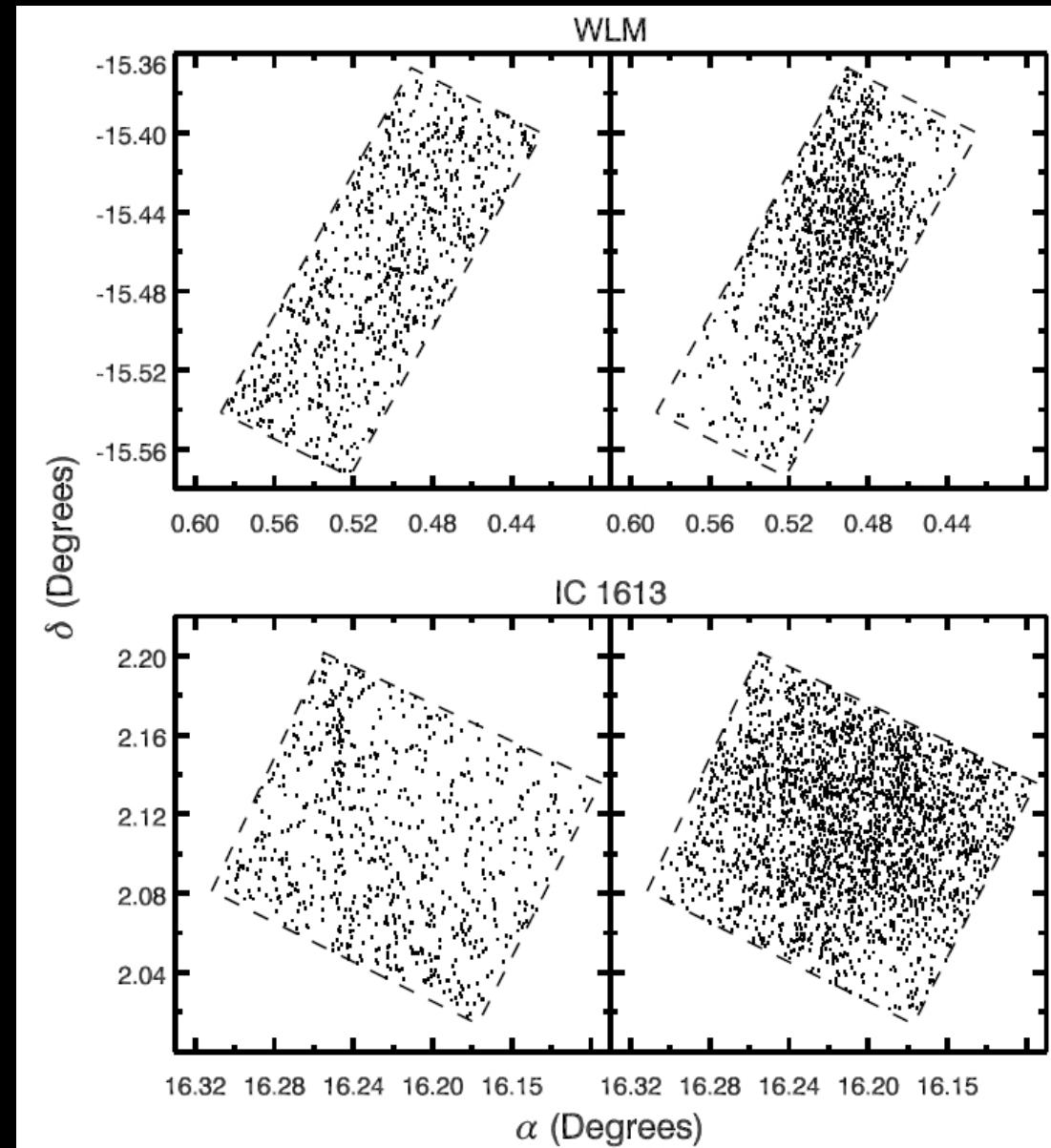
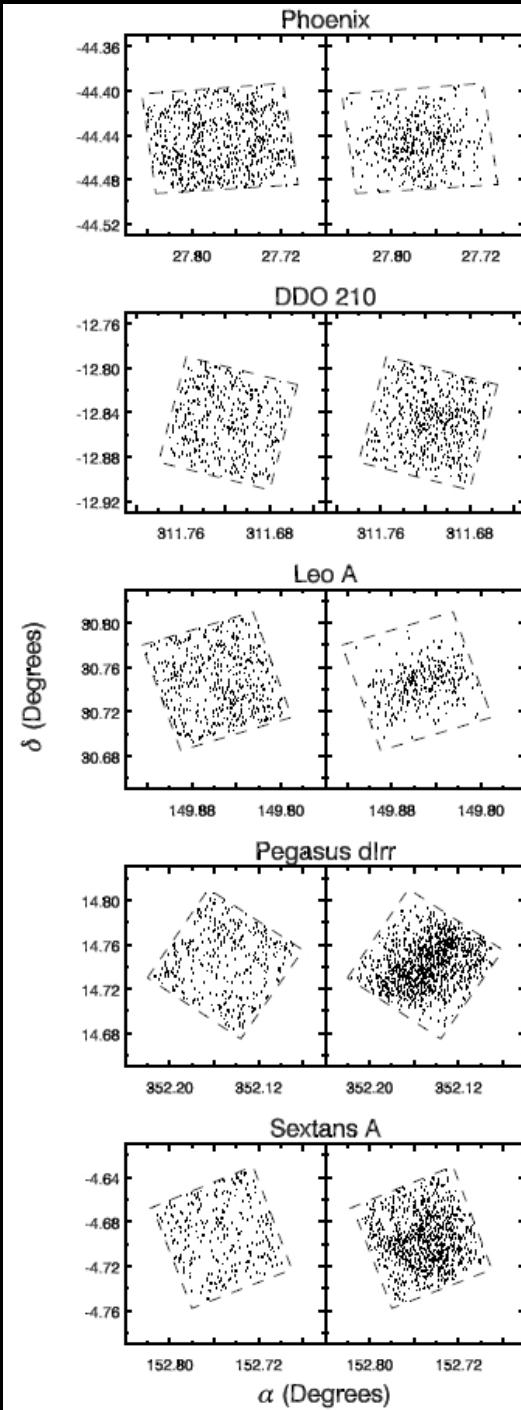
see also the talks by Lagadec, Matsuura

6+2 nearby dwarf irregular galaxies

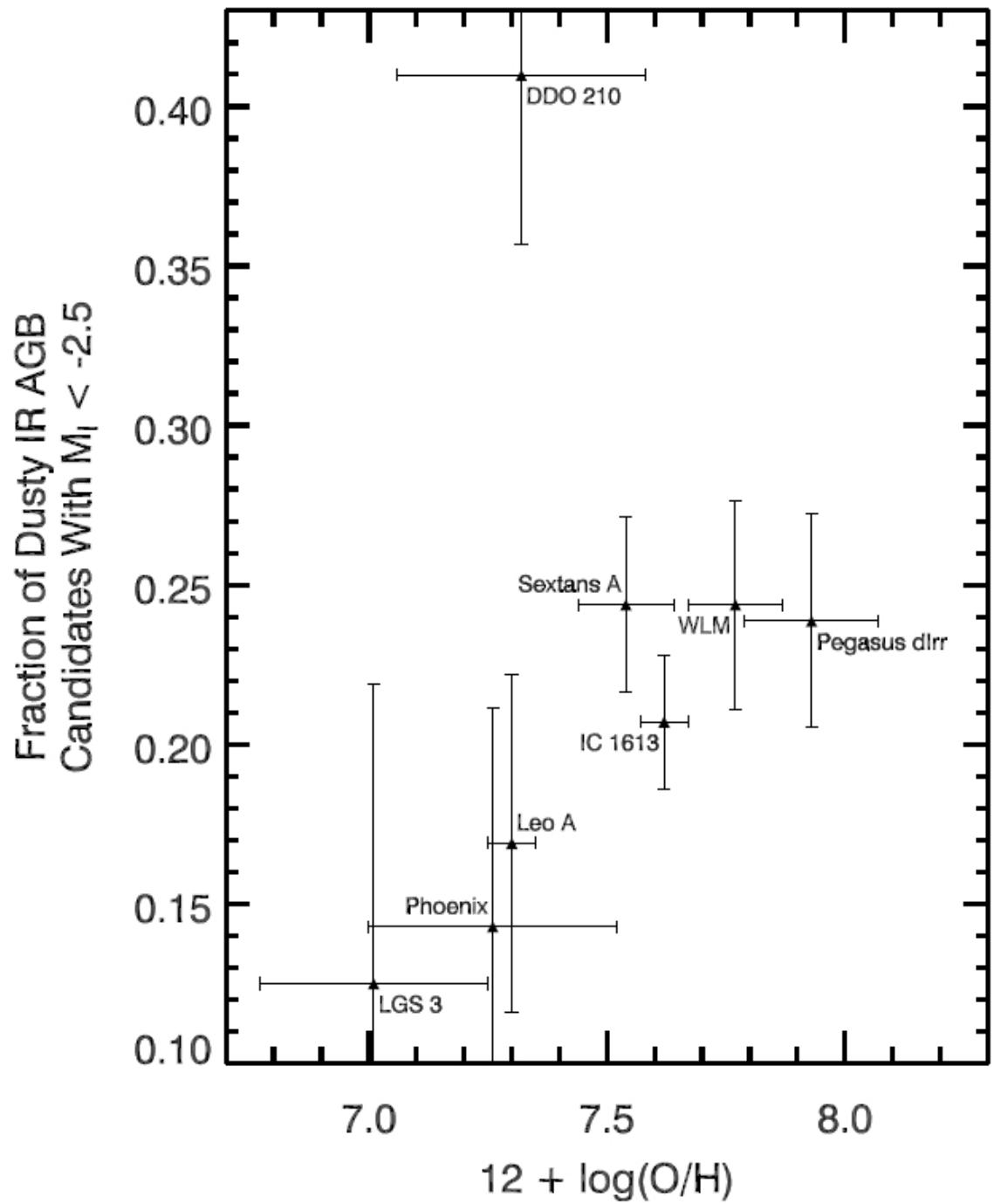


Boyer et al. (2009)

seperate out background galaxies



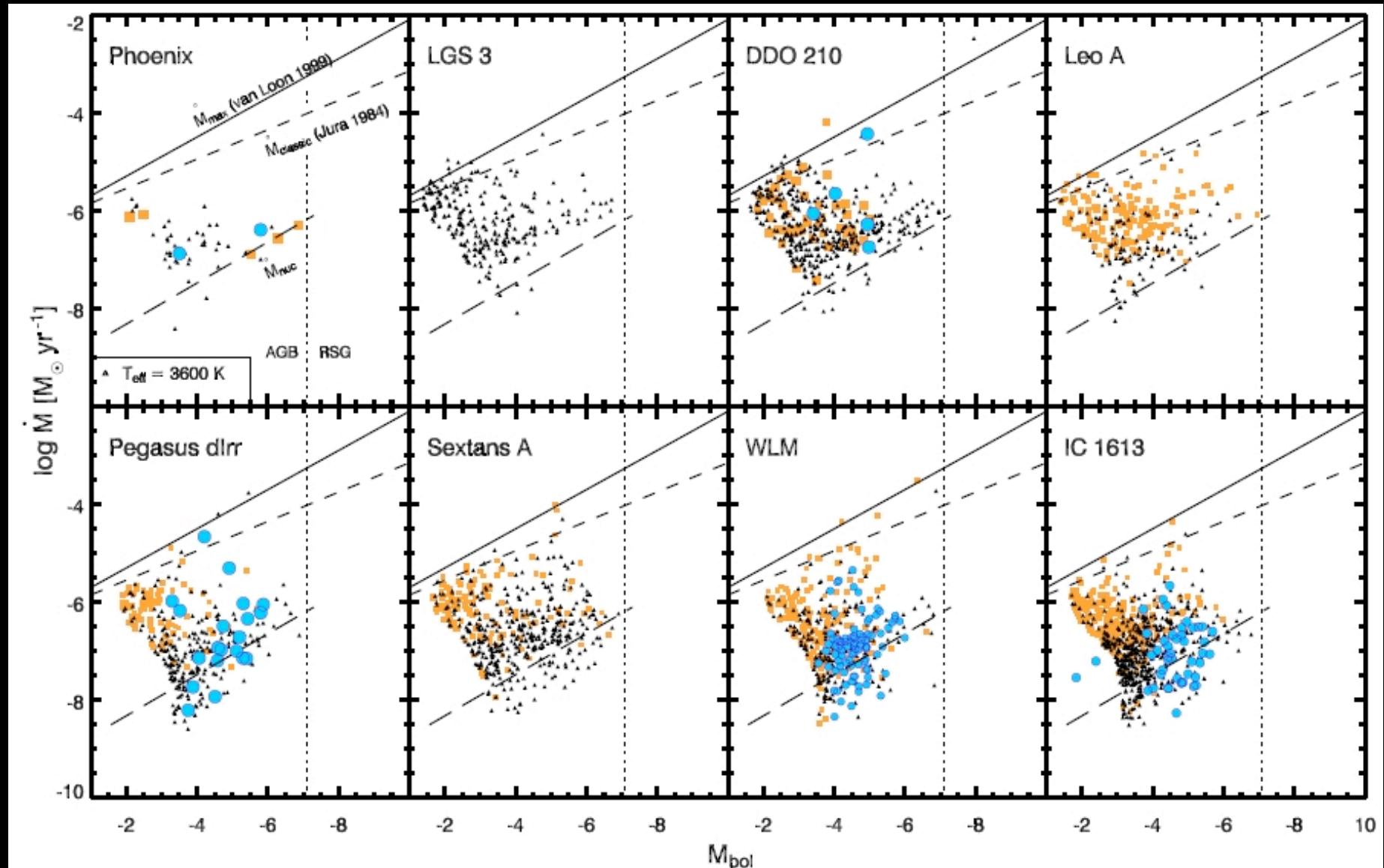
Boyer et al. (2009)



dust forms, but
less abundantly, at
lower metallicity

Boyer et al. (2009)

but mass-loss rates largely consistent with Magellanic Clouds



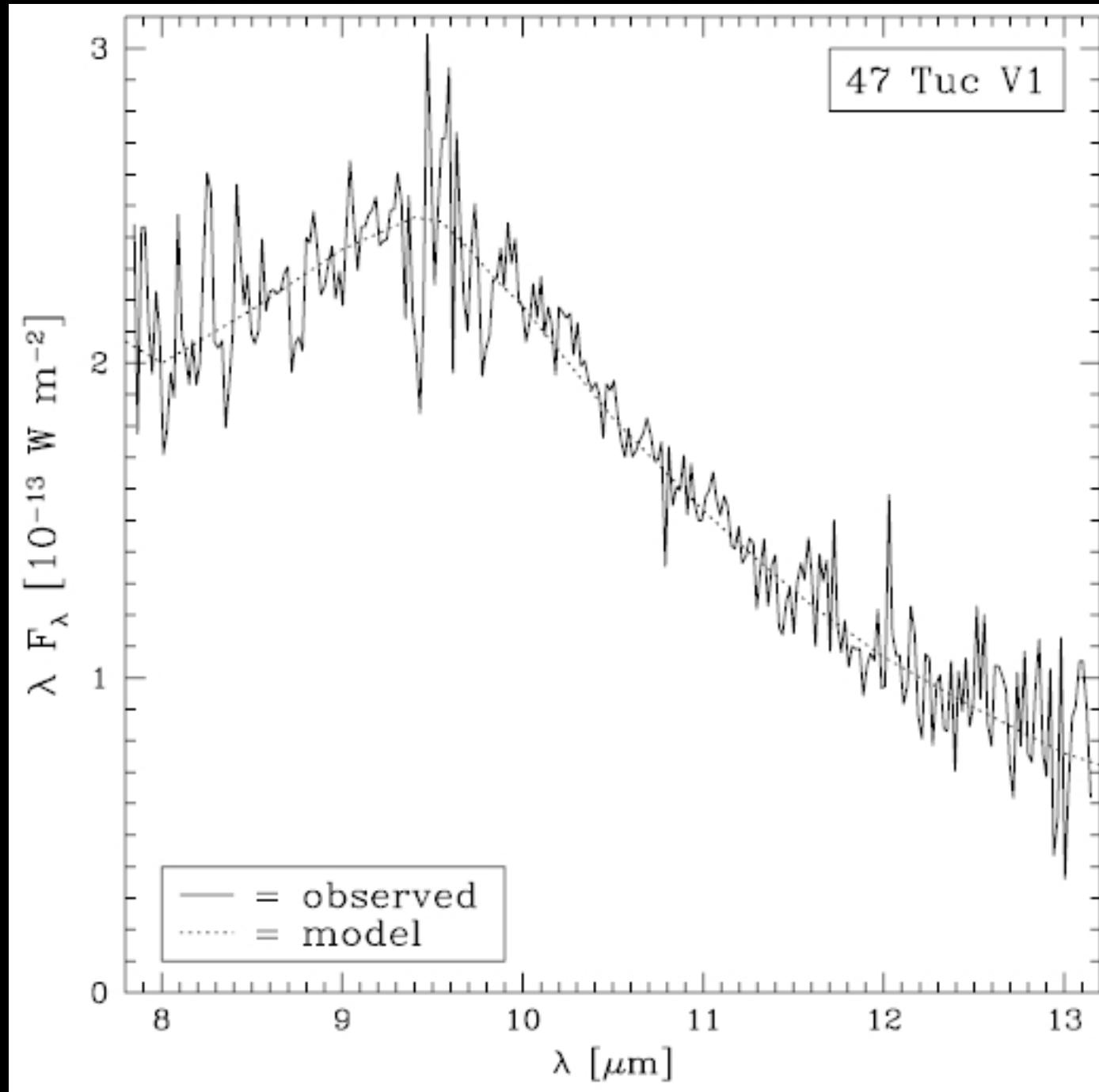
■ = likely background galaxies

• = known carbon stars

Boyer et al. (2009)

Galactic globular clusters

metal-poor, low-mass RGB (and AGB) stars
similar composition, age, history in a cluster
clusters differ mainly in composition (& size)

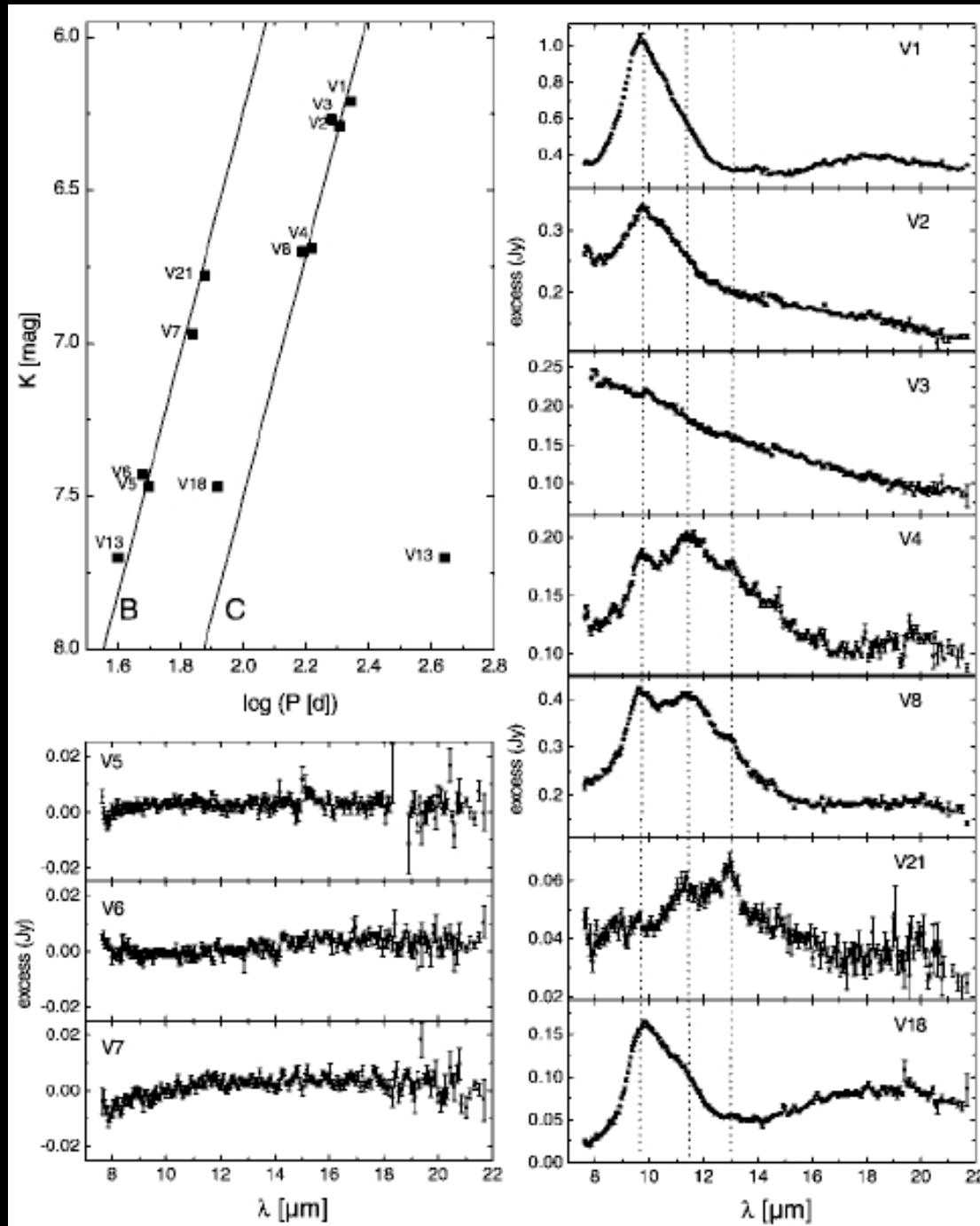


47 Tuc

“SMC metallicity”

silicates!

van Loon et al. (2006)



... but not
just silicates!

aluminium-oxide bonds?

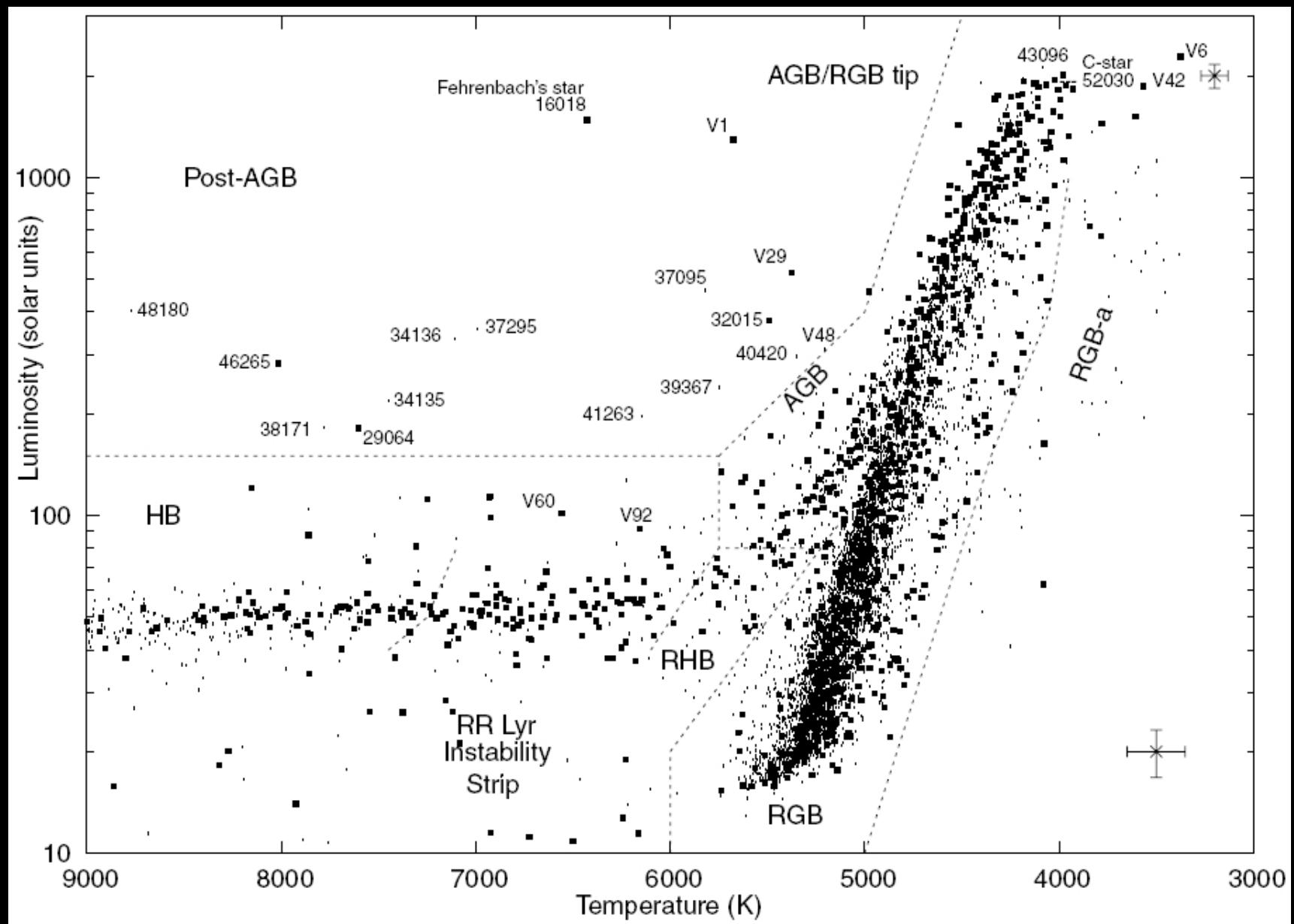
Lebzelter et al. (2006)



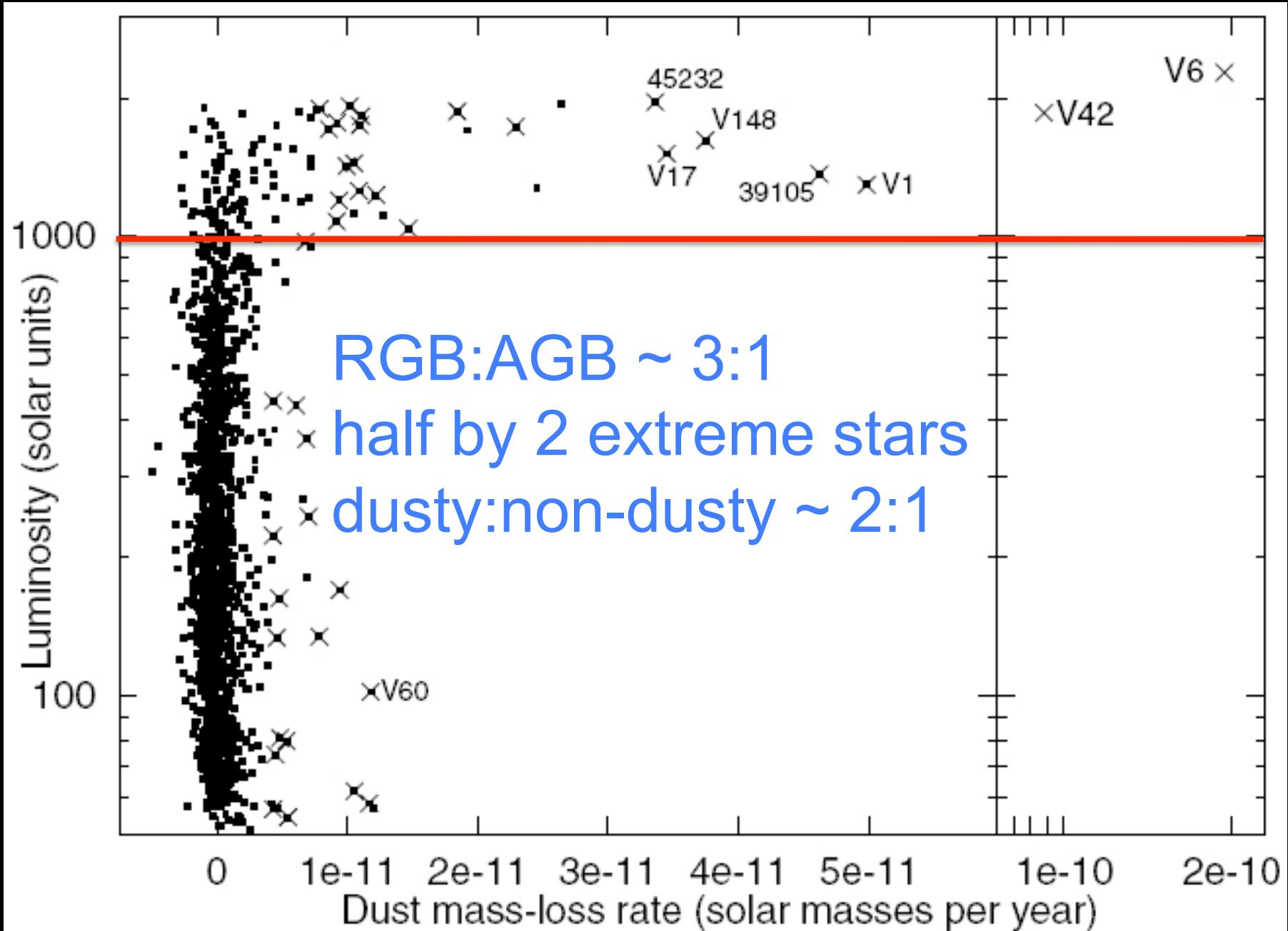
ω Cen

Spitzer IRAC
+MIPS imaging
(Boyer et al. 2008;
McDonald et al.
2009) and IRS
spectroscopy
(17+18 April 2009)

very populous so well-samples rare phases of evolution



McDonald et al. (2008)

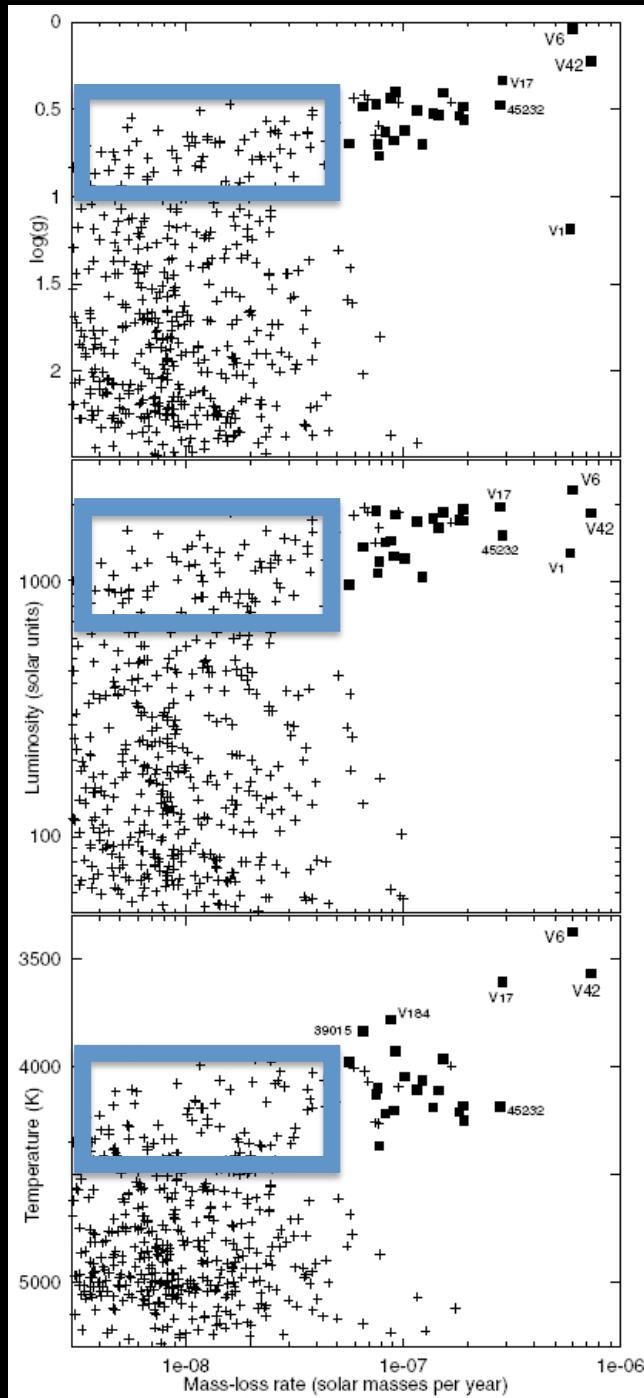


McDonald et al. (2008)

gravity

luminosity

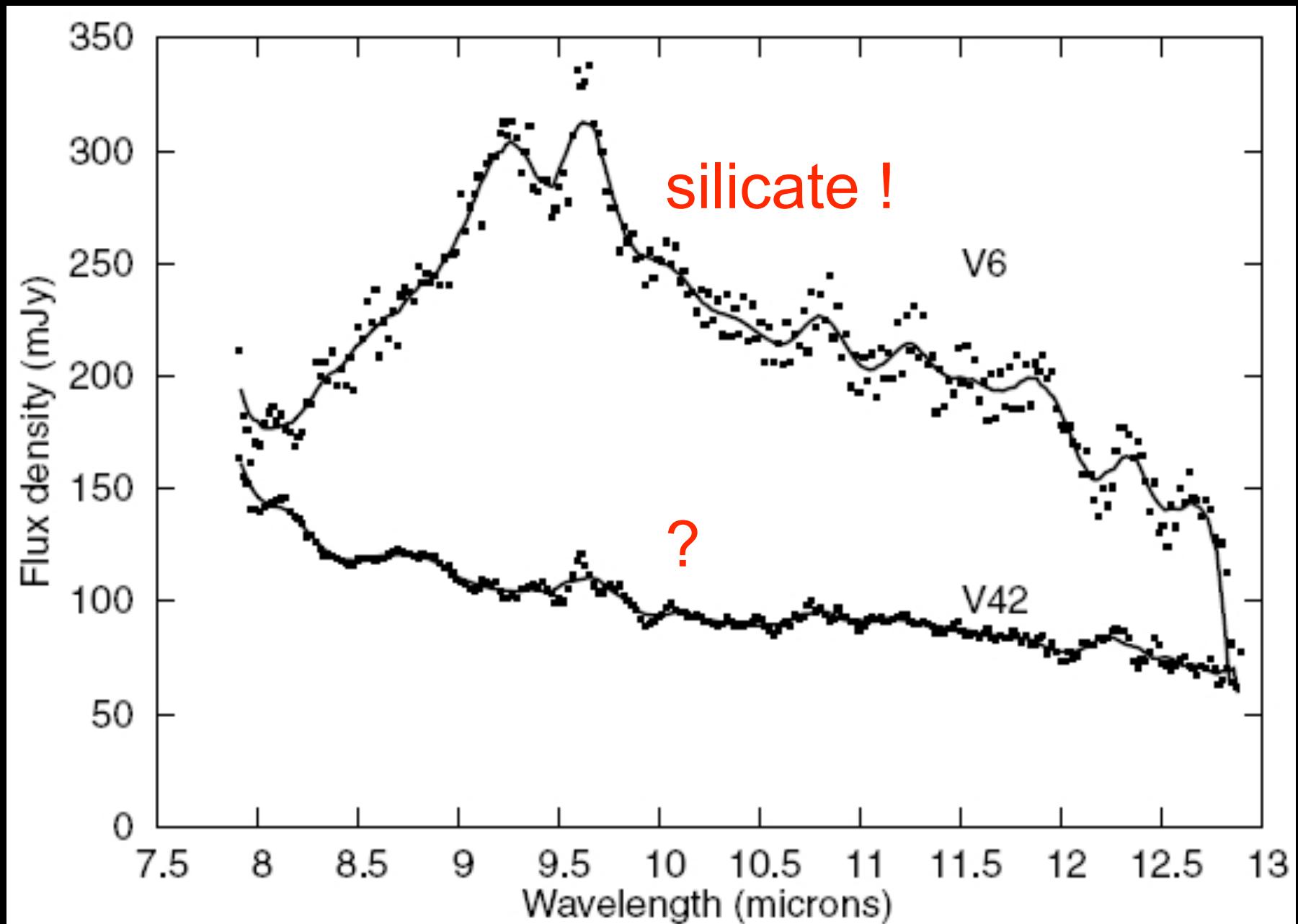
temperature



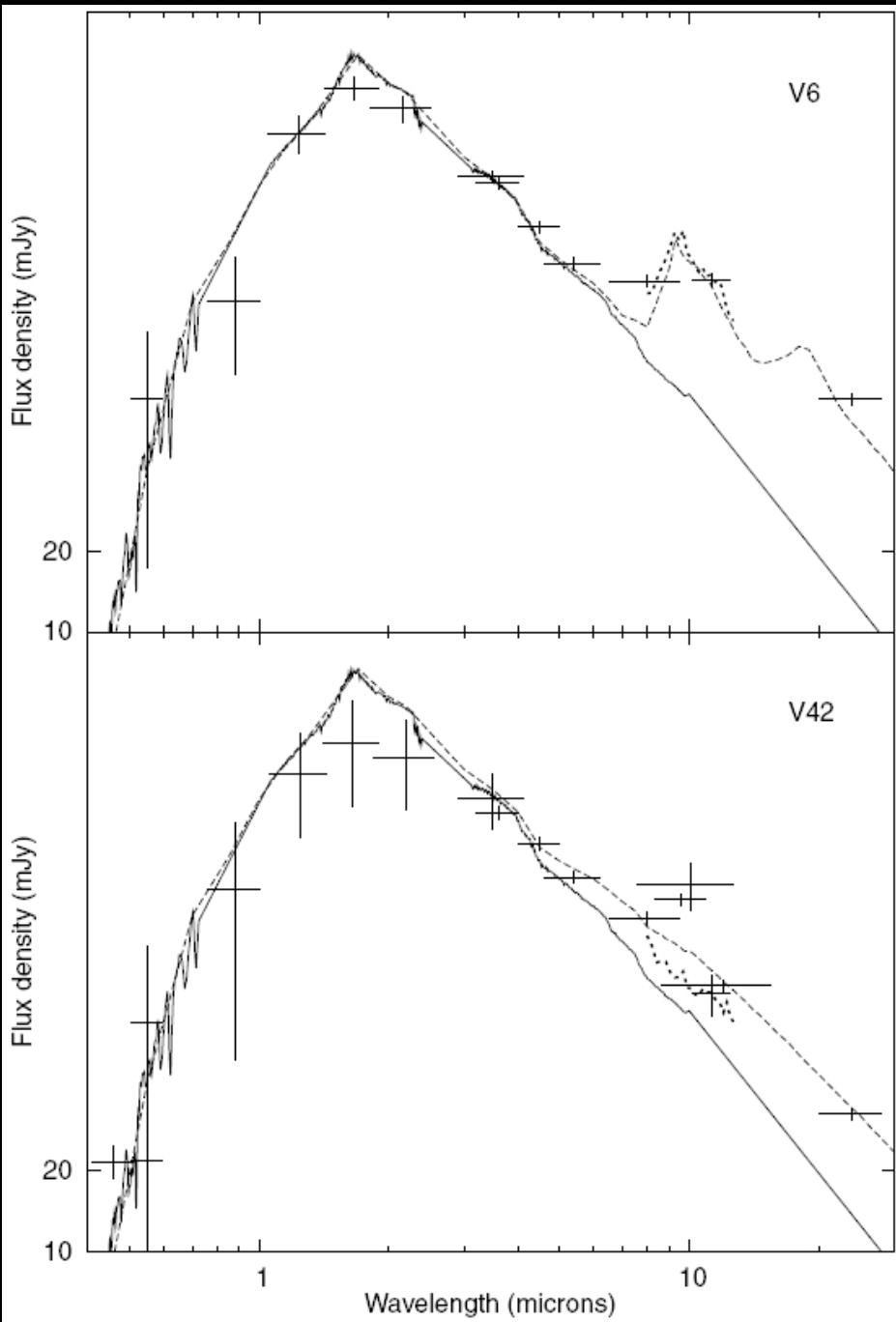
versus
mass-loss
rate

not all
luminous
cool stars
are dusty !

McDonald et al. (2008)



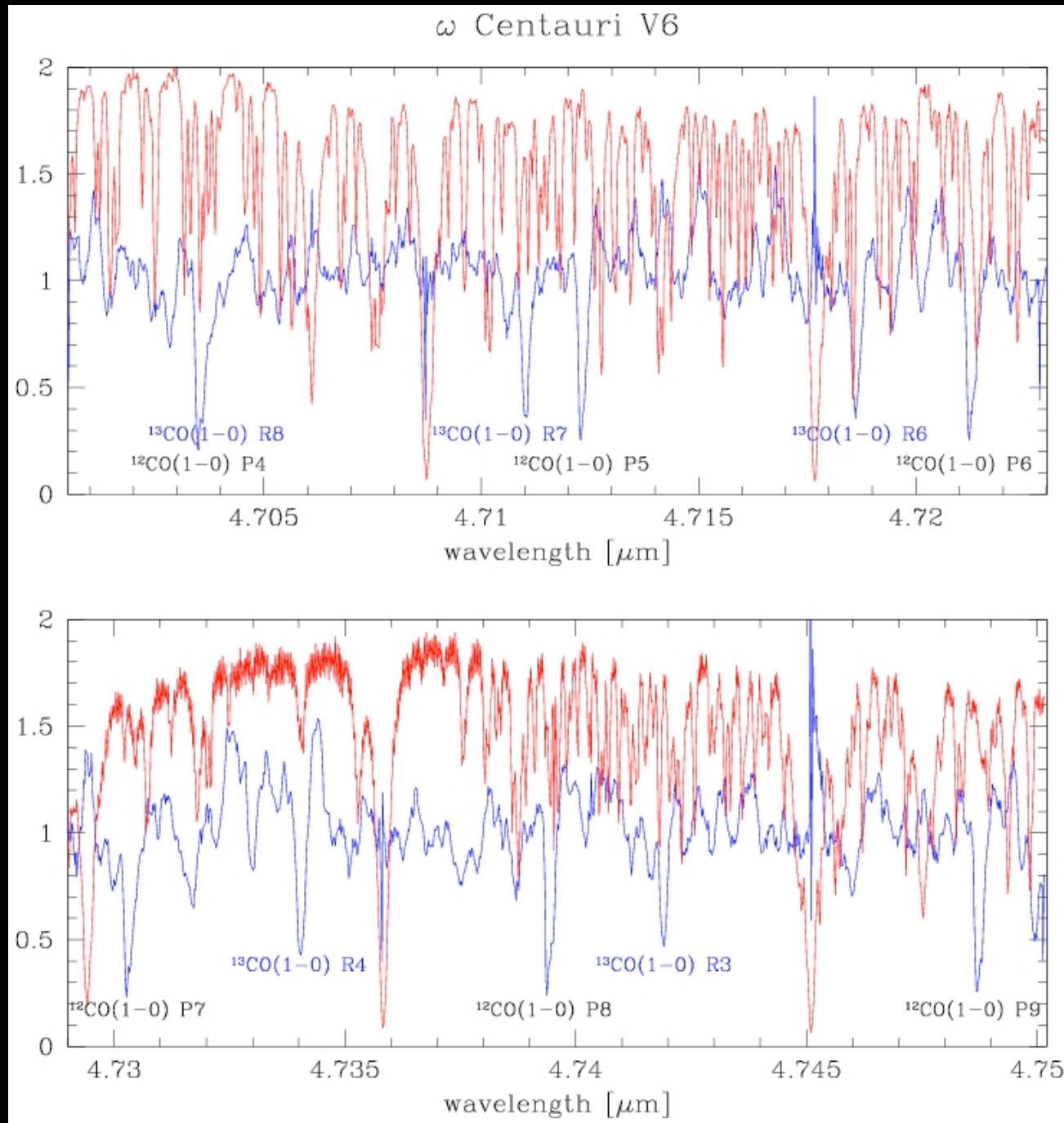
McDonald et al. (2008)



M giant with
silicate dust

M giant with
“some kind”
of dust
carbon dust ?

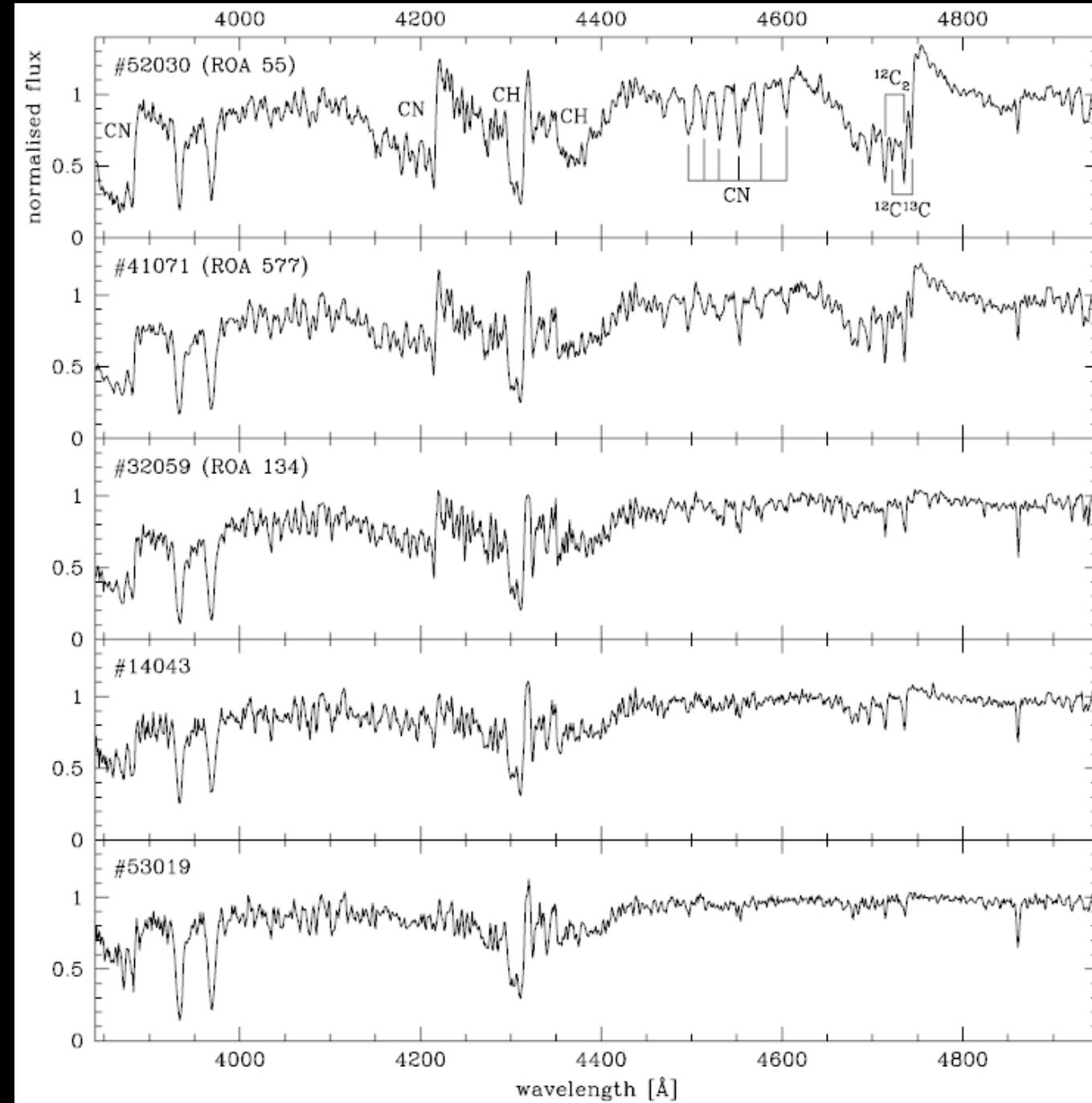
McDonald et al. (2008)



any carbon dust from globular cluster giants will be ^{13}C rich!

see also the talk by King

CRIRES, 9 April 2009

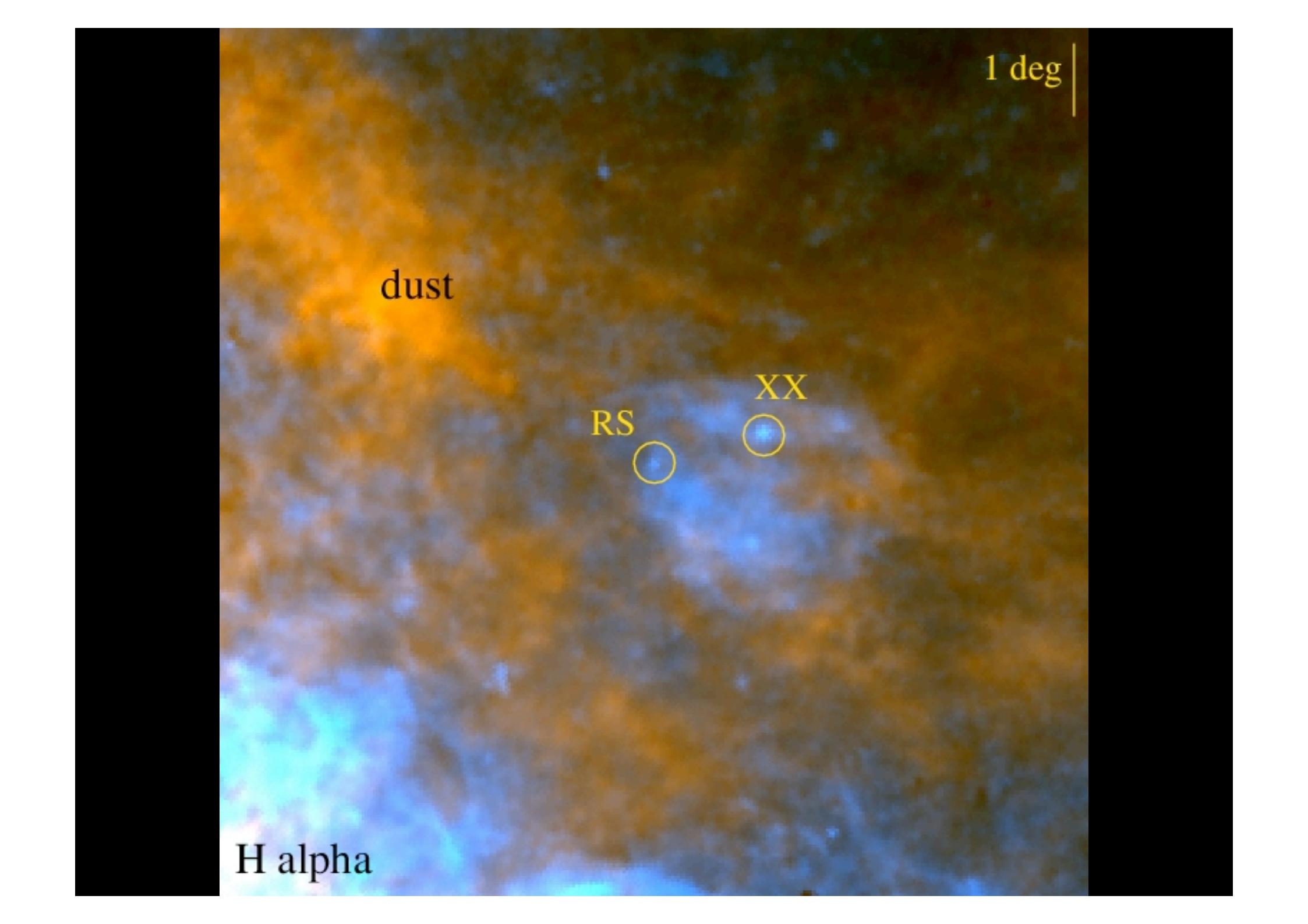


globular
cluster
carbon
stars
must
produce
carbon
dust!

van Loon et al. (2007)

Novae, et cetera

laboratories for studying dust
(production) in exotic conditions



1 deg

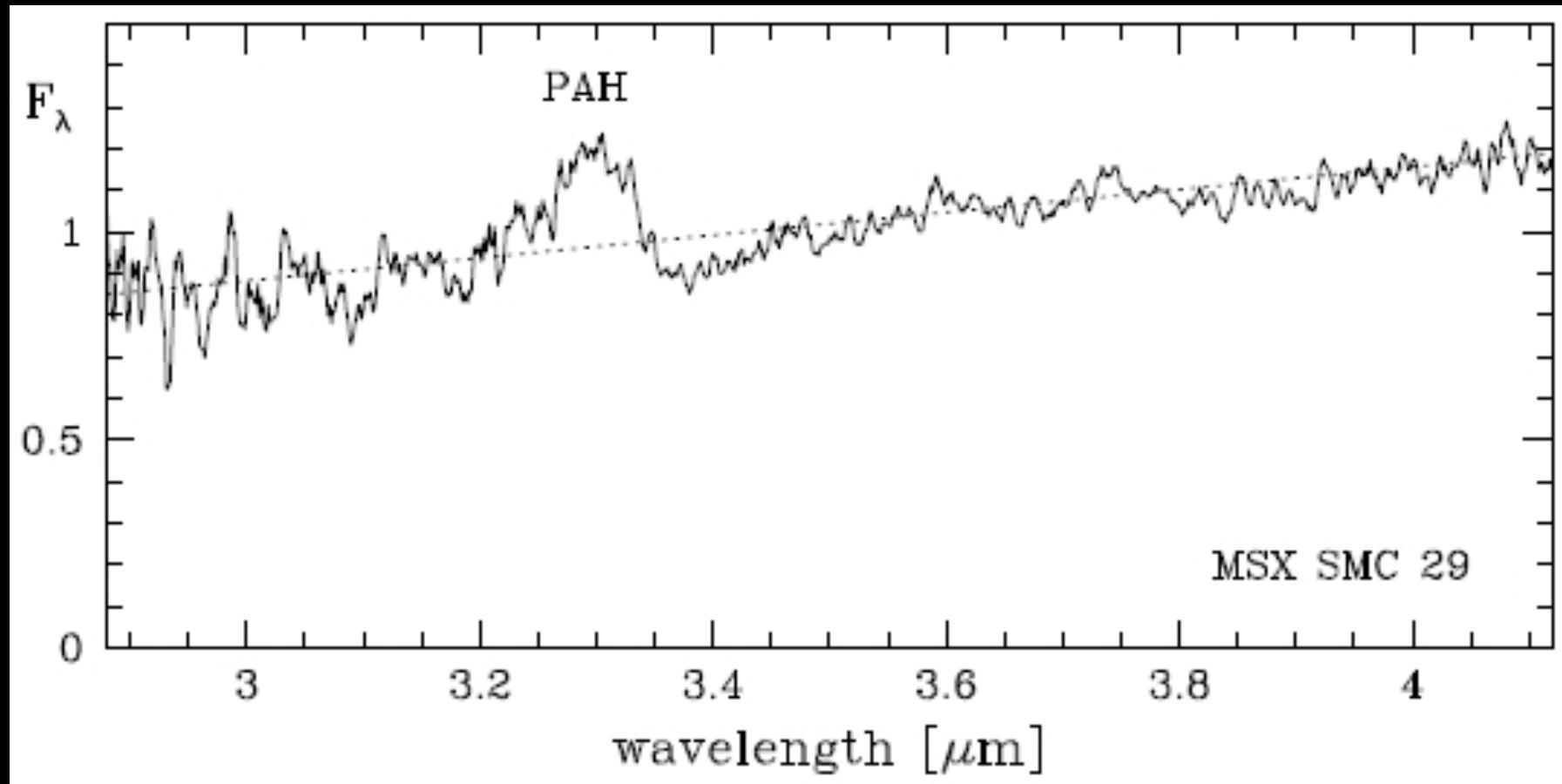
dust

RS

XX

H alpha

post-AGB / PNe : processing / eroding dust



van Loon et al. (2008)

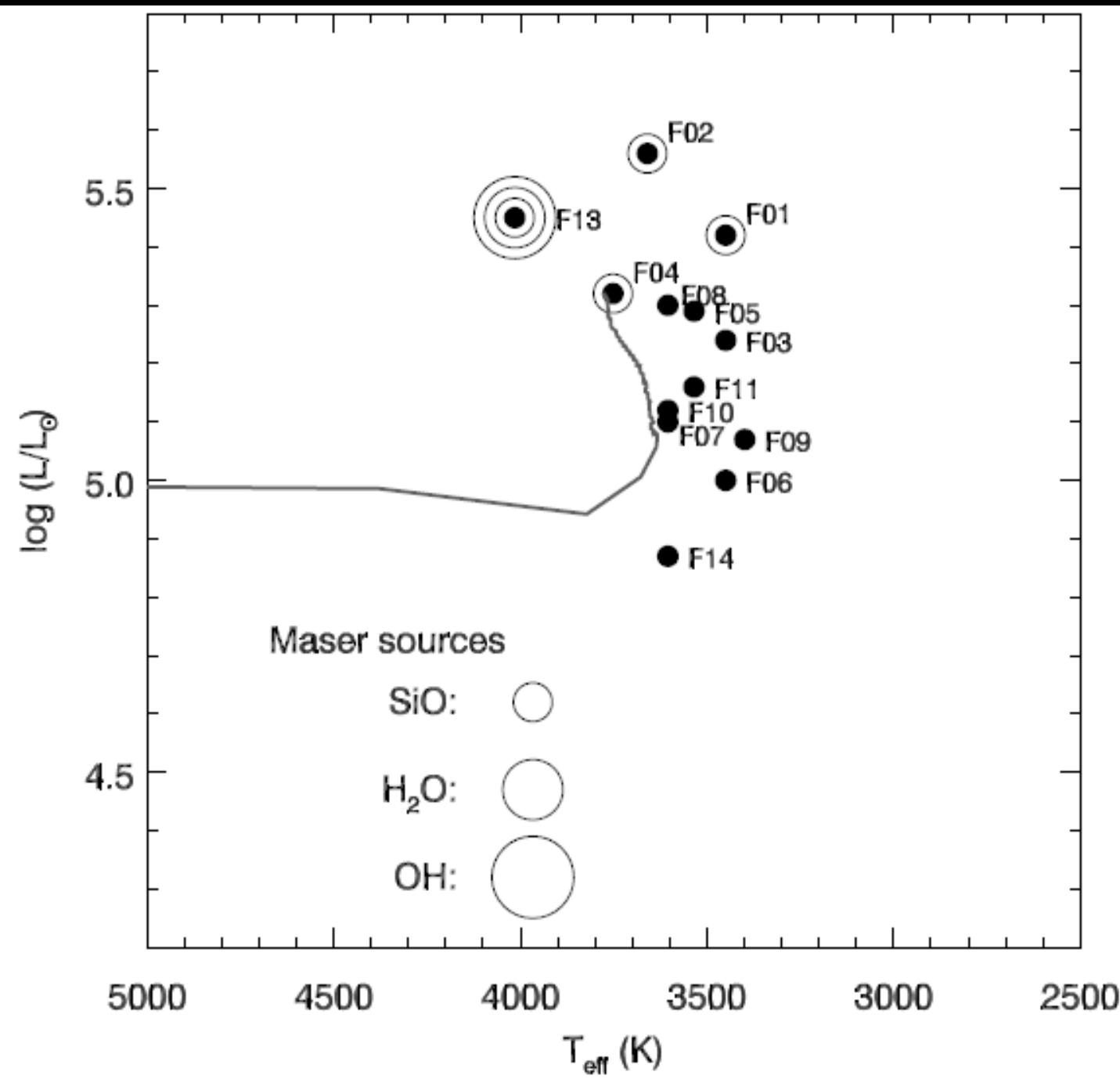
do grains form from PAHs, or do PAHs form from grains?

Supernova progenitors

LBVs, WR stars... red supergiants

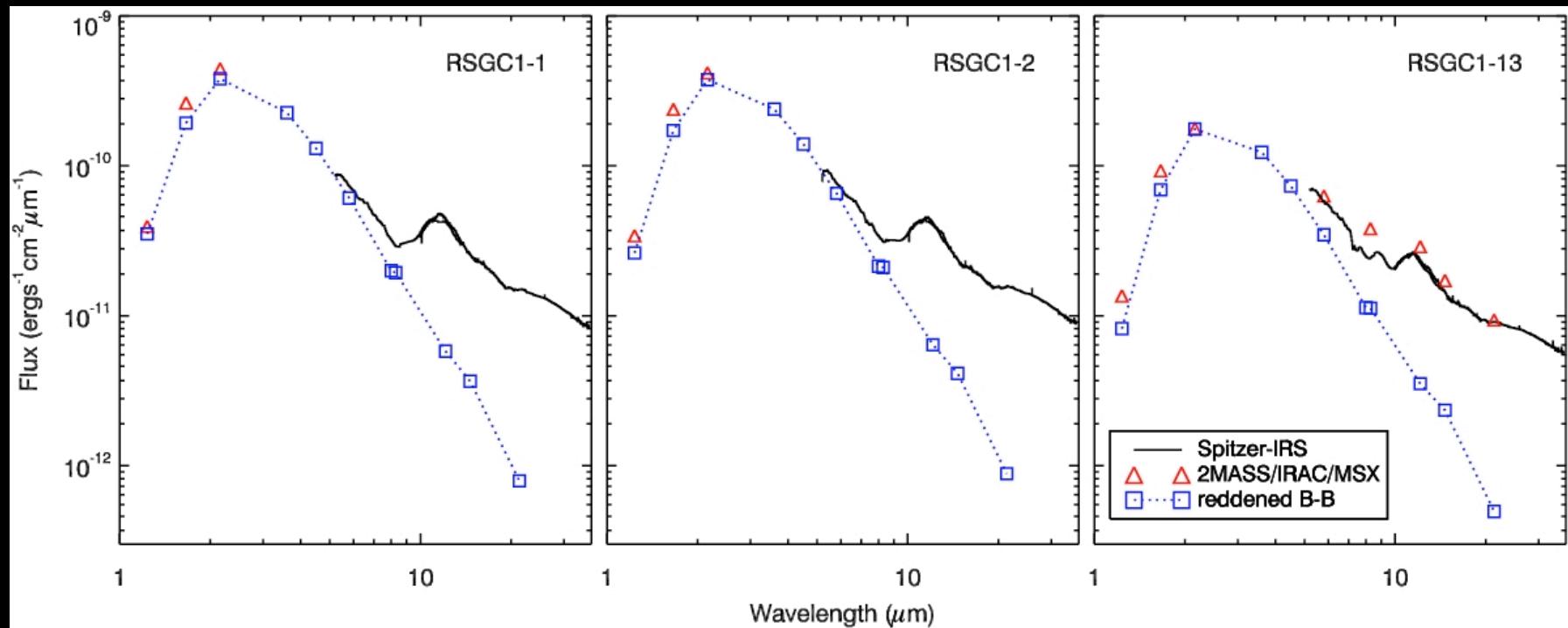
a “movie”
of stellar
evolution

RSG-C1 (& C2)



Davies et al. (2008)

First “movie” of RSG dust production

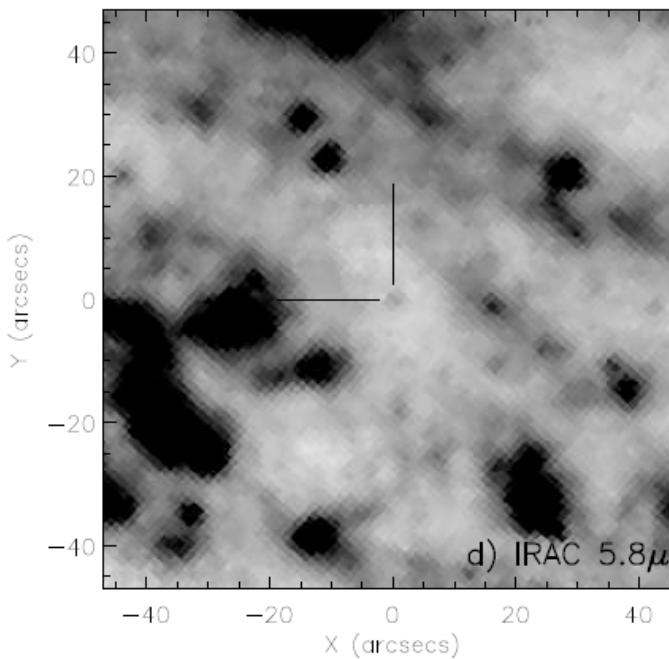
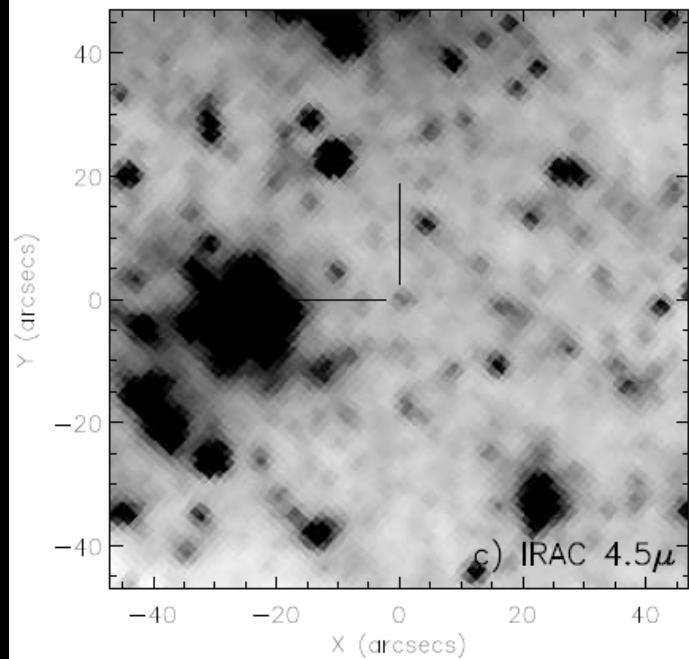
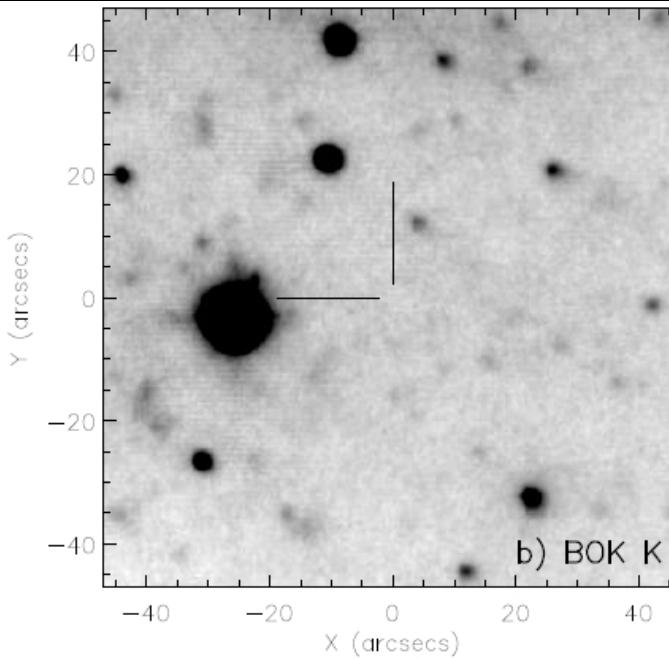
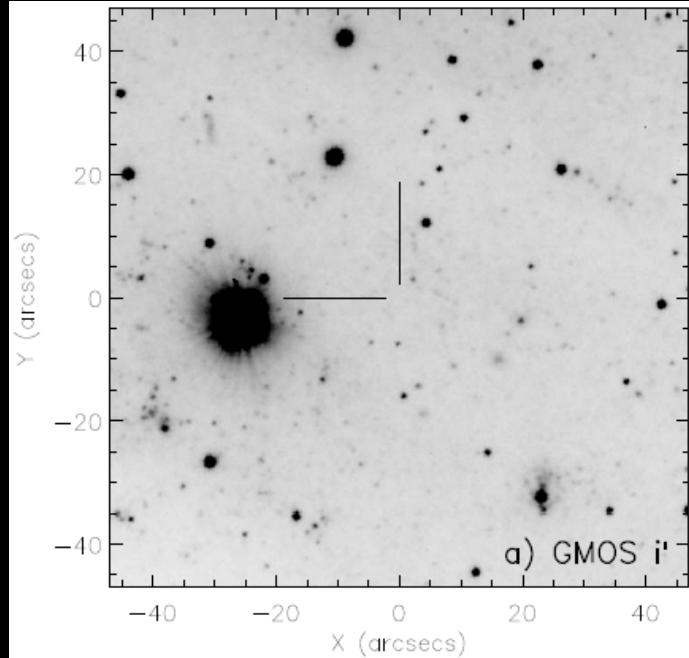


Davies et al. (in preparation)

+ CO measurements (IRAM Plateau de Bure)

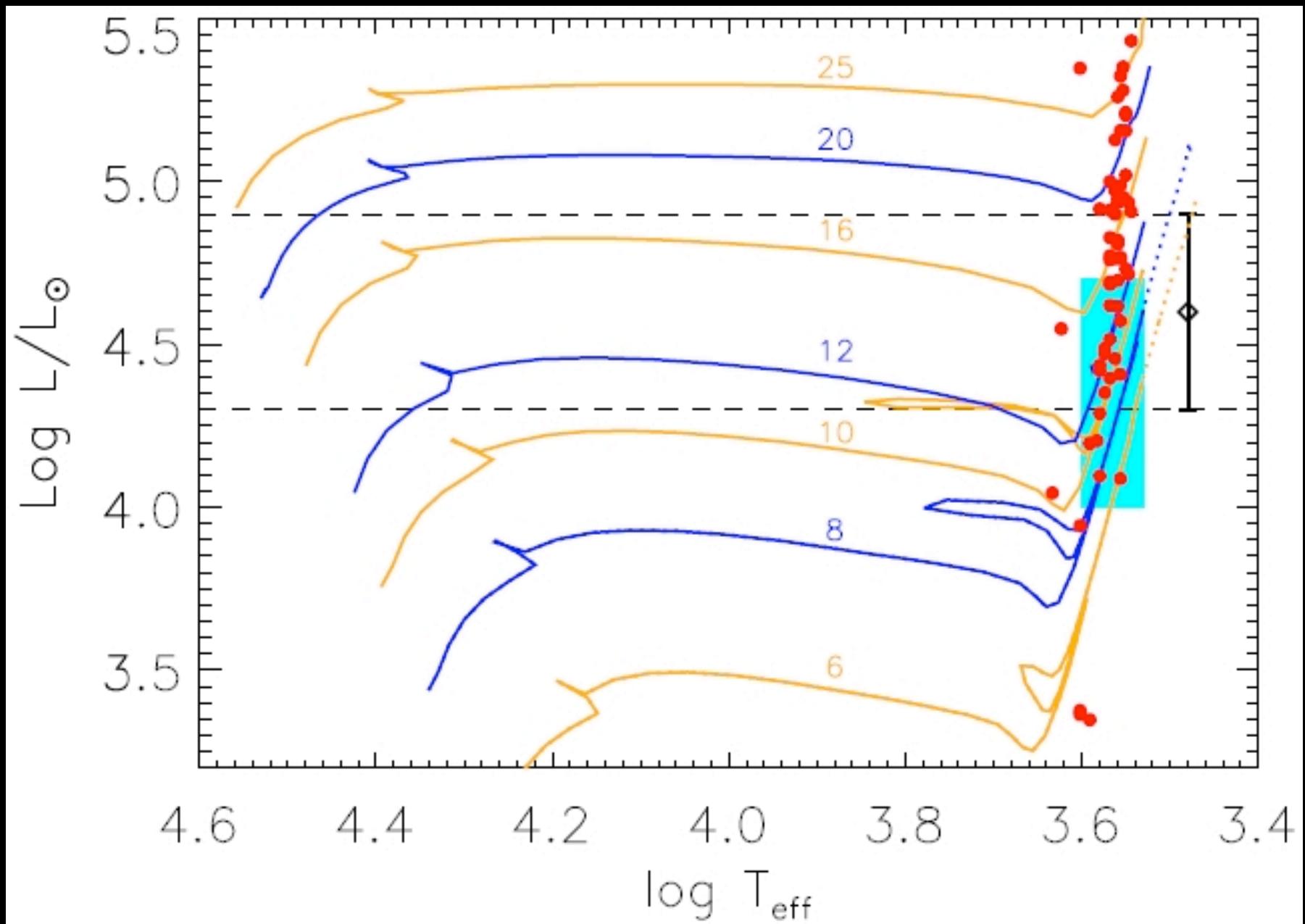
Supernovae, for example SN2008S

Botticella et al. (2009), see also the talk by Wesson



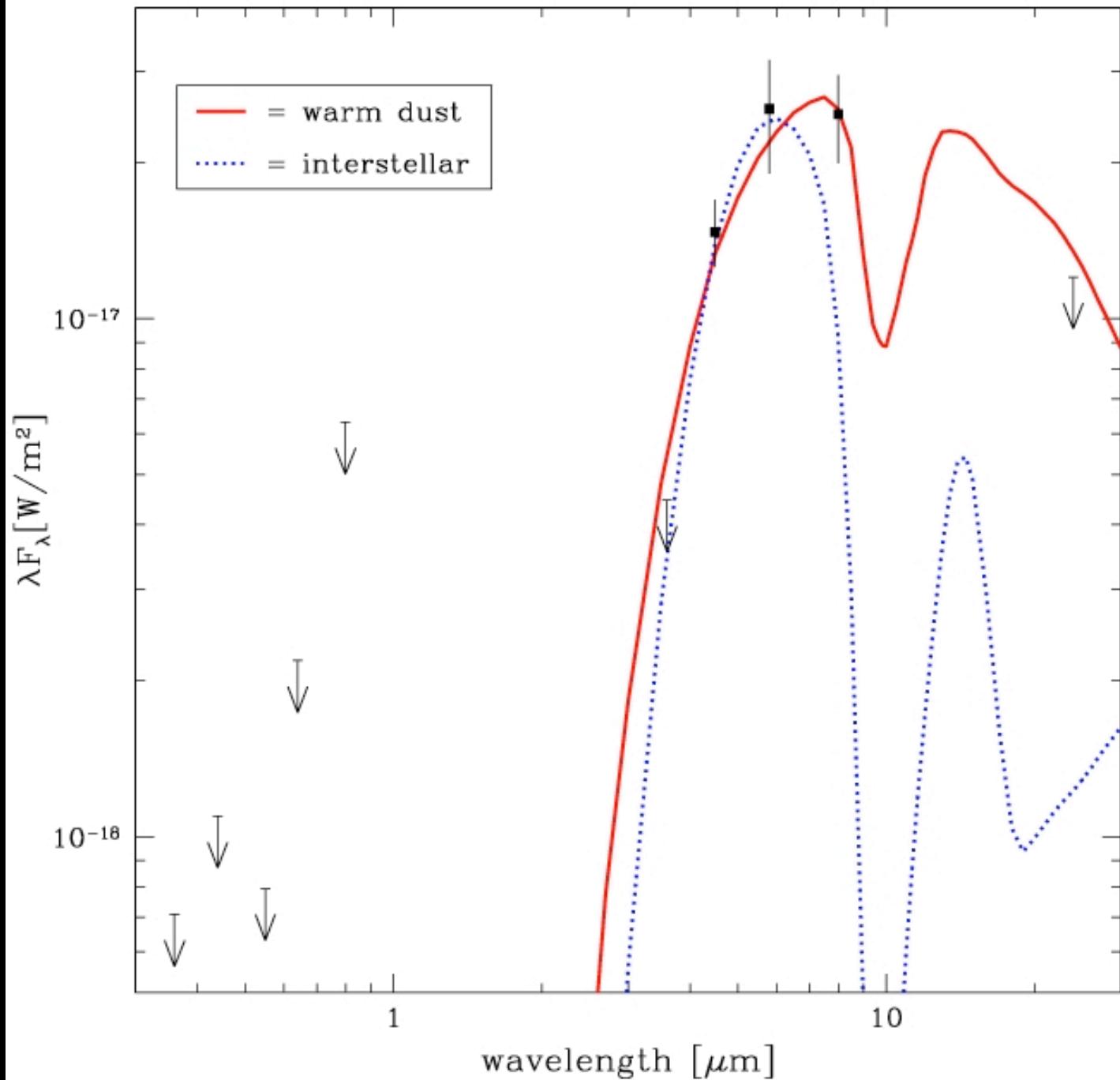
dust-enshrouded
progenitor star

Botticella et al.
(2009)

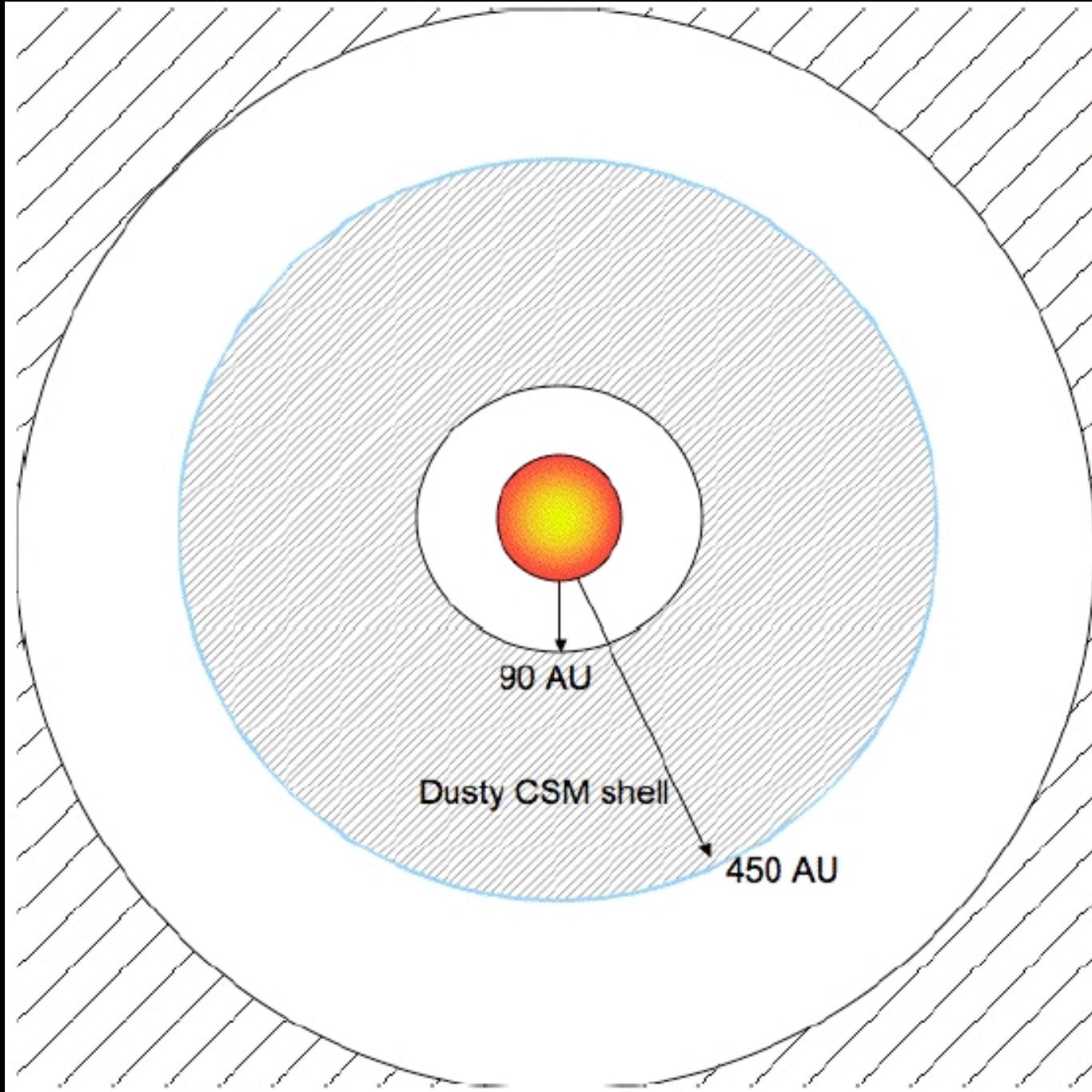


super-AGB star progenitor ?

Botticella et al. (2009)



Botticella et al.
(2009)

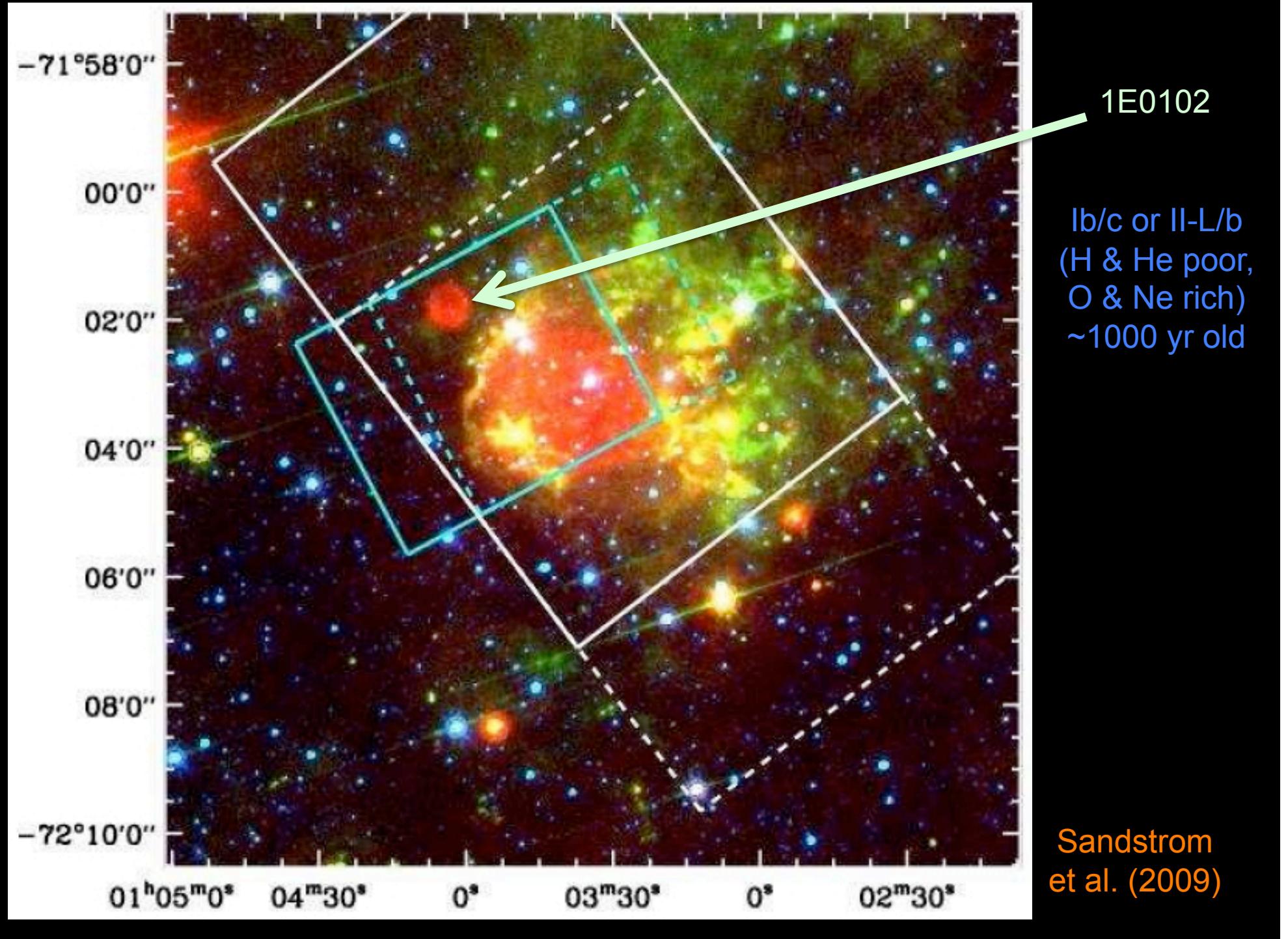


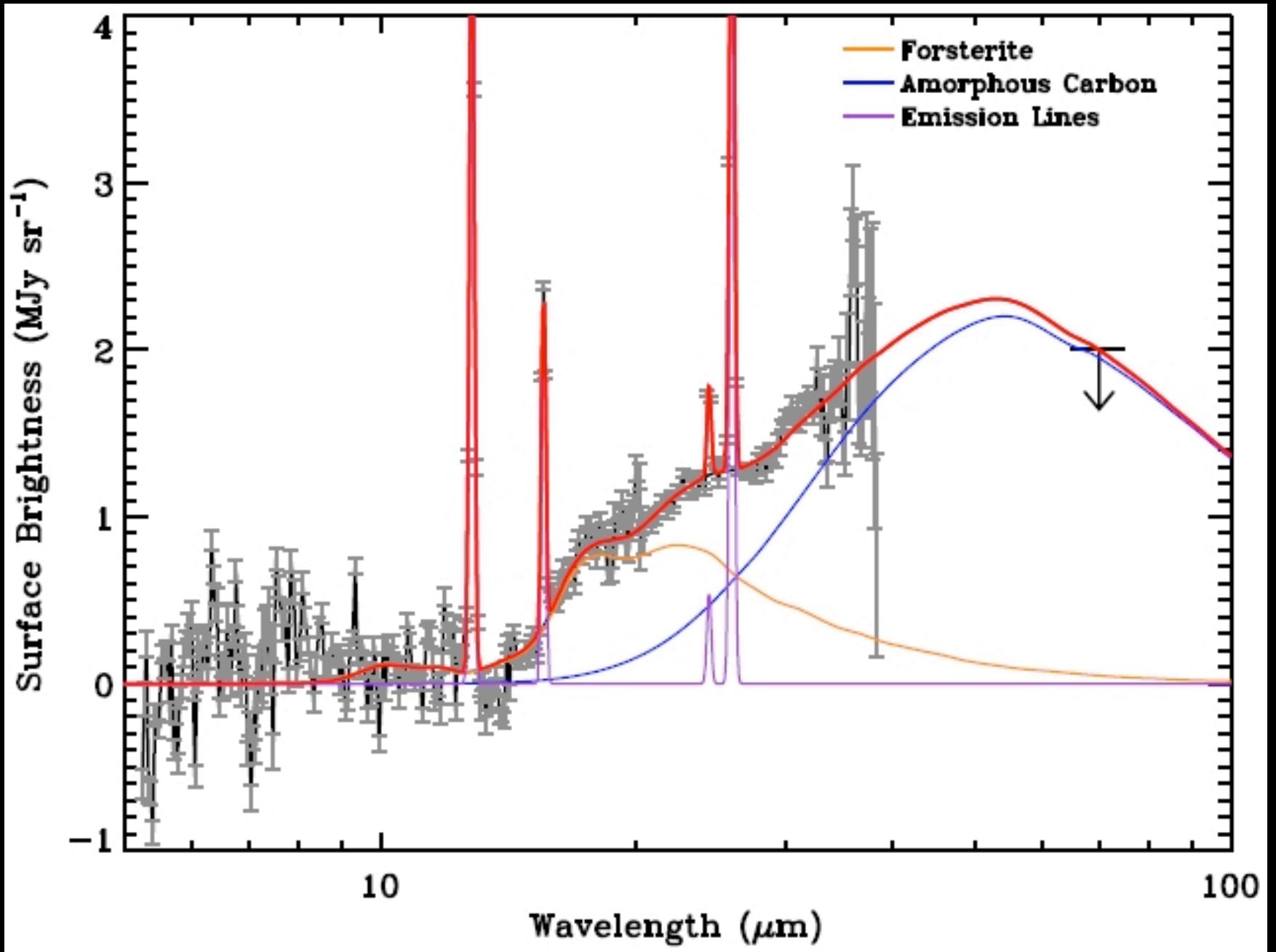
pre-SN
dust shell

Botticella et al.
(2009)

Supernova remnants,
for example 1E0102.2-7219
in the Small Magellanic Cloud

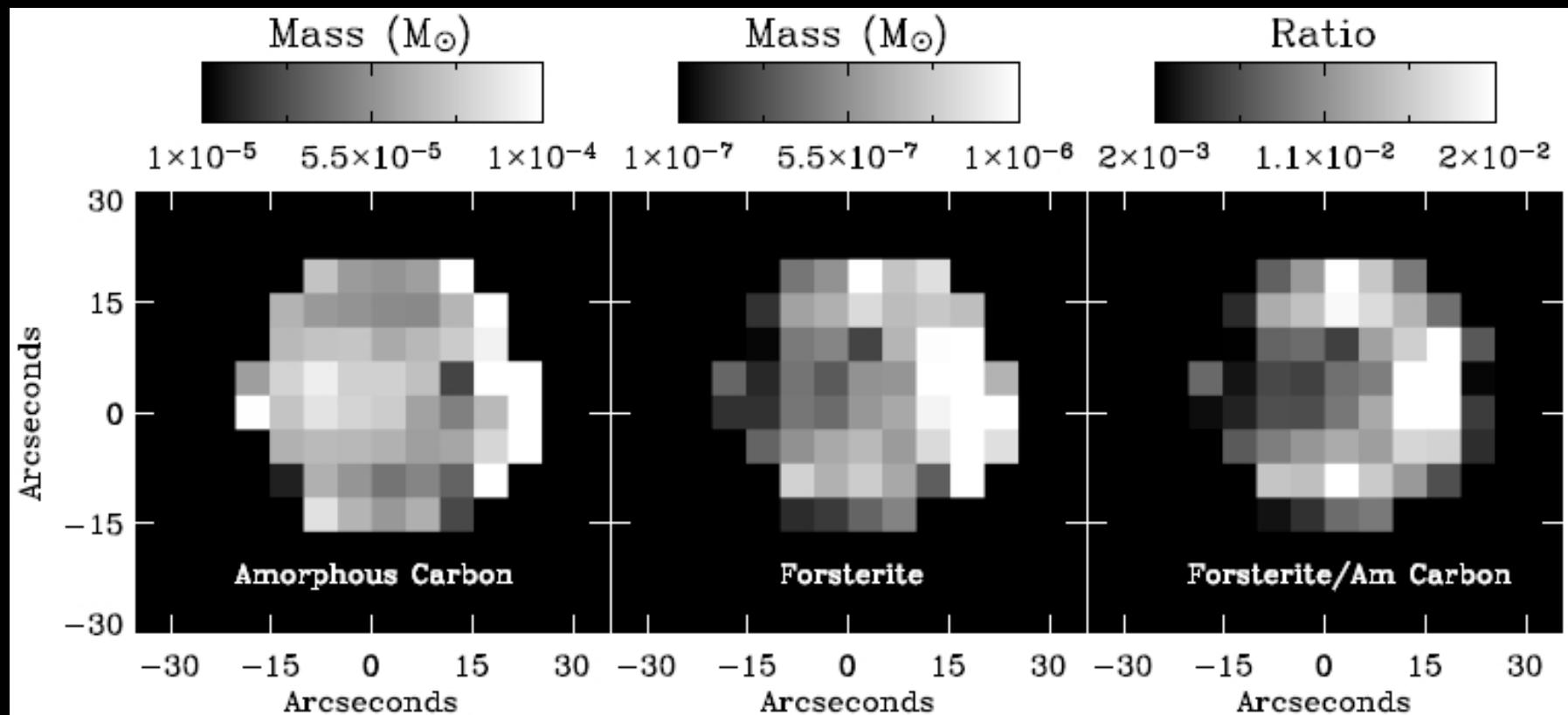
see also the talks by Gomez, Dunne
on other H-poor supernova remnants
and the talk by Cherchneff





Sandstrom et al. (2009)

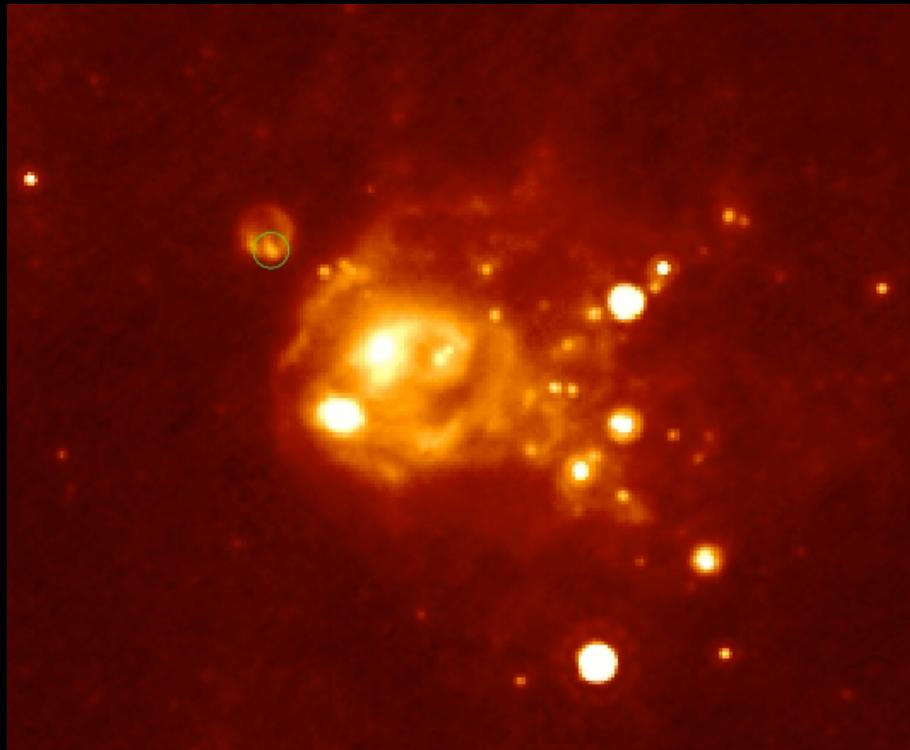
Spatially resolved dust emission



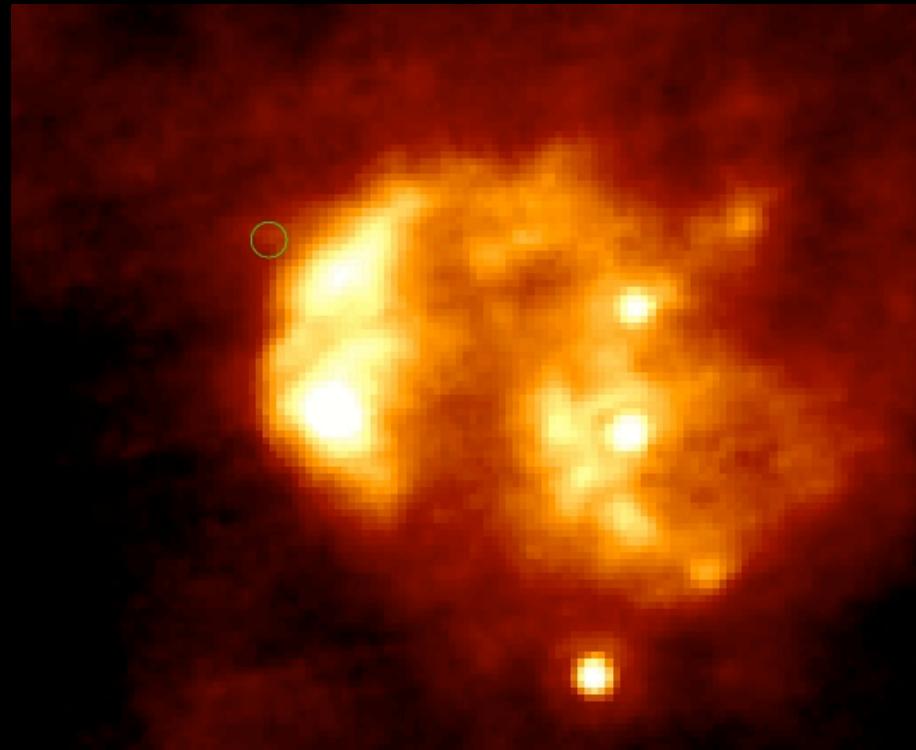
Sandstrom et al. (2009)

carbon dust in reverse-shocked ejecta $\sim 3 \times 10^{-3} M_{\text{sun}}$

Detecting cold dust in 1E0102



Spitzer 24 μm



Spitzer 70 μm

consistent with previous upper limit

Final remarks (for now)

- dust production depends on metallicity
- ... on main dust condensates ...
- ... as well as trace condensation seeds
- dust aids mass loss but may not be crucial
- red supergiants are prolific dust producers
- ... but supernovae may destroy it ...
- ... as well as produce dust themselves
- lots of different angles of attack needed