
Large Magellanic Cloud

CO mass-loss rate of red-supergiants at low metallicity

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Memory of Olivier Chesneau
VLTI observations of OH 231.8+4.2

THE ASTROPHYSICAL JOURNAL, 646:L123–L126, 2006 August 1

THE COMPACT CIRCUMSTELLAR MATERIAL AROUND OH 231.8+4.2[1]

M. MATSUURA,[2,3,4] O. CHESNEAU,[5] A. A. ZIJLSTRA,[2] W. JAFFE,[6] L. B. F. M. WATERS,[7,8] J. A. YATES,[9]
E. LAGADEC,[2] T. GLEDHILL,[10] S. ETOKA,[2] AND A. M. S. RICHARDS[11]
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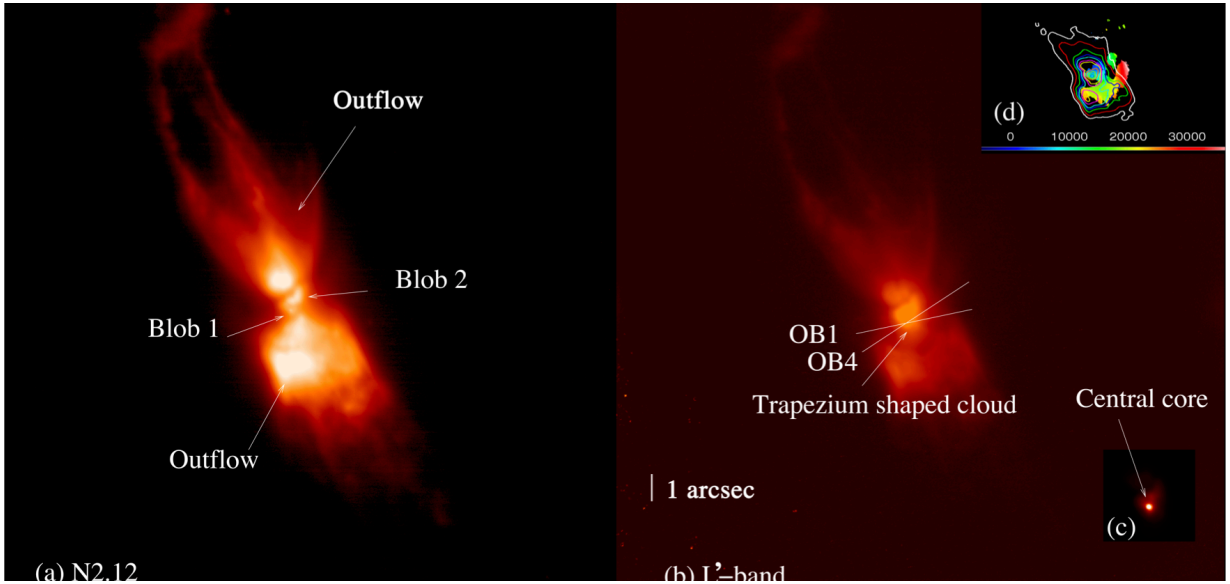

MIDI/VLTI resolved
torus in the post-AGB star, OH 213


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How does metallicity effect on mass-loss rate?

- Galaxies have wide range of metallicities
- How does metal content affect stellar-wind of red-supergiants (RSGs) and AGB stars?
  - Stellar wind (super wind): driven by radiation pressure on dust grains
  - Dust grains are made of metals
  - Theoretical prediction:

'Mass-loss rate is lower at low metallicity at a given luminosity'

Bowen & Willson (1991, ApJ 375, L53)

Testing hypothesis

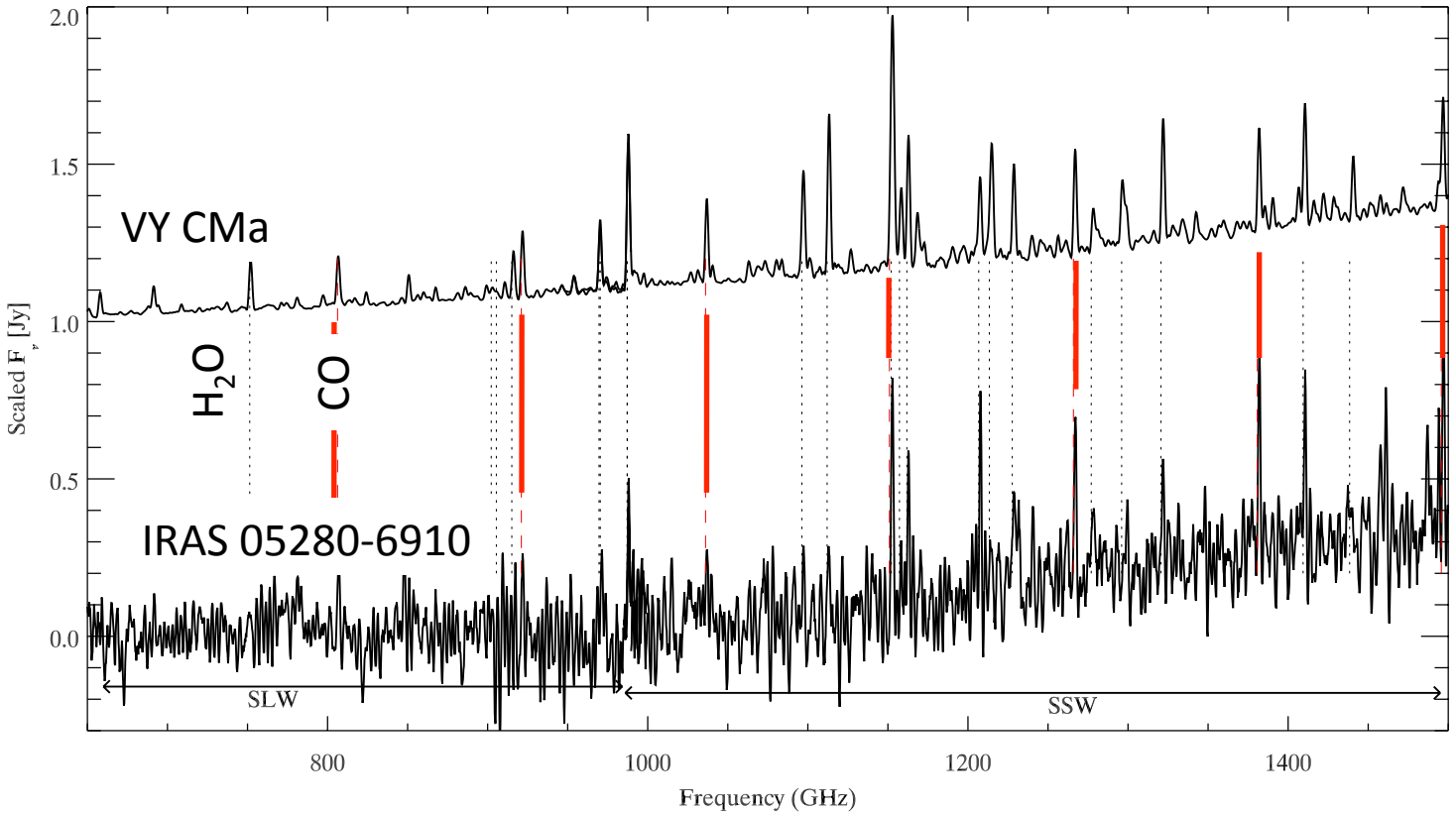
- Galaxies have wide range of metallicities
  - Milky Way : metallicity ~$Z_{\odot}$
  - Large Magellanic Cloud
    - Metallicity~ 1/2 $Z_{\odot}$
    - Distance = 50 kpc
    - Constituting stars are well resolved

  - LMC: ideal site to test how metallicities affect mass-loss rate
  - Targeting on two red-supergiants in the LMC

Observations

Herschel SPIRE FTS + PACS spectrometer

Herschel SPIRE FTS spectrum



Galactic red-supergiant

LMC red-supergiant

8 CO and 15 H_2O lines detected

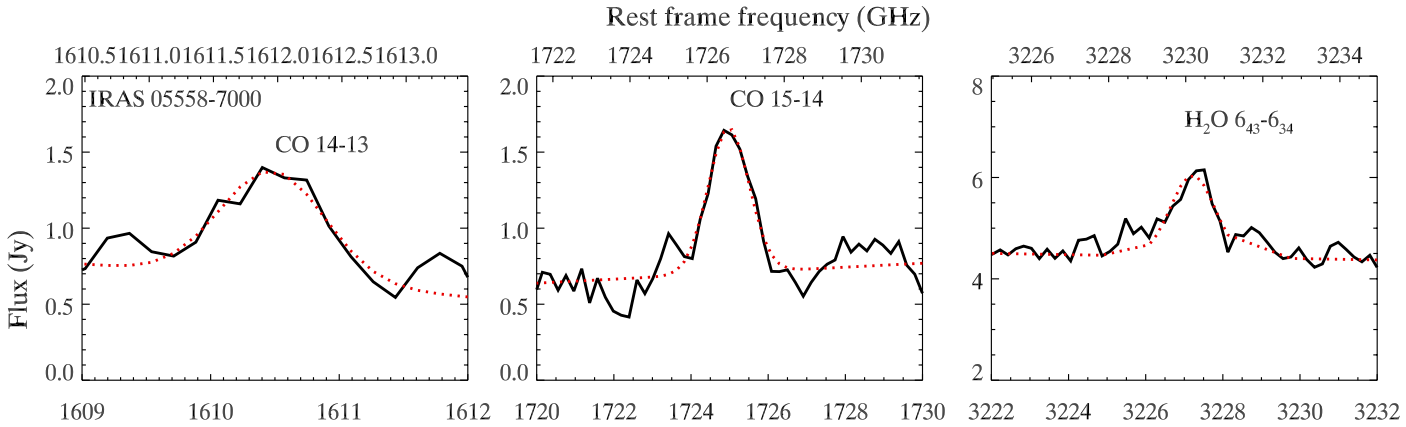
CO J=6-5 to J=13-12

Observations

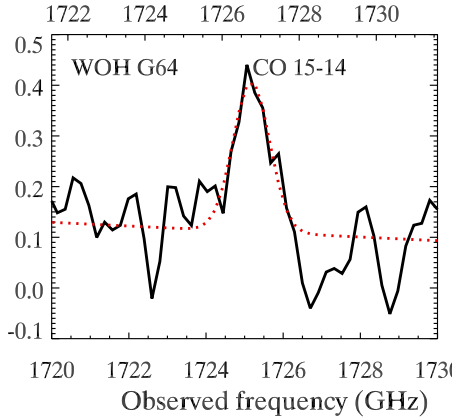
Herschel SPIRE FTS + PACS spectrometer

Herschel PACS spectra

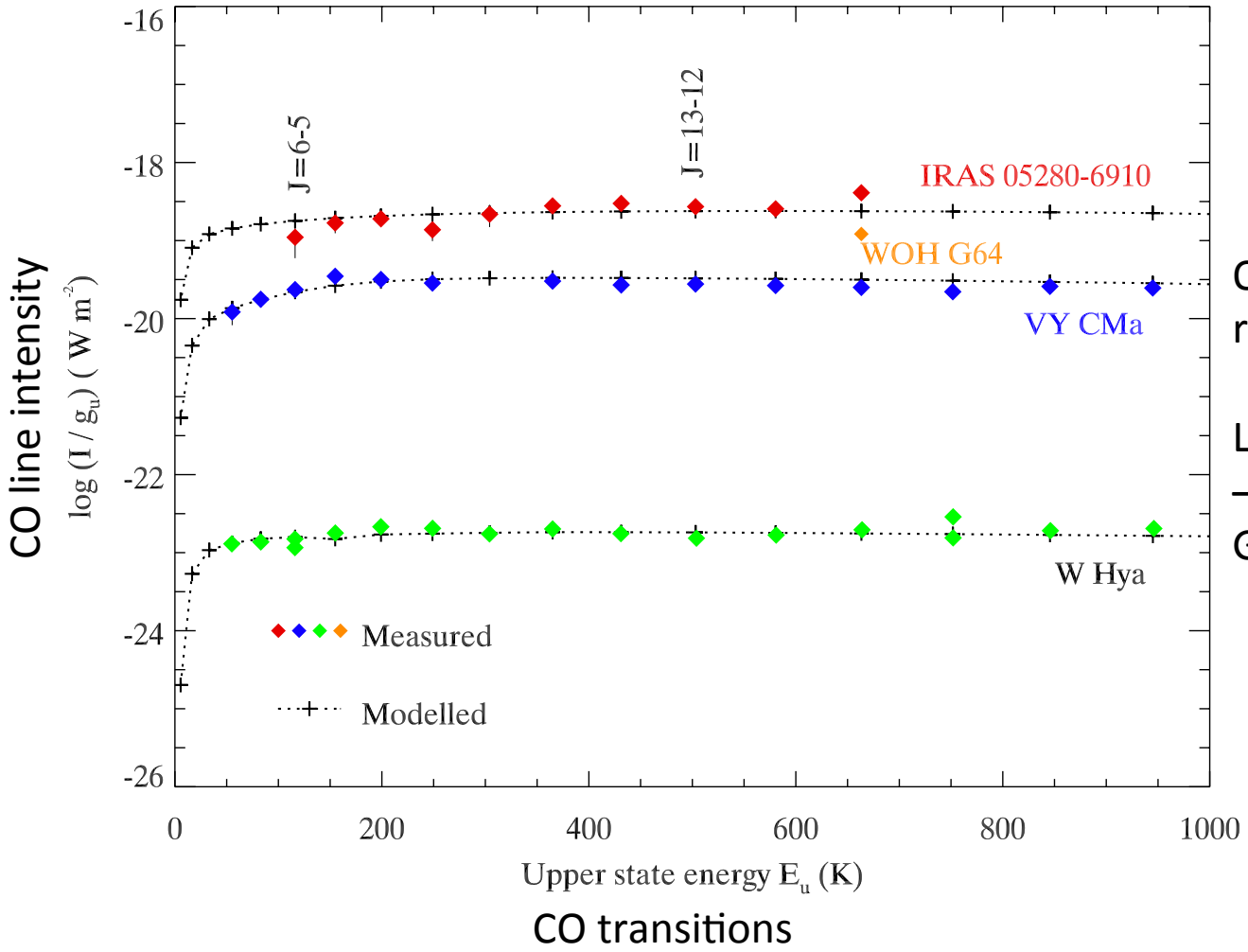
IRAS 05280-6910



WOH G64



Analysis of CO : rotational diagramme



Overall CO intensity reflects the CO density

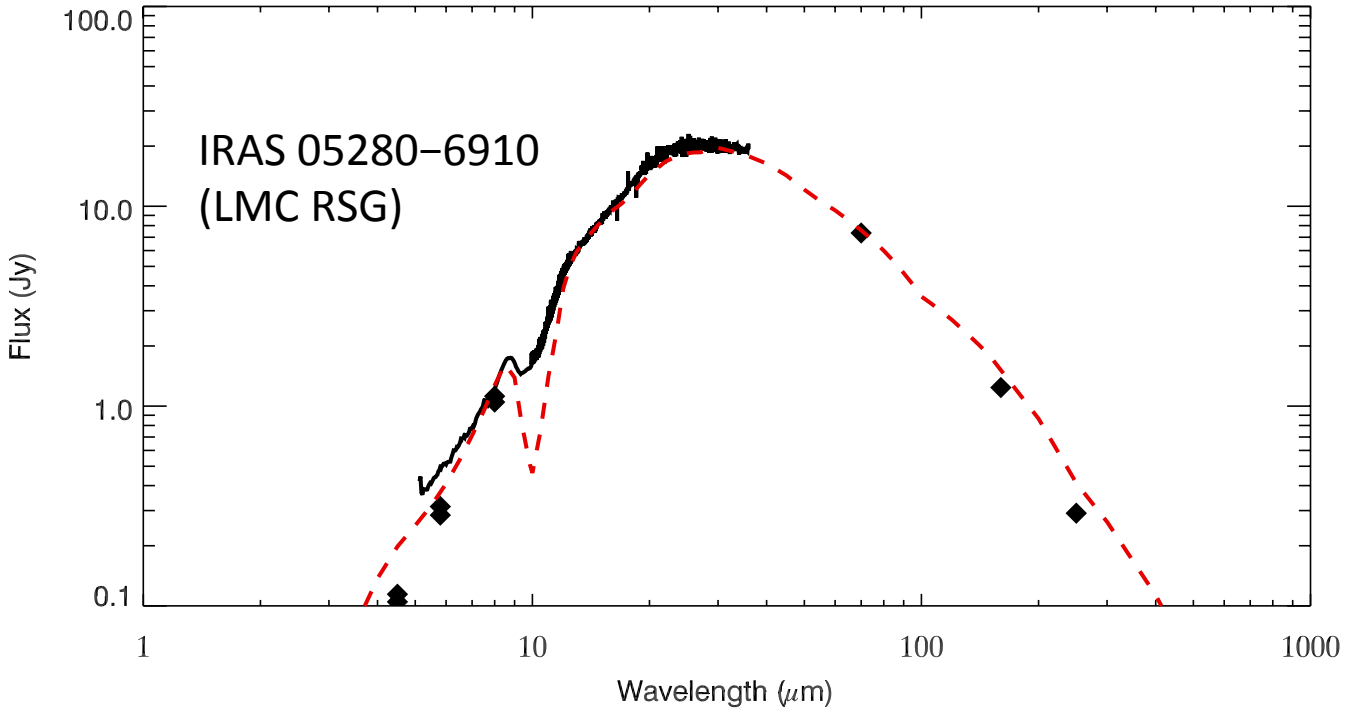
LMC RSG, IRAS 05280-6910 – stronger CO lines than Galactic RSG, VY CMa

Two different methods of mass-loss rate measurements in AGB stars and RSGs

- Mass-loss rate from dust excess
- Mass-loss rate from CO emissions

Estimating dust mass-loss rate

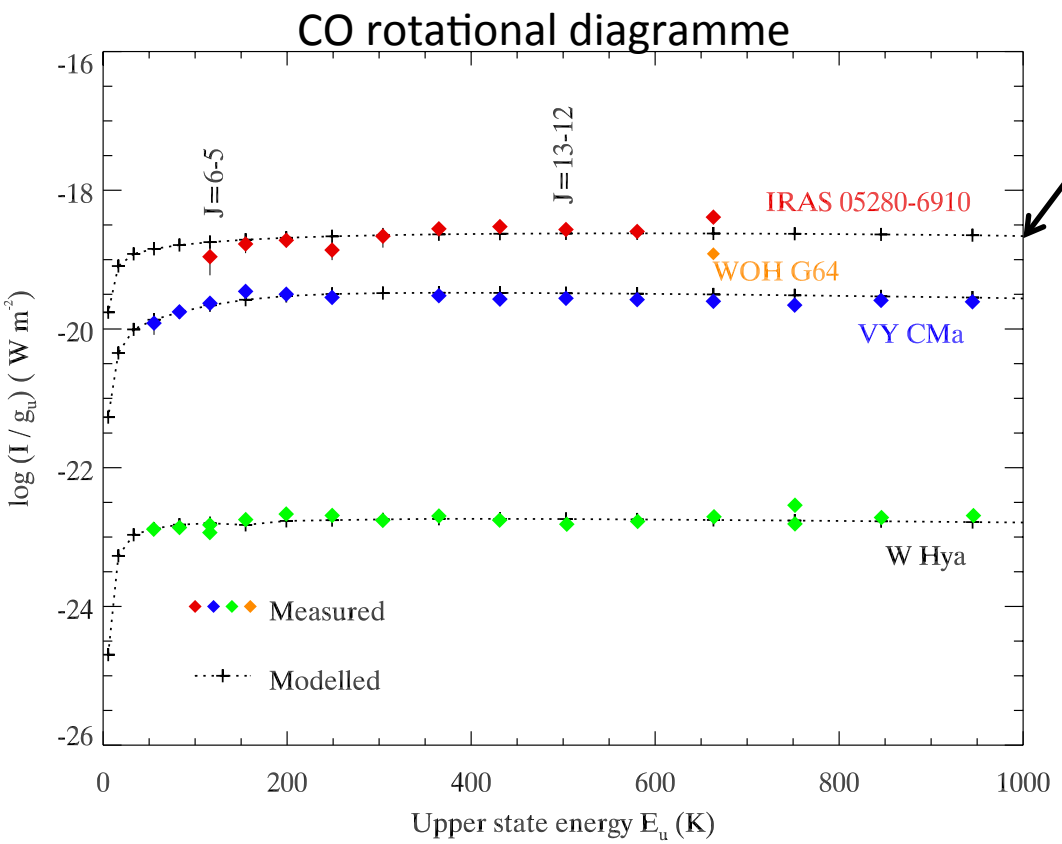
Fitting the SED with dust radiative transfer code (Dusty; Ivezic & Elitzur 1997)



Key parameters

- Mass-loss rate : $3 \times 10^{-4}\ M_{\odot}\ yr^{-1}$ (converted to gas-mass loss rate)
- Gas-to-dust ratio : 500
  - Limited by available mass of refractory elements
  - Higher than Galactic value

Estimating gas mass-loss rate

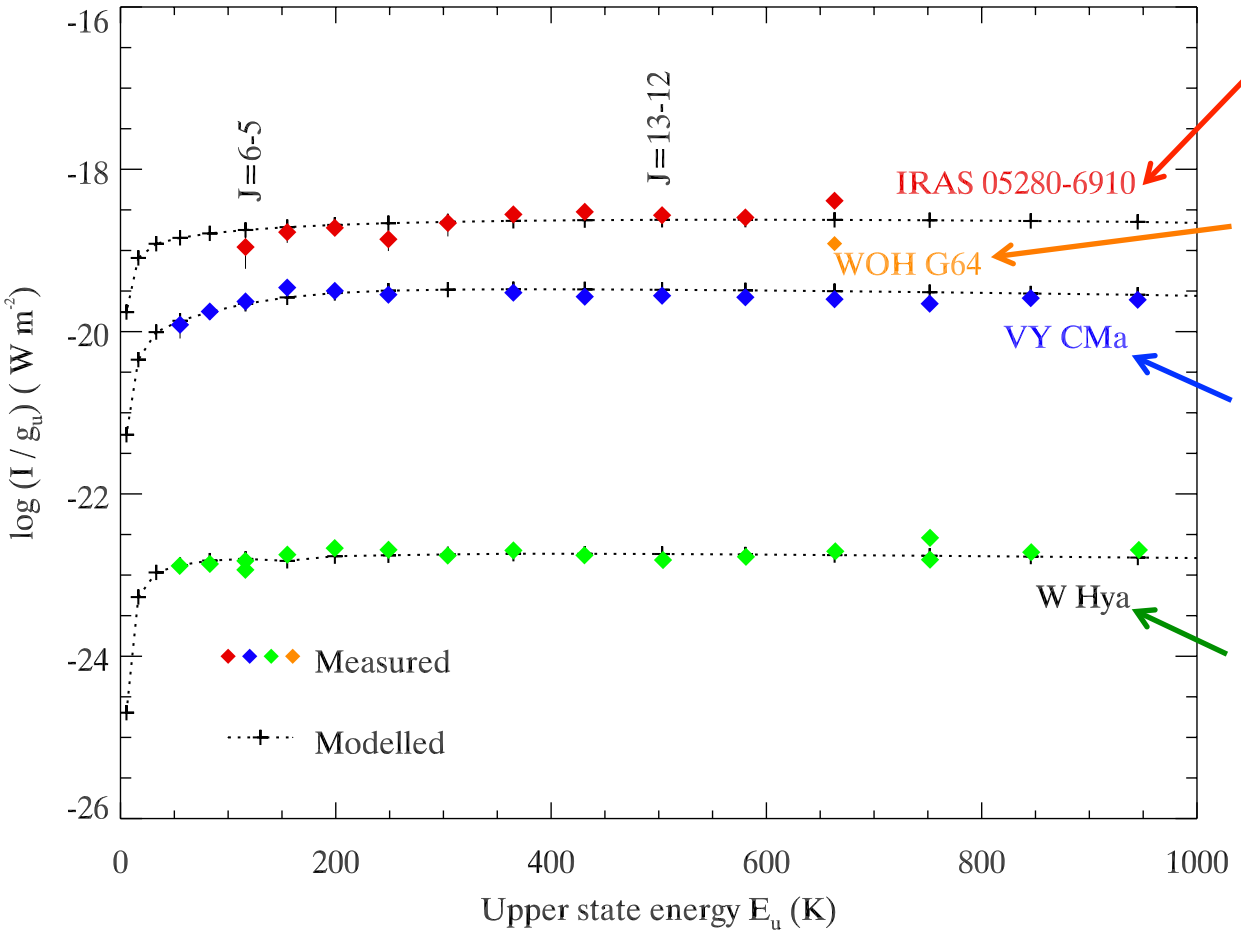


Modelling with non-LTE radiative transfer code (SMMOL; Rawlings & Yates 2001)

Key parameters for IRAS 05280 (LMC RSG)

- Mass-loss rate : 3×10^{-4} $M_{\odot}$ yr^{-1}
  - As dust SED
- CO/H_2 ratio: 2.7×10^{-4}
  - Limited by available C mass
  - Lower than Galactic value as metallicity is lower

Did we see metallicity effects on mass loss rate?



IRAS 05280 (LMC RSG):
3×10^{-4} $M_\odot$ yr^{-1}

WOH G64 (LMC RSG):
2.3×10^{-4} $M_\odot$ yr^{-1}
(IR-SED; Ohnaka et al. 2008)

VY CMa (Galactic RSG)
2×10^{-4} $M_\odot$ yr^{-1}

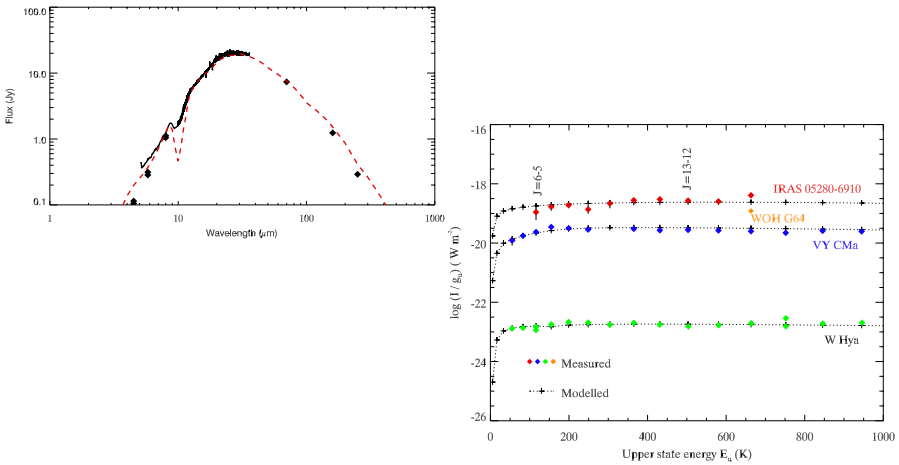
W Hya (Galactic AGB)
1.5×10^{-7} $M_\odot$ yr^{-1}

No evidence of reduced mass-loss at LMC metallicity (half solar)

Results from dust & gas mass-loss rate estimates

IRAS 05280-6910

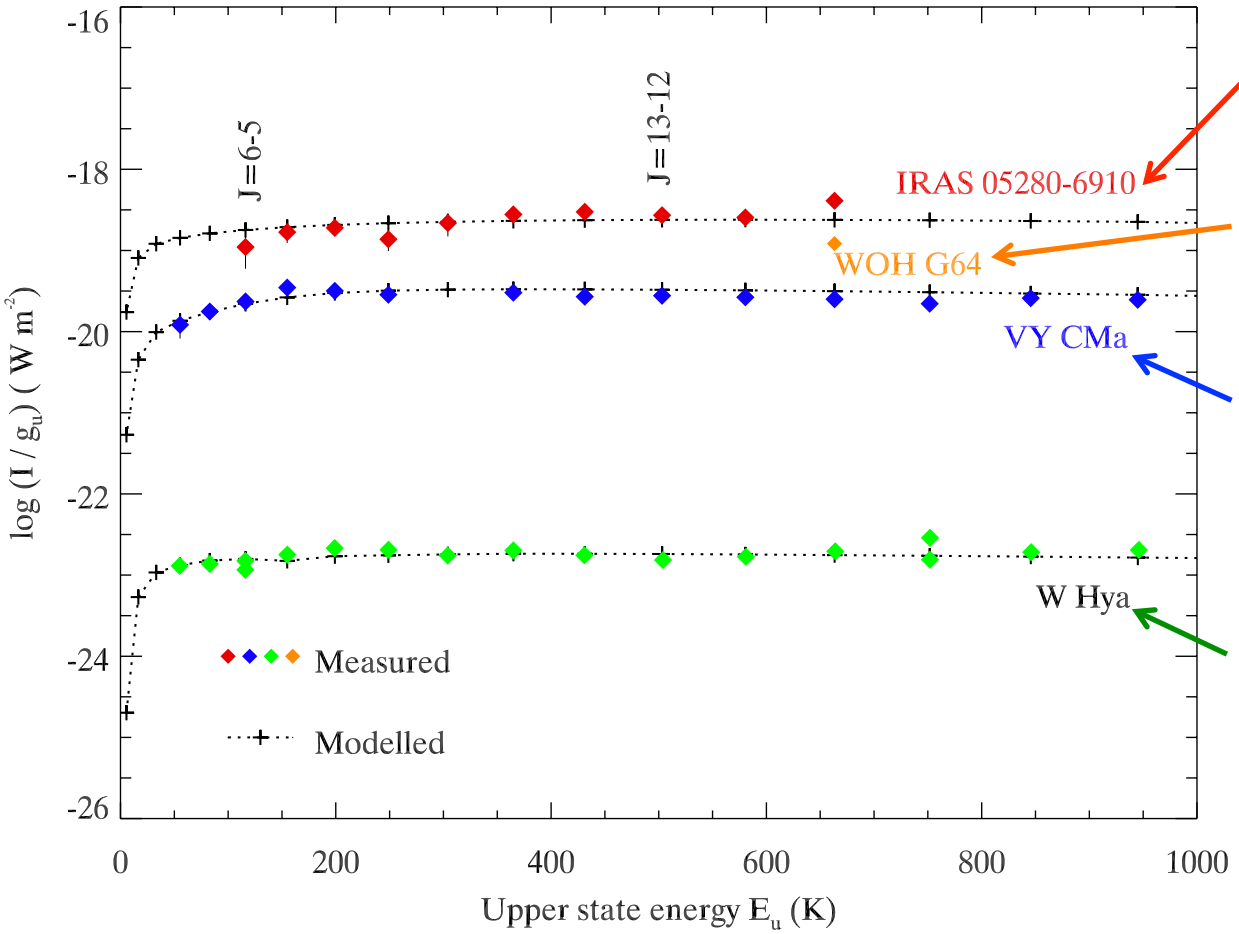
- High mass-loss rate
  - : 3×10^{-4} $M_{\odot}$ yr^{-1}
- Did not find a reduced mass-loss rate at low metallicity



- Indirect metallicity effect
  - Assumed
    - CO / H_2 ratio
    - Gas-to-dust ratio
  - Scaled accordingly to metallicity
- No metallicity dependence in CO/dust ratio

Instead of metallicity

Luminosity is the key



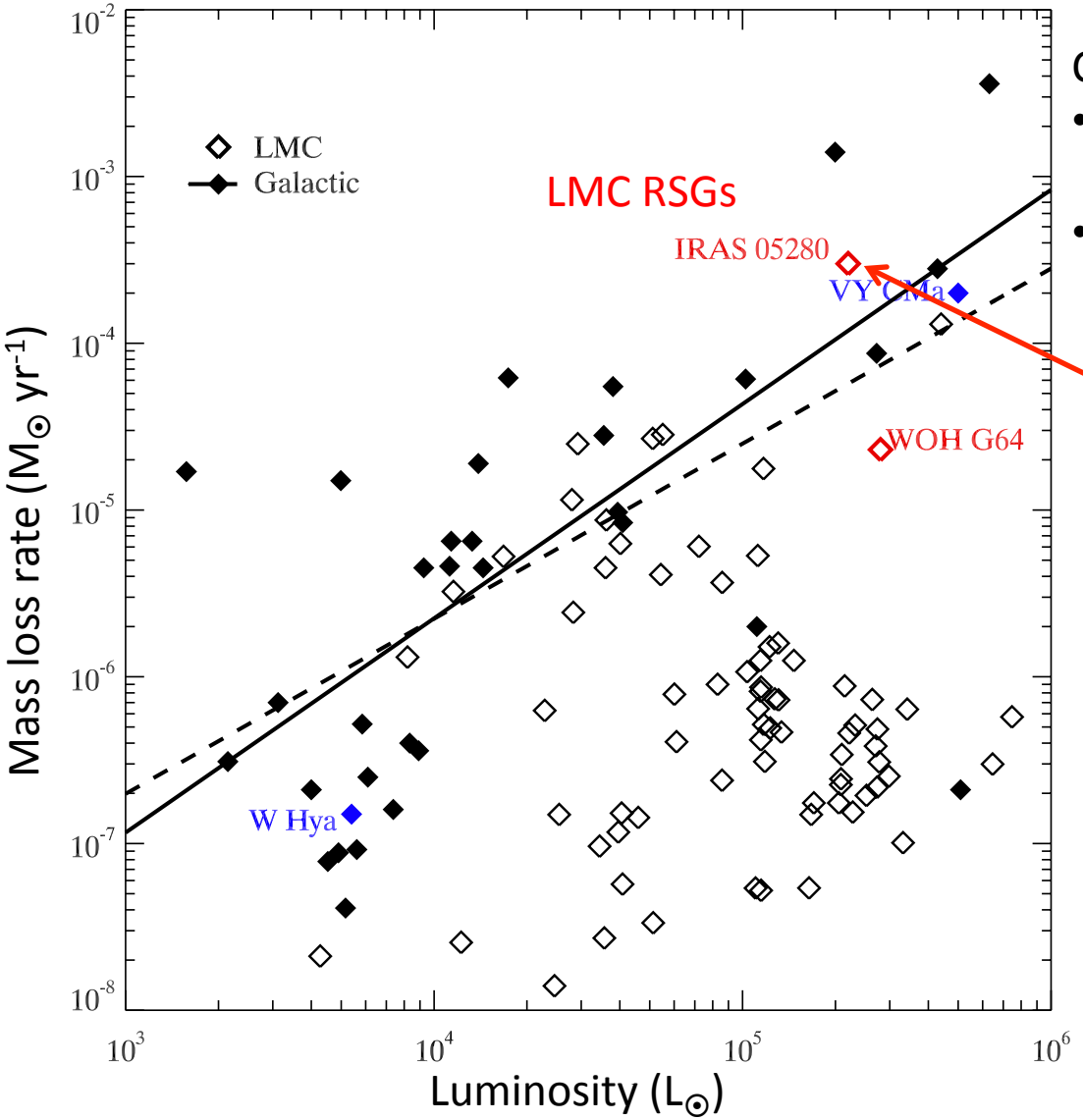
IRAS 05280 (LMC RSG):
$2.2 \times 10^5\ L_\odot$

WOH G64 (LMC RSG):
$2.8 \times 10^5\ L_\odot$

VY CMa (Galactic RSG)
$5 \times 10^5\ L_\odot$

W Hya (Galactic AGB)
5400 $L_\odot$

Mass-loss rate vs luminosity

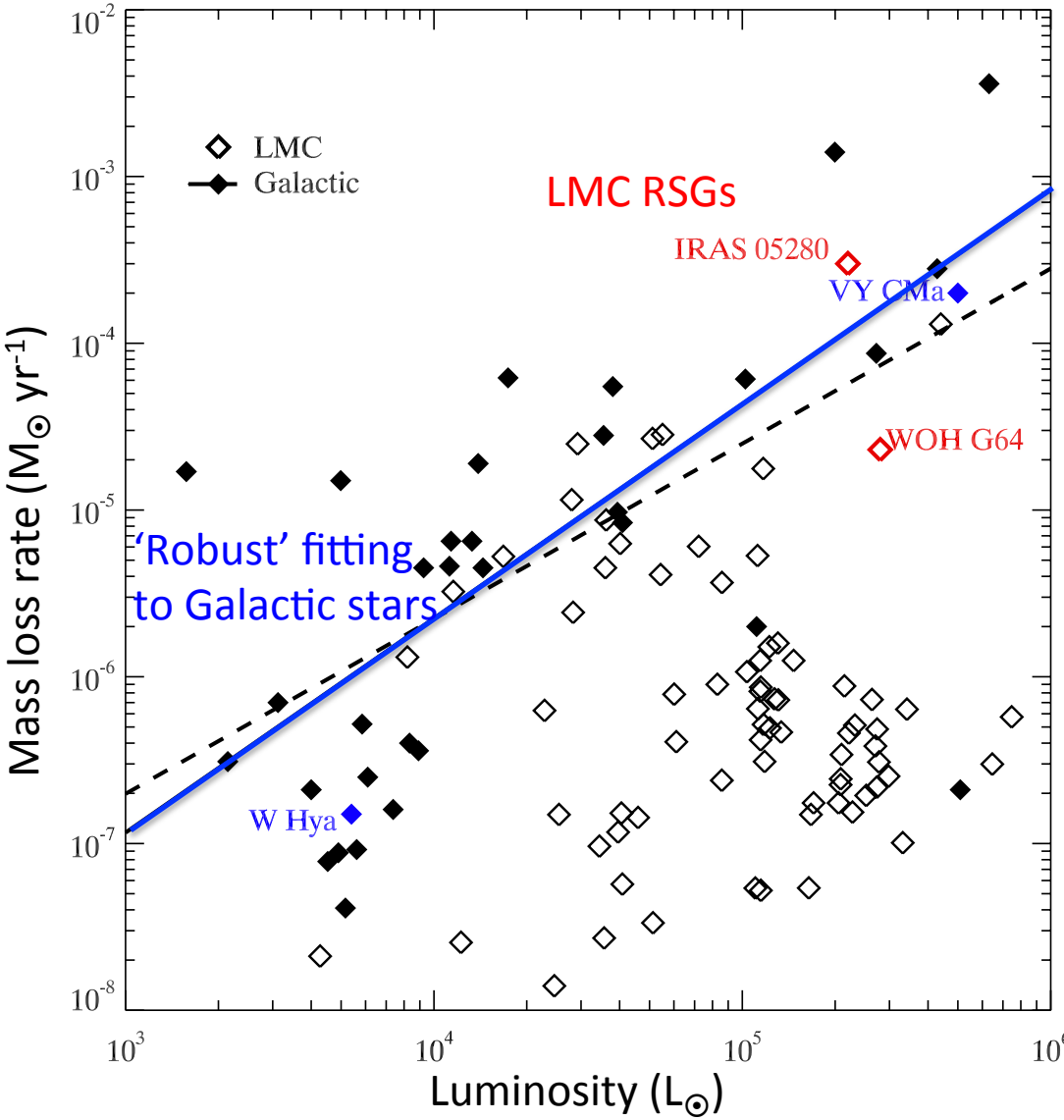


Collecting sample from

- Galactic oxygen-rich AGB+RSG (CO+IR)
  De Beck et al. (2010)
- LMC oxygen-rich AGB+RSG (IR)
  Groenewegen et al. (2009)

Two LMC RSGs – fill a gap in LMC sample (high mass-loss rate and high luminosity end)

Mass-loss rate vs luminosity



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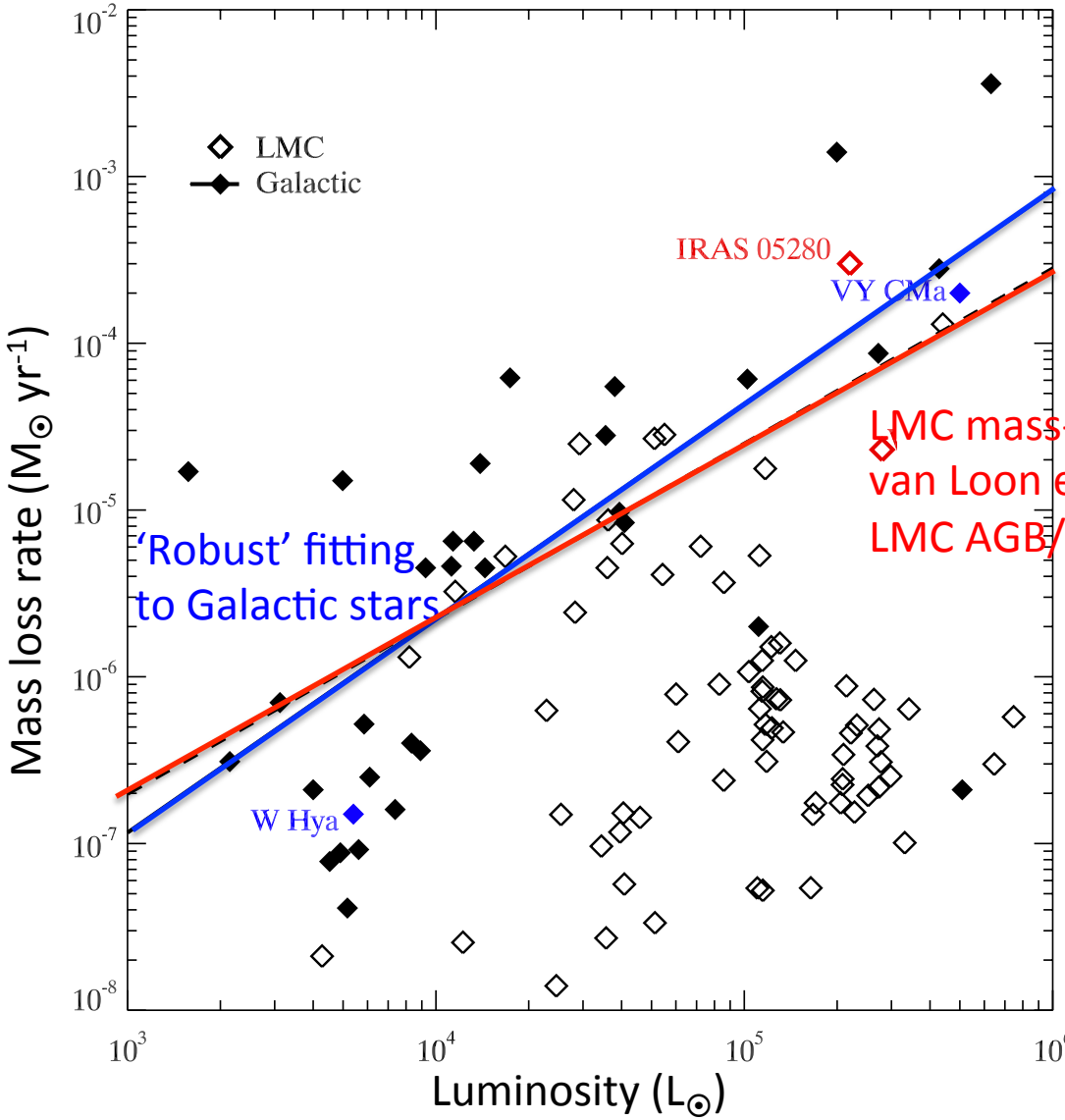
Two LMC RSGs follow the mass-loss rate vs luminosity relation of Galactic stars

Increasing trend in highest mass-loss rate at a given luminosity

Mass-loss rate vs luminosity



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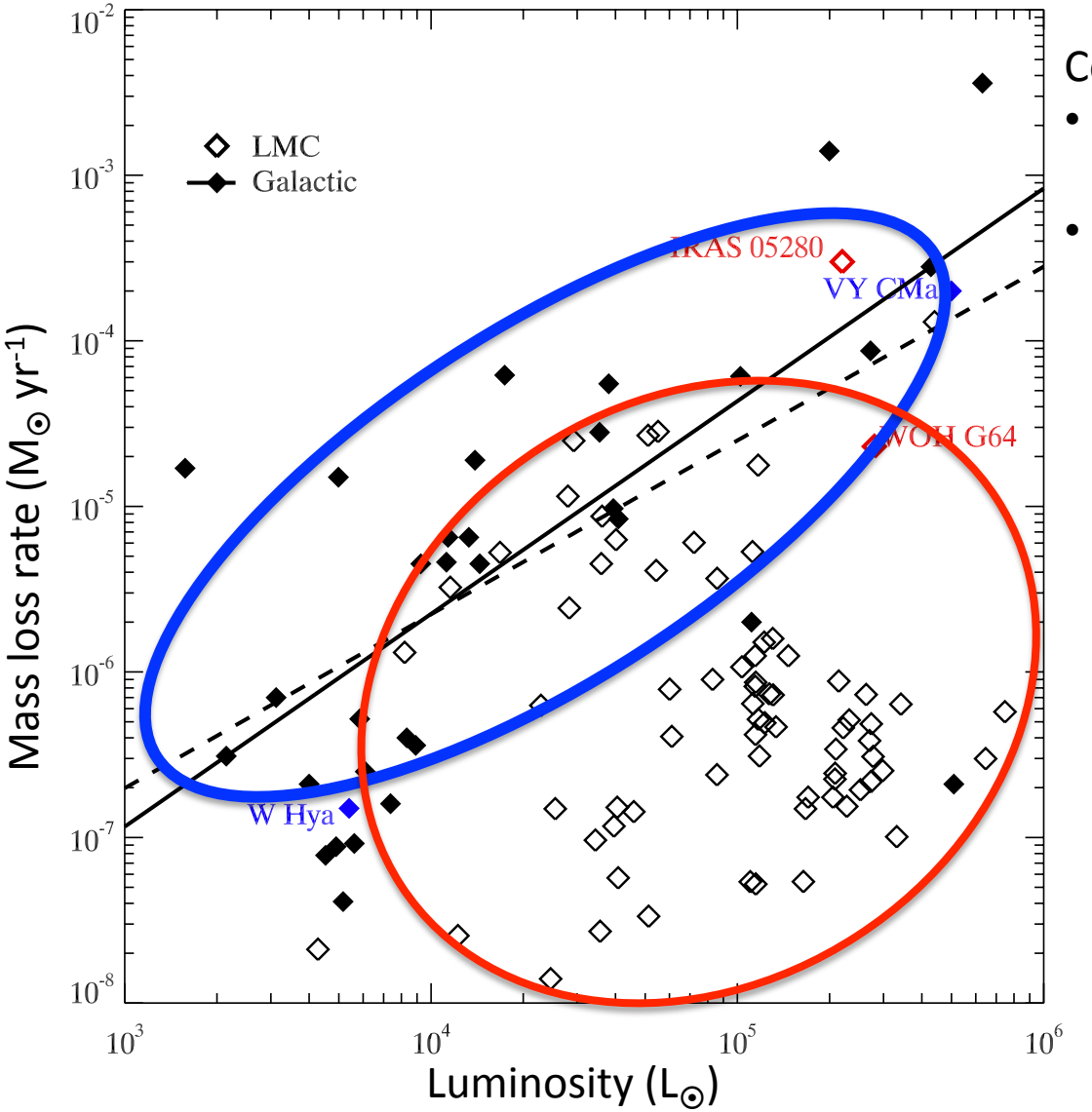
LMC mass-loss rate vs luminosity by van Loon et al. (2005) – IRAS detected LMC AGB/RSGs

No strong difference in fitted results in LMC/Galactic samples

Mass-loss rate vs luminosity



Collecting sample from

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Selection biases in samples

- Galactic AGB/RSG
  CO sensitivity limited sample
  Bright stars
- LMC AGB/RSG
  2MASS detection in JHK
  Relatively blue stars
  (=low mass-loss rate stars)

Tribute to Bruce Swinyard

7 Nov 1962 – 22 May 2015

Summary

- First detection of rotational CO lines in Magellanic Clouds red-supergiants stars
  - LMC red-supergiants have strong CO lines
- No clear evidence of reduced mass-loss rate in LMC (half of solar metallicity)
  - Assumption : reduced fractional abundance of CO and dust mass with respect to H_2
  - Total gas (H_2) mass has little metallicity dependence
- Mass-loss rate: luminosity is the key
  - Increasing trend in the upper end of mass-loss rate at given luminosity