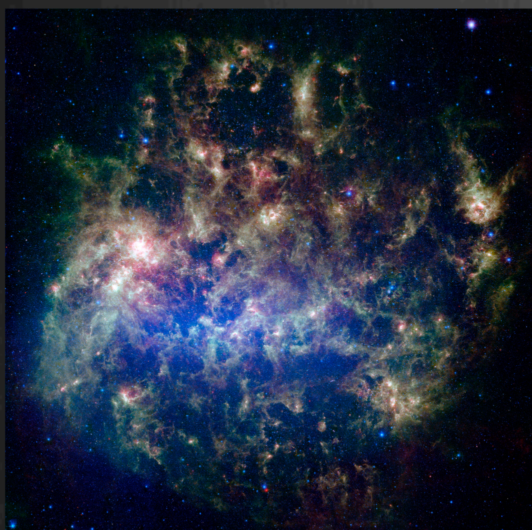
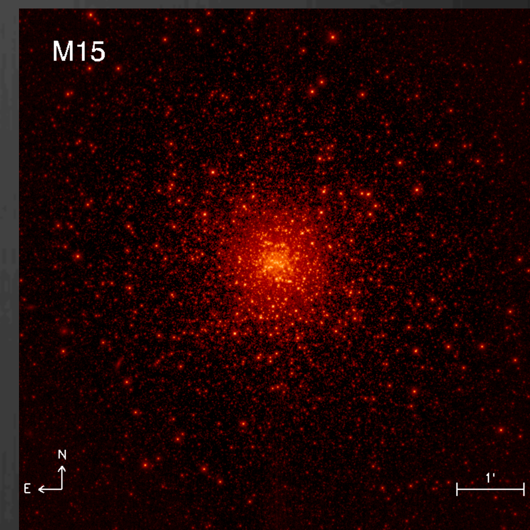
Mass-loss from evolved stars: effect of metallicity



Eric Lagadec

(Cornell University)



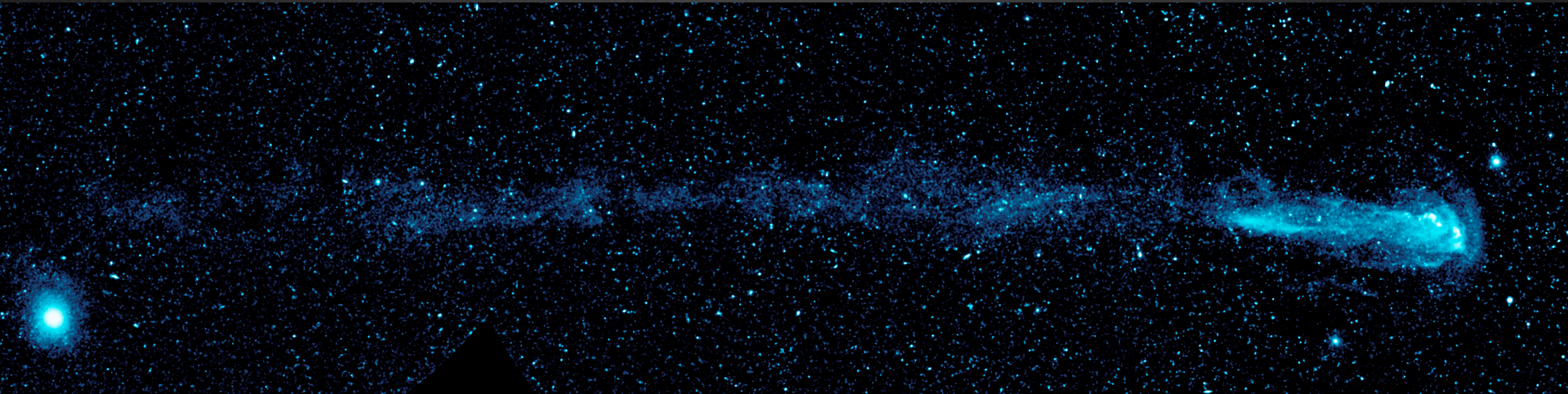
Main co-workers:

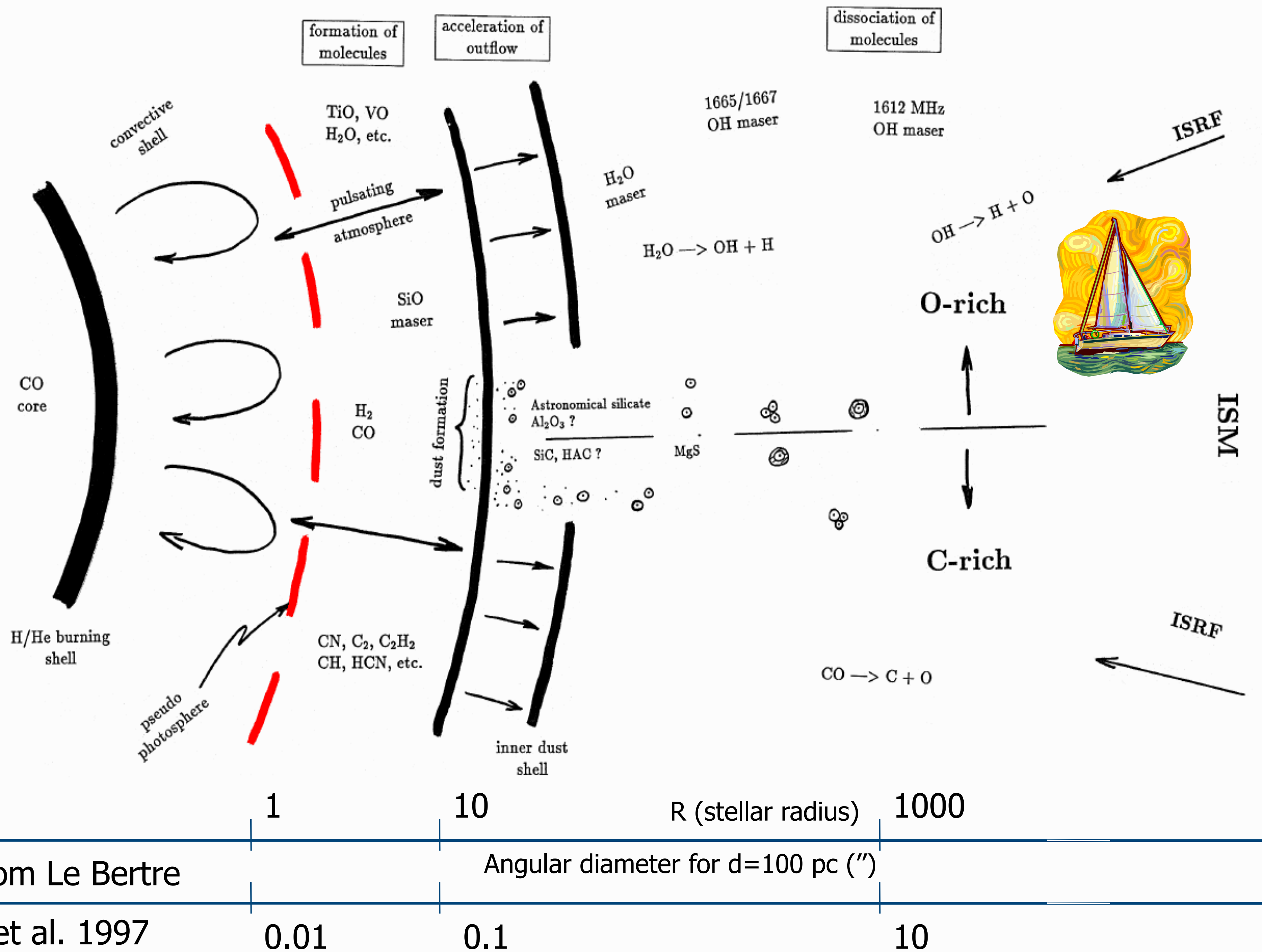
Greg Sloan (Cornell), Albert Zijlstra, Iain McDonald (Manchester) Mikako Matsuura (UCL), Kathleen Kraemer (Boston University), Nicolas Mauron (Montpellier), Peter Wood (Mt Stromlo), Martin Groenewegen (Brussels)

DSLG 2013, Santiago

Why studying the effect of metallicity on the mass-loss from AGB stars?

- Chemical enrichment of the galaxies through cosmic times (carbon, s-elements) (see Sundar Srinivasan's talk)
- Constraints for stellar and galactic evolution models
- We want to determine mass-loss rates from initial parameters (mass+metallicity)





From Le Bertre et al. 1997

Mass loss

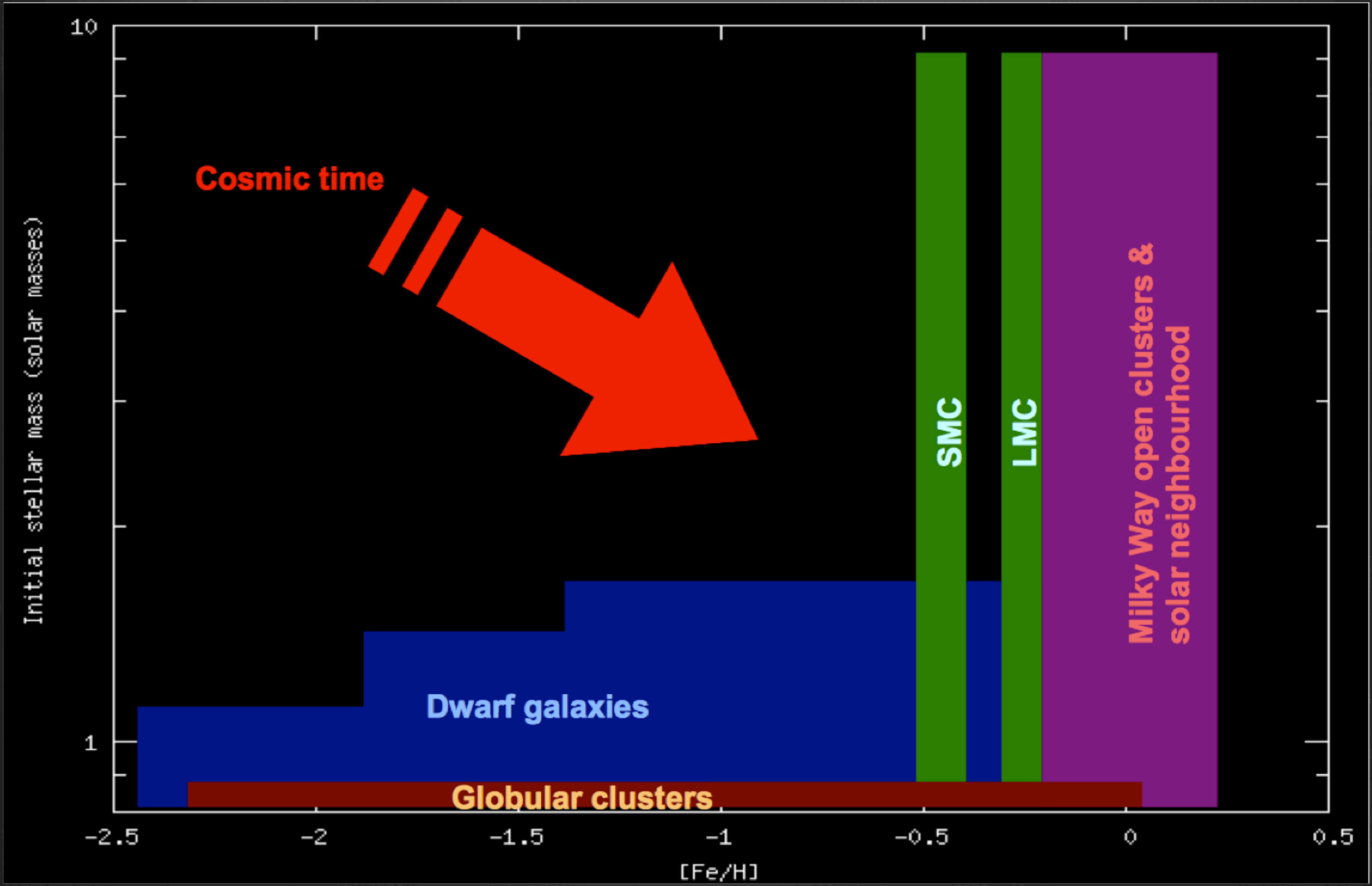
- Driven by: pulsations, dust formation and radiation pressure on dust
- Limiting factors
  - Dust opacity (Woitke 2006)
  - Radiative momentum (Vassiliadis & Wood 1993)
  - Pulsation energy
  - Metallicity

- Low metallicity : less dust, weaker mass-loss? Mass-loss delayed ? What is the primary driver?

Why studying mass-loss from AGB stars in Local Group galaxies and Globular clusters?

- Distance known (luminosity and mass-loss rates (MLR))
- Range of metallicities and initial masses
- Spitzer sensitive enough
- Spitzer can resolve individual stars
  - ISO could only detect brightest LMC stars

Initial masses and metallicities



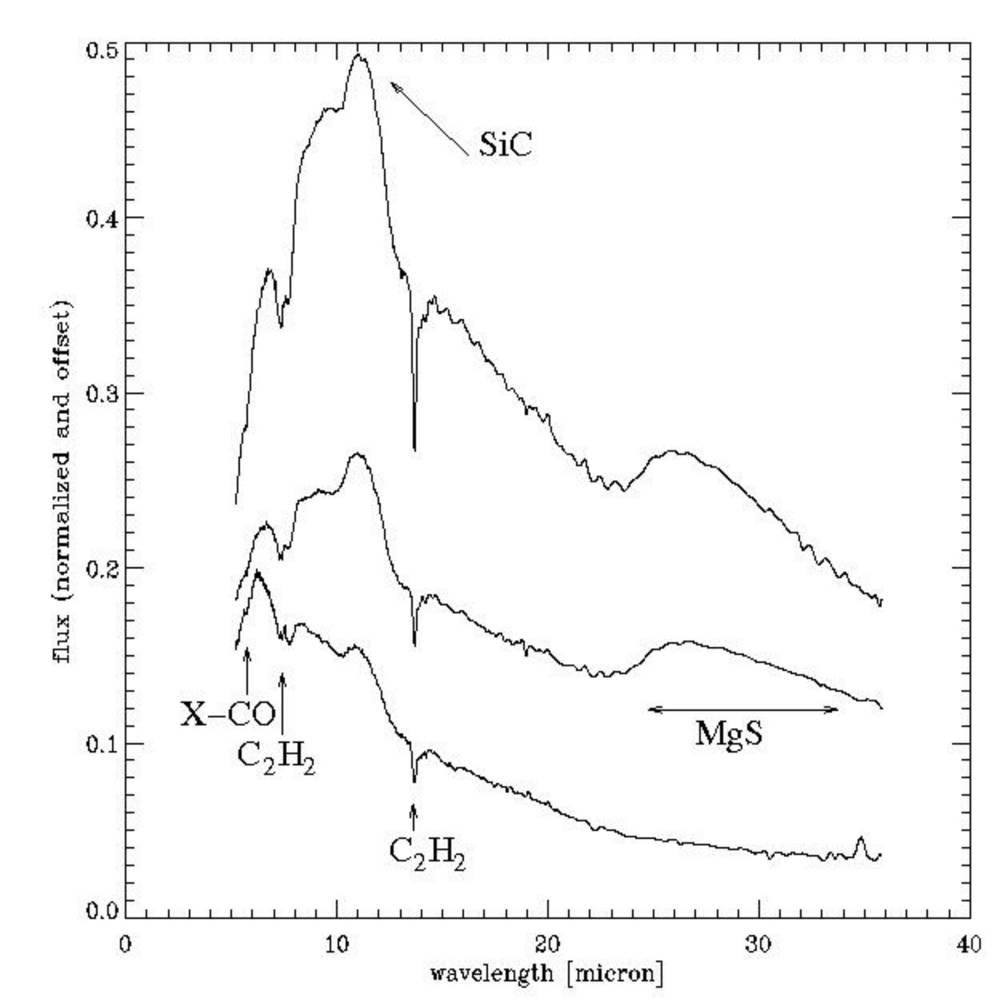
Our Spitzer observations

- Low resolution spectroscopy (5-38 microns)
- 29 stars in the LMC (Zijlstra et al. 2006)
- 14 stars in the SMC (Lagadec et al. 2007)
- 11 stars in Fornax (Matsuura et al. 2007, Sloan et al. 2012)
- 6 stars in Sgr dSph (Lagadec et al., 2009)
- 8 star in Sculptor, Carina, Leo I (Sloan et al. 2009, 2012)
- 6 stars in the Halo (Lagadec et al., 2010; 2012)
- 35 stars in globular clusters (Sloan et al., 2010)

- Study of molecules and dust features
- Mass-loss rates estimation (Groenewegen et al. 2007, Matsuura et al. 2007, Lagadec et al. 2008, Lagadec et al. 2009, Sloan et al. 2009, Lagadec et al. 2010; 2012)

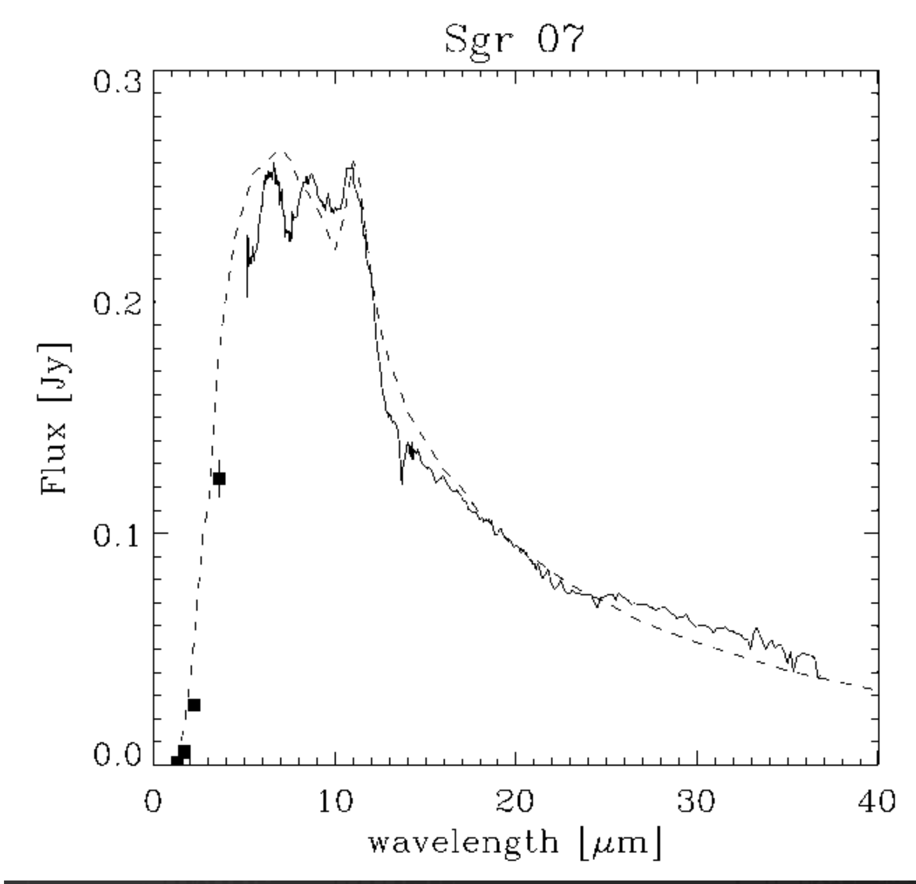
MIR emission in C stars

Spitzer spectra



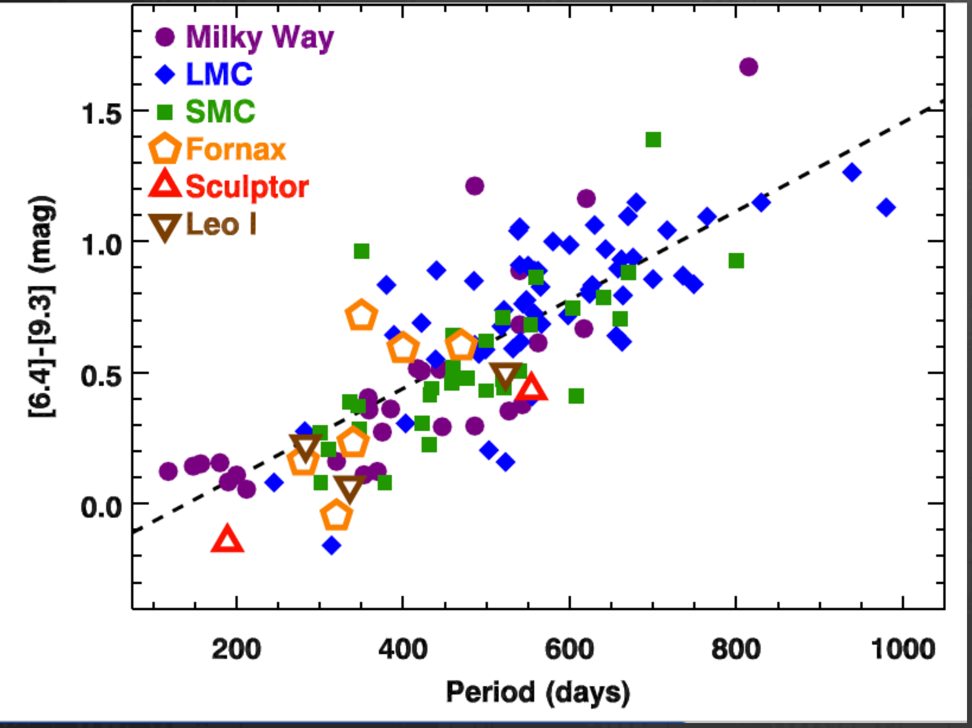
Zijlstra et al. (2006)

DUSTY RT model



Lagadec et al. (2009)

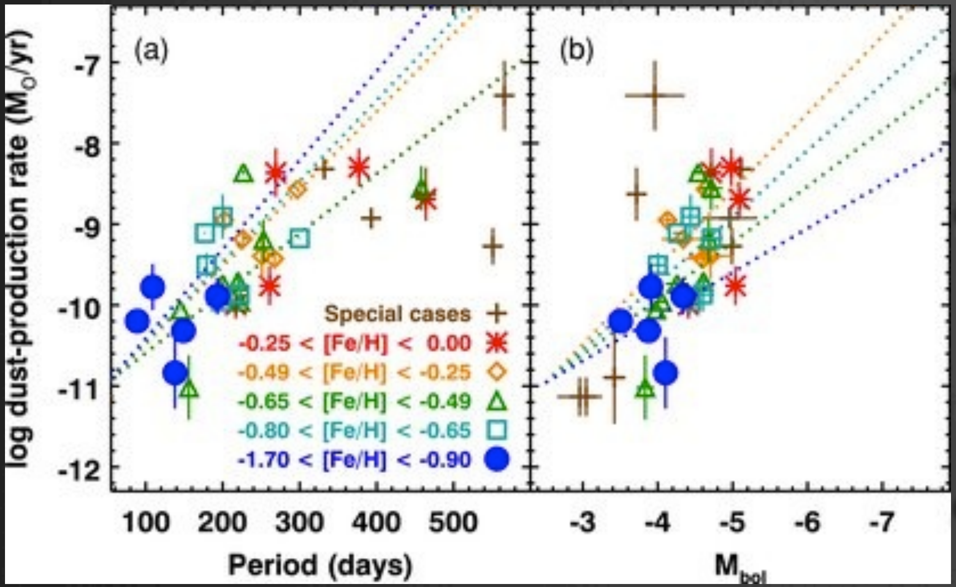
Carbon stars mass loss



Sloan et al. (2012)

- Dust MLR up to 10^{-7} $M_{\odot}.yr^{-1}$
- Similar to Galactic AGB stars
- No clear evidence the MLR depends on Z (Slight decrease when [Fe/H]<-1; Sculptor, Leo 1)
- Superwind triggered when C/O>1 (Lagadec & Zijlstra 2008)

O-rich stars mass loss



Sloan et al. (2010)

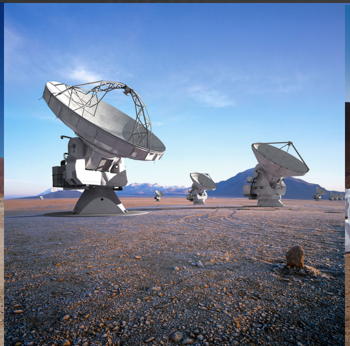
- Dust MLR decrease with Z
- Elements needed to produce O-rich dust not produced by AGB stars
- AGB stars produce carbon

Limitations

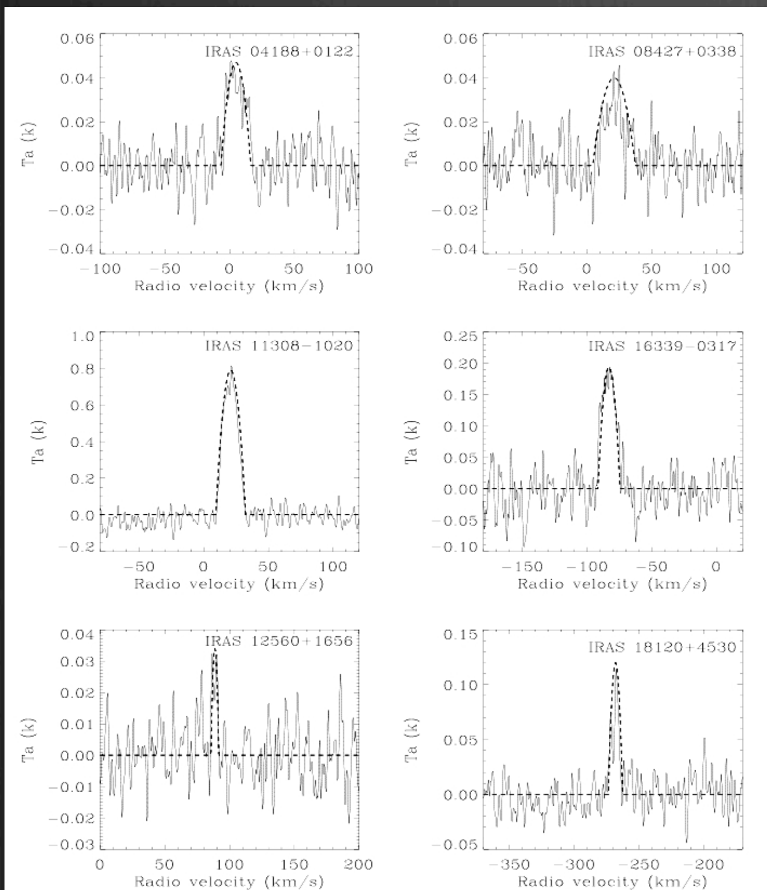
- Expansion velocities not known
- Gas mass-loss rates neither
- Gas-to-dust mass ratio not well determined
- (indication that it is higher at low Z (Matsuura et al. 2007))
- Biased samples (brightest stars observed)
- Study of the impact of AGB stars on the chemical evolution of the galaxies still mainly qualitative

Solution: ALMA

- Low Z AGB stars discovered in the Halo (Mauron et al. 2004, 2005, 2007)
- ALMA "pathfinder" CO observation at JCMT+ MOPRA (V_{exp}+ gas mass-loss rates) (Lagadec et al., 2010; 2012)
- Ground-based MIR photometry+ Spitzer (dust composition) (Lagadec et al., 2012)
- Near-infrared CRIRES spectroscopy to determine Z (P.I.:Lagadec)

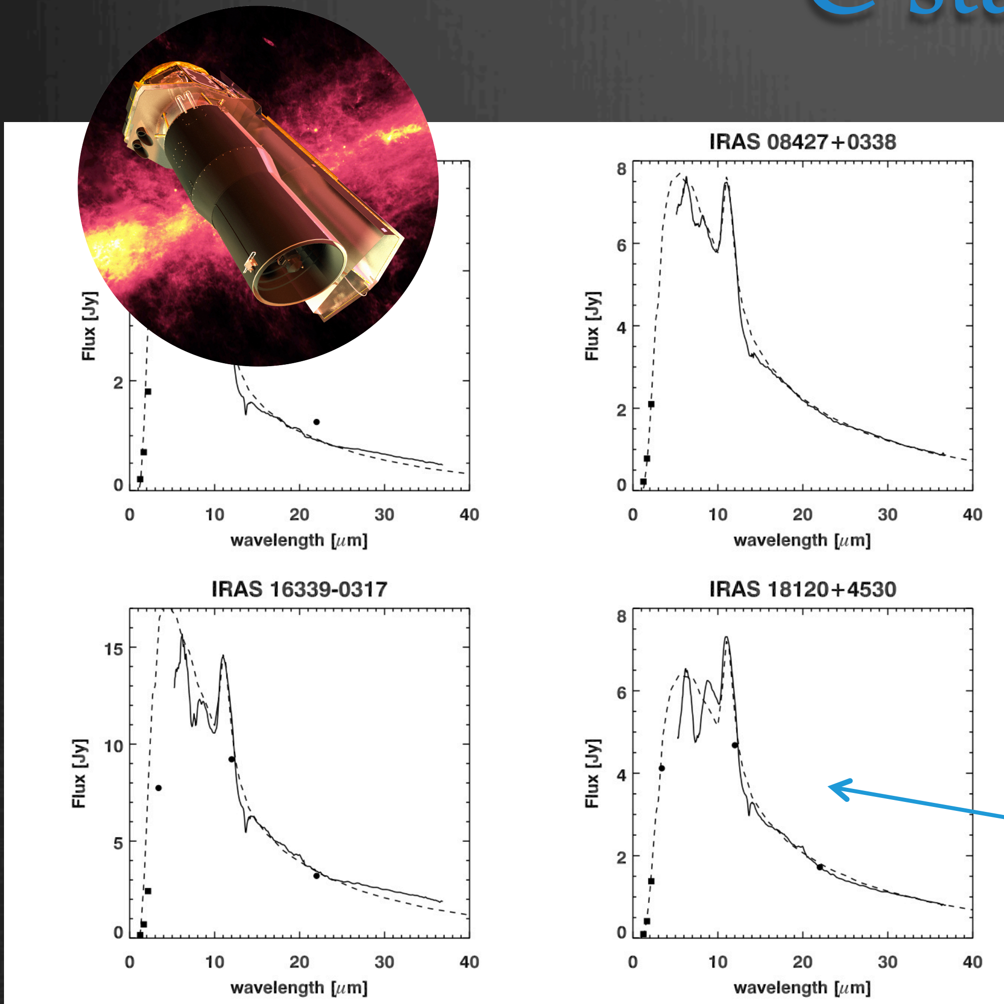
CO observations of Halo C stars



Lagadec et al. (2010)

- Stars selected from their IR colours
- Measurement of V_{lsr} allowed to confirm (or not) that stars were in the Halo
- 3 Thick disc stars
- 1 Sgr dSph star
- 2 Halo stars

Spitzer observations of Halo C stars

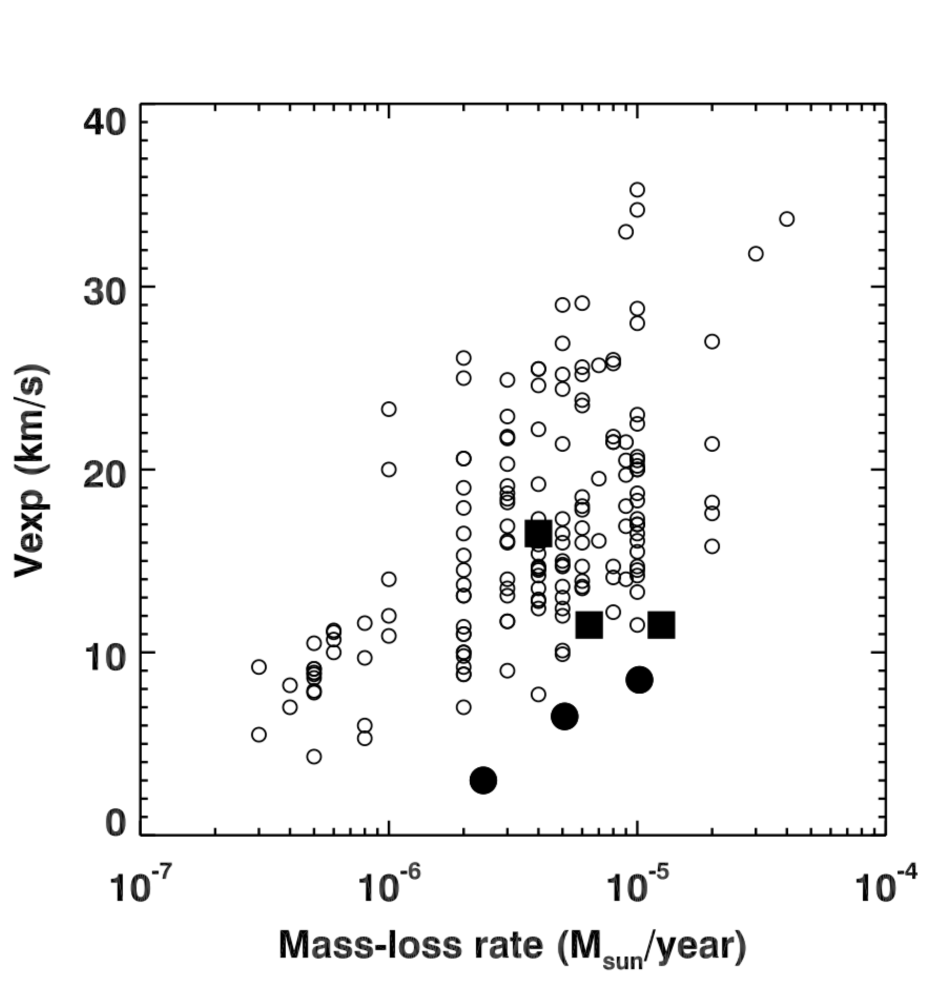


- IR+Radiative transfer: dust production rate
- CO: gas mass-loss rate
- Gas-to-dust mass ratio

Last ever Spitzer spectrum

Lagadec et al. (2012)

Halo AGB stars have a lower V_{exp}



Lagadec et al. (2012)

- Low expansion velocities in the Halo
- High mass-loss rates
- Metallicity, mass??
- ALMA needed!!
- But with better samples!

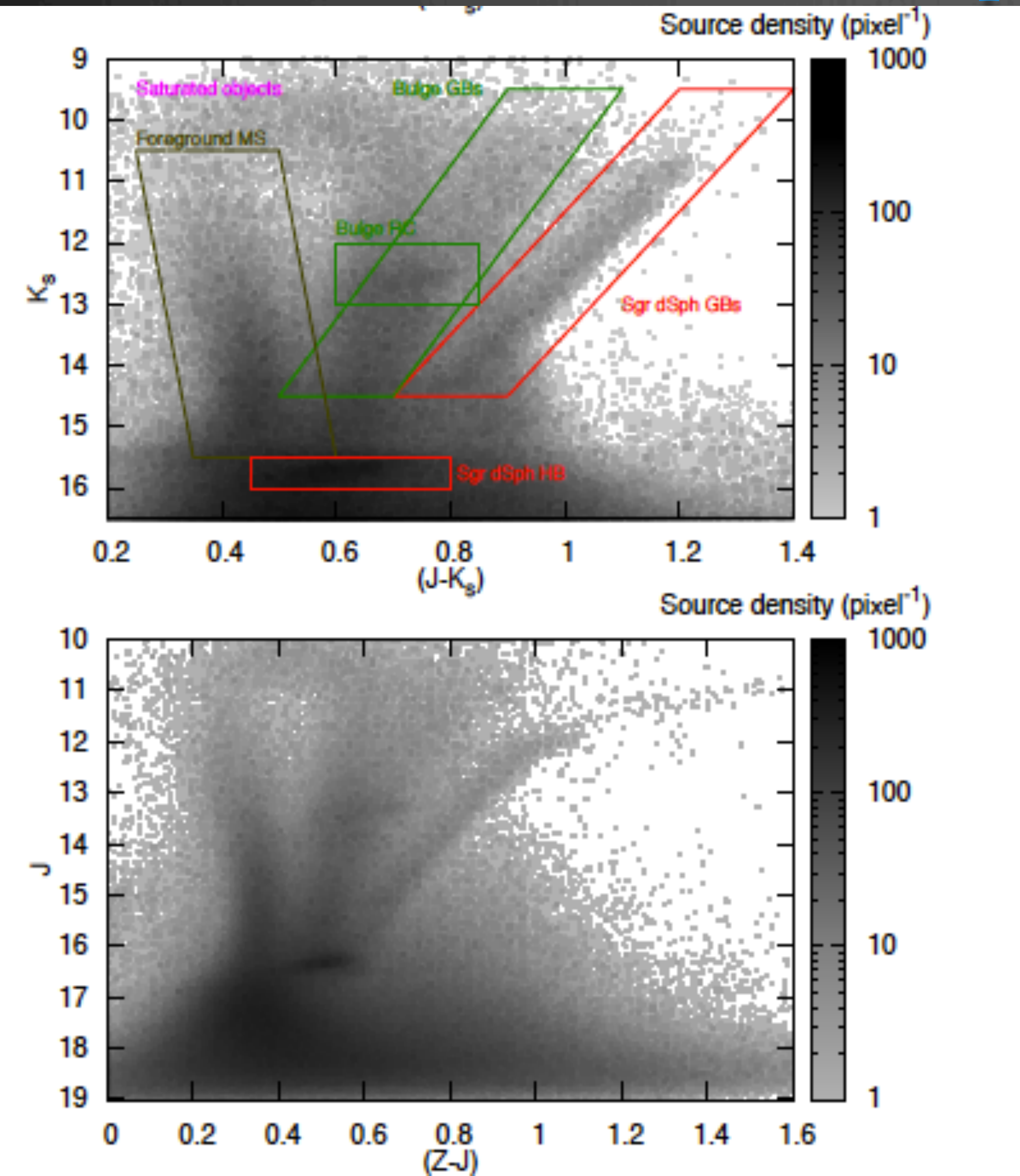
Defining new samples

- Globular clusters (M and Z well known) (M5, M15: CFHT, SOAR, Lowell)
- Galaxies with clearly defined populations (Sextans, Sculptor, Sgr dSph: CFHT, VISTA)
- Multi-epochs photometry: pulsation+luminosity

Primary mass-loss driver: pulsation or luminosity?

Defining new samples

Local Group galaxies

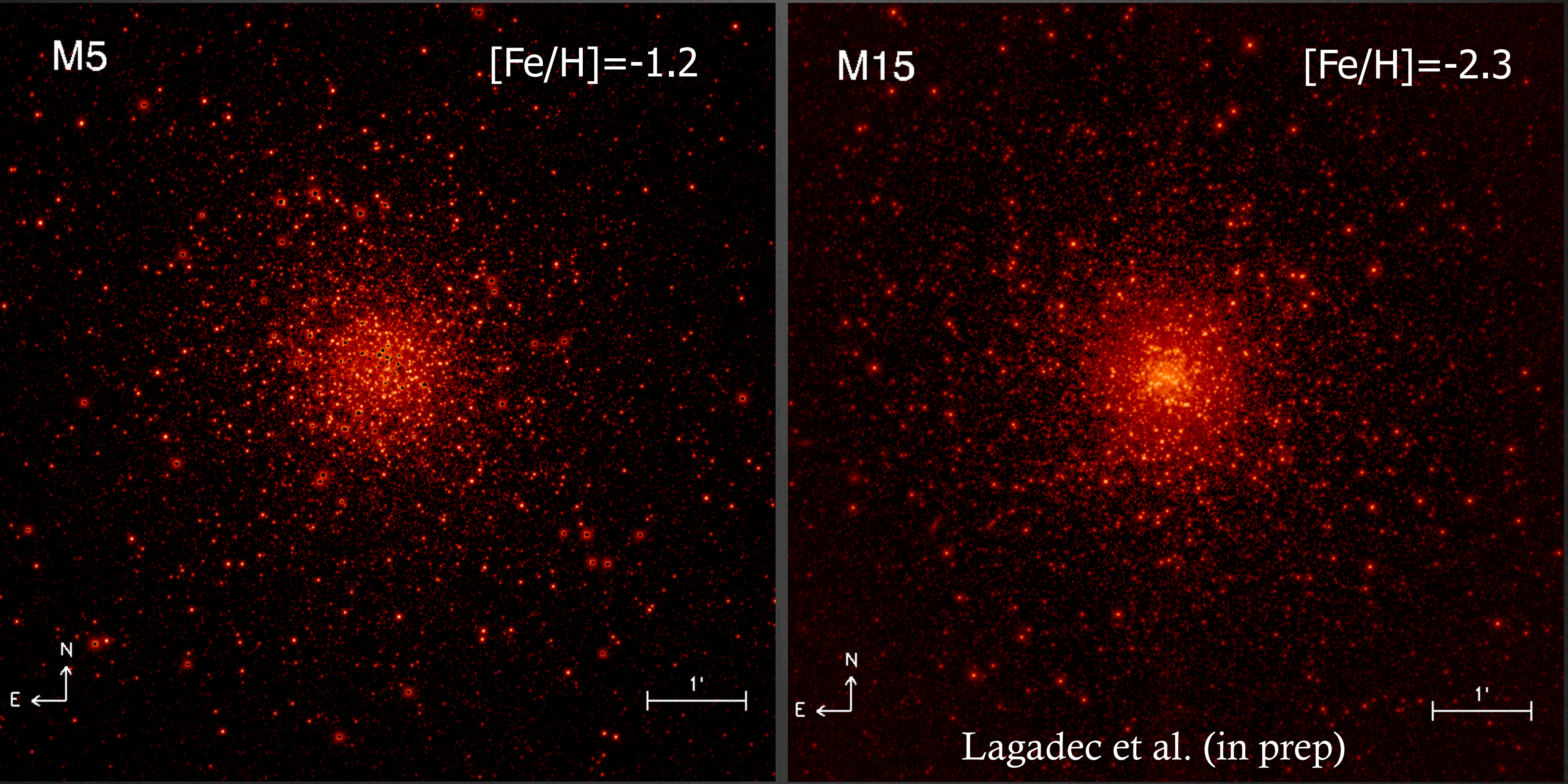


- Sgr dSph mapped with VISTA (McDonald et al., in prep), 3 million sources, 1.5 square degrees
- Sextans mapped with CFHT (Lagadec et al., in prep), 6 square degrees, 2 epochs, more to come
- Sculptor observations to come?

McDonald et al., in prep

Defining new samples

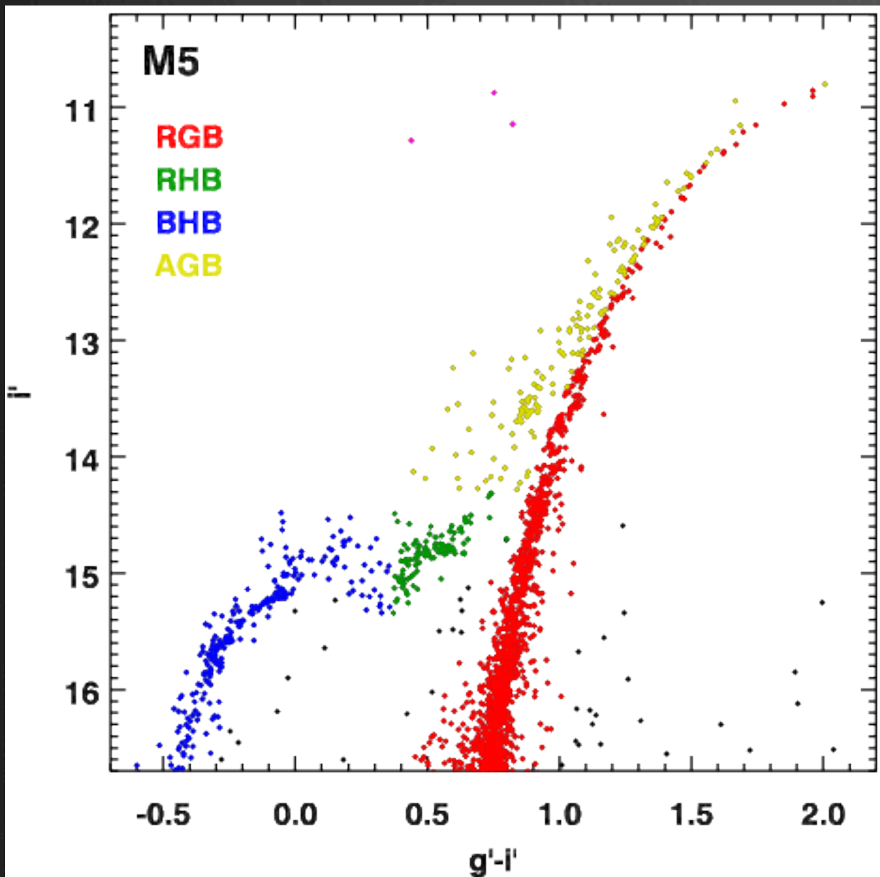
Globular clusters

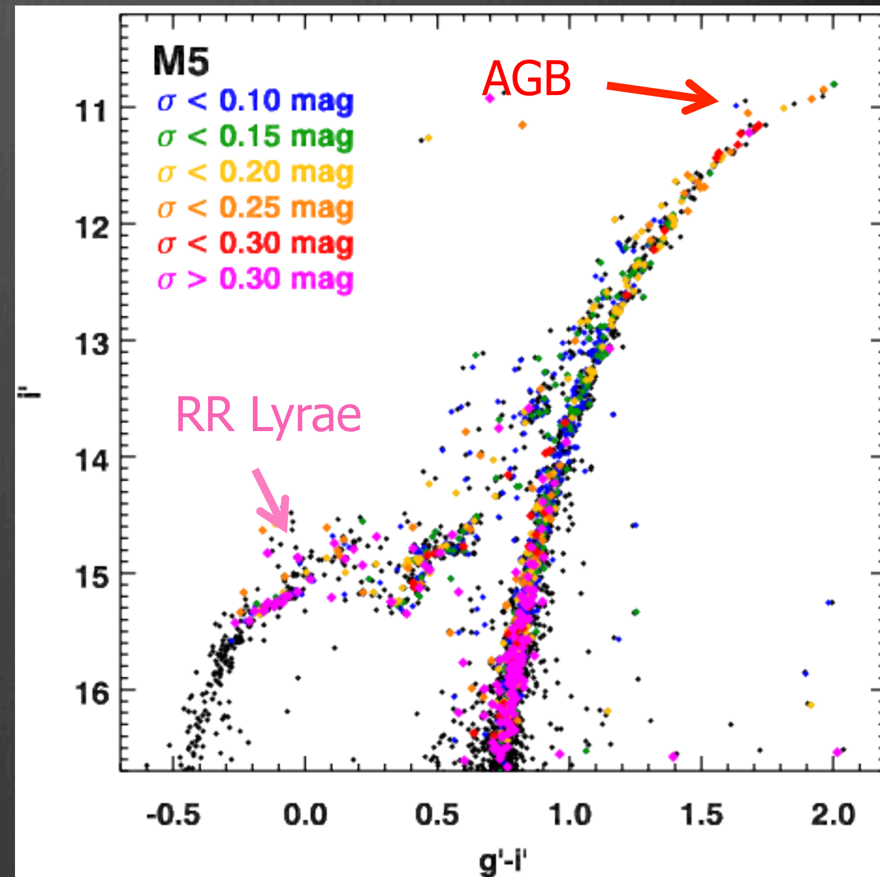


M5 and M15 observed with CFHT (optical and NIR), Lowell (IR), baseline up to 1 year now

Defining new samples

Globular clusters





AGB clearly identified

Baseline: 1 month

Lagadec et al, in prep

Conclusions and perspectives

- Spitzer survey of mass-losing AGB stars in 8 Local Group Galaxies
- High mass-loss rates observed (carbon stars)
- Chemistry dominated by carbon
- Mass-loss triggered earlier at low Z, triggered by carbon?
- Observations of Halo stars show a lower Vexp and high MLR
- Samples with known M_i, Z and pulsation needed
- **ALMA observations of Local Group and Globular Clusters AGB stars needed!!!!**

Yes, you are right, this dinner invitation from the French embassy is highly suspicious

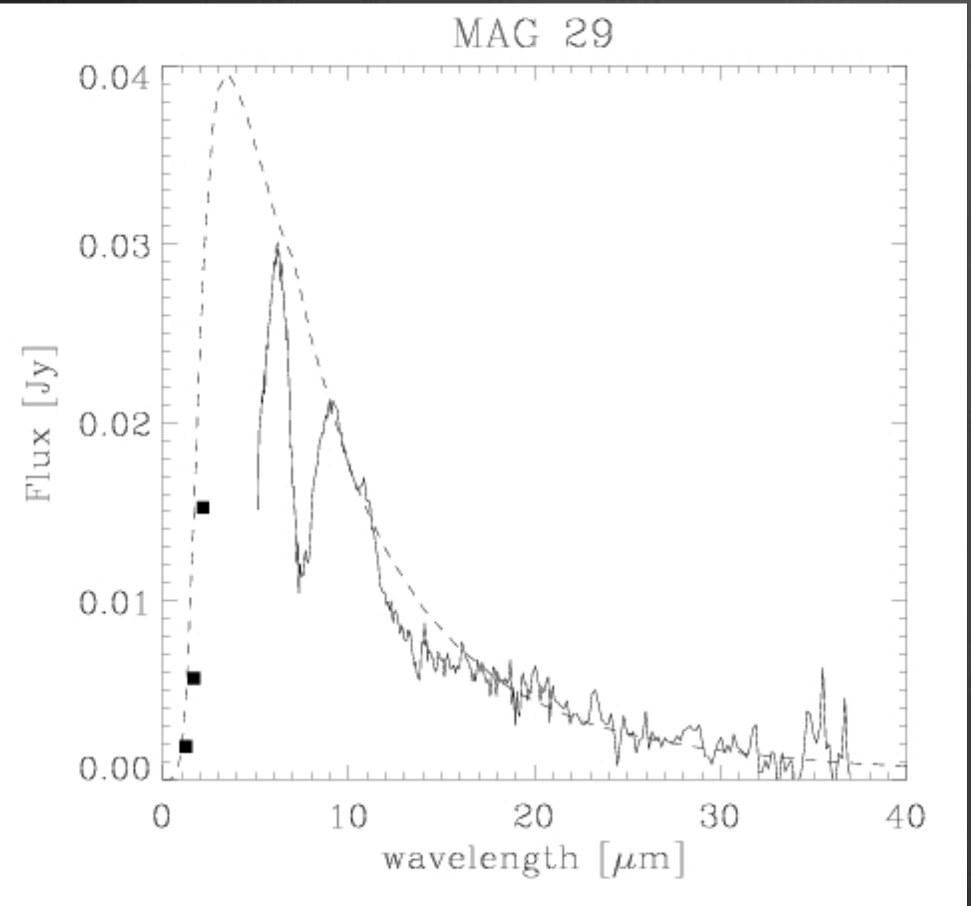
Yes, you are right, this dinner invitation from the French embassy is highly suspicious

MERCI!

Yes, you're right... This dinner invitation from the French Embassy is highly suspicious!

Merci!

Mass-loss from an AGB star with primordial metallicity



- MAG 29 in Sculptor galaxy ($Z=1/25\ Z_{sun}$)
- Significant mass-loss rate

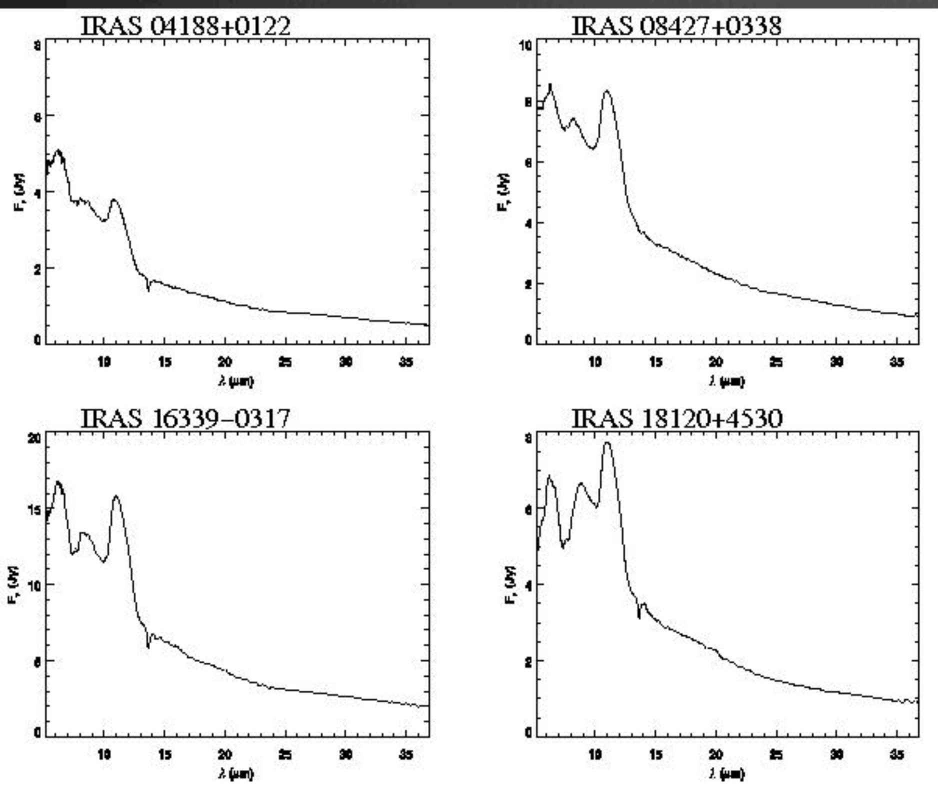
Sloan, Matsuura, Zijlstra, Lagadec et al. 2009 (Science)

AGB stars are sources of dust at high redshift?

- Star formation begins at z = 10
  - t = 480Myr
- Dust is detected at z = 6.4
  - t = 870 Myr
- AGB stars appear after 70 Myr
  - At z = 6.4, AGB stars trace down to M = 3 Msol
  - All important dust sources are in place
    - (apart from SNe Ia)
- AGB dust can contribute

Spitzer spectra of "Halo" carbon stars

Thick disc



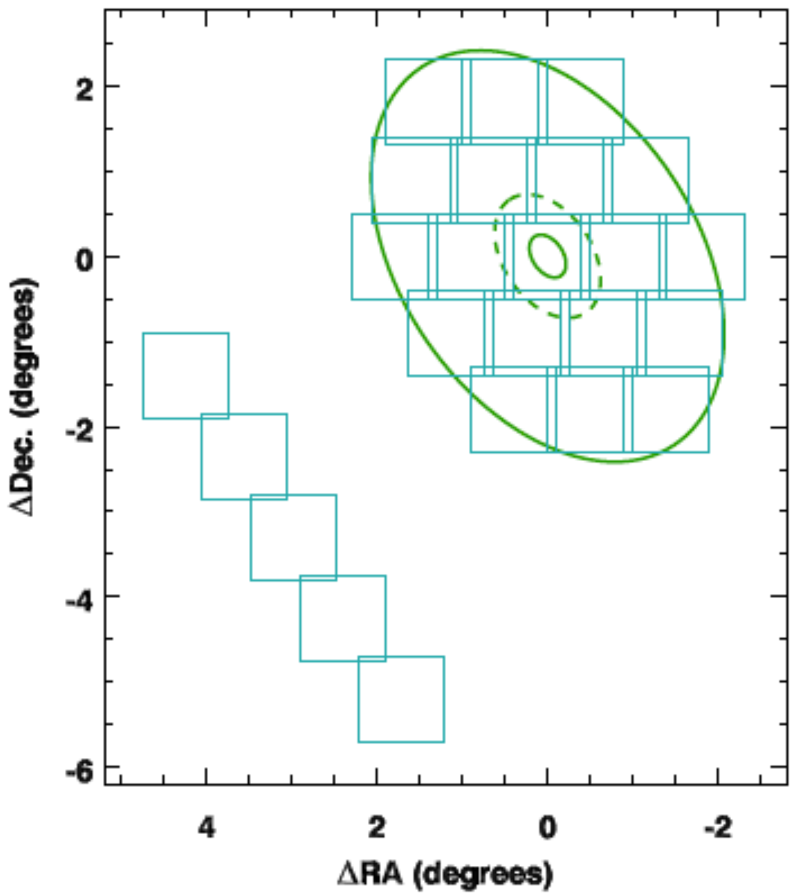
Halo

- Spectra for 4 out 6 stars observed in CO
- Very strong SiC
- Very weak C_2H_2
- Are these stars metal-rich?
- Are SiC/ C_2H_2 not Z indicators?

Carbon stars mass loss

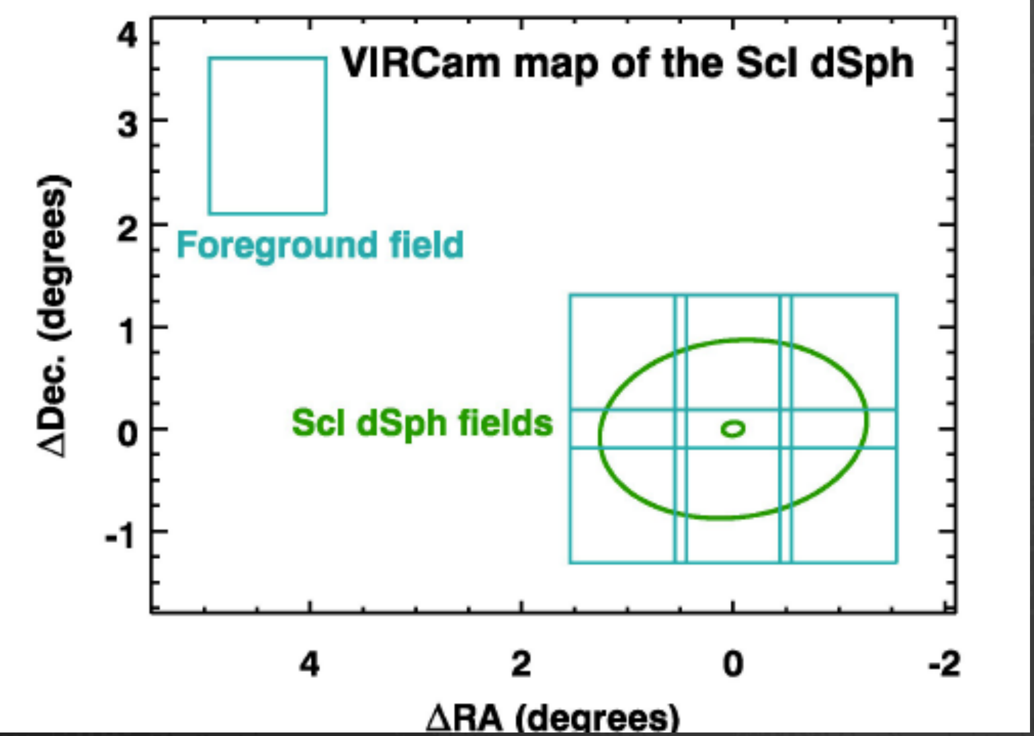
- Much larger fraction of dusty AGB stars are carbon-rich at low Z
- Onset of the superwind earlier at low Z
  - At this point, Galactic AGB stars with the same luminosity are still O-rich
- O-rich metal-poor stars have lower MLR
- Carbon triggers the superwind? (Lagadec & Zijlstra 2008)

Sextans



- 2 populations
- 86 kpc
- [Fe/H]~-2, inner kpc
- [Fe/H]=-2.7, outter parts

Sculptor



- 2 populations
- 87 kpc
- [Fe/H]~-1.5, inner kpc
- [Fe/H]=-2.3, outter parts