The Impact of Dust on Wind-Blown Bubbles

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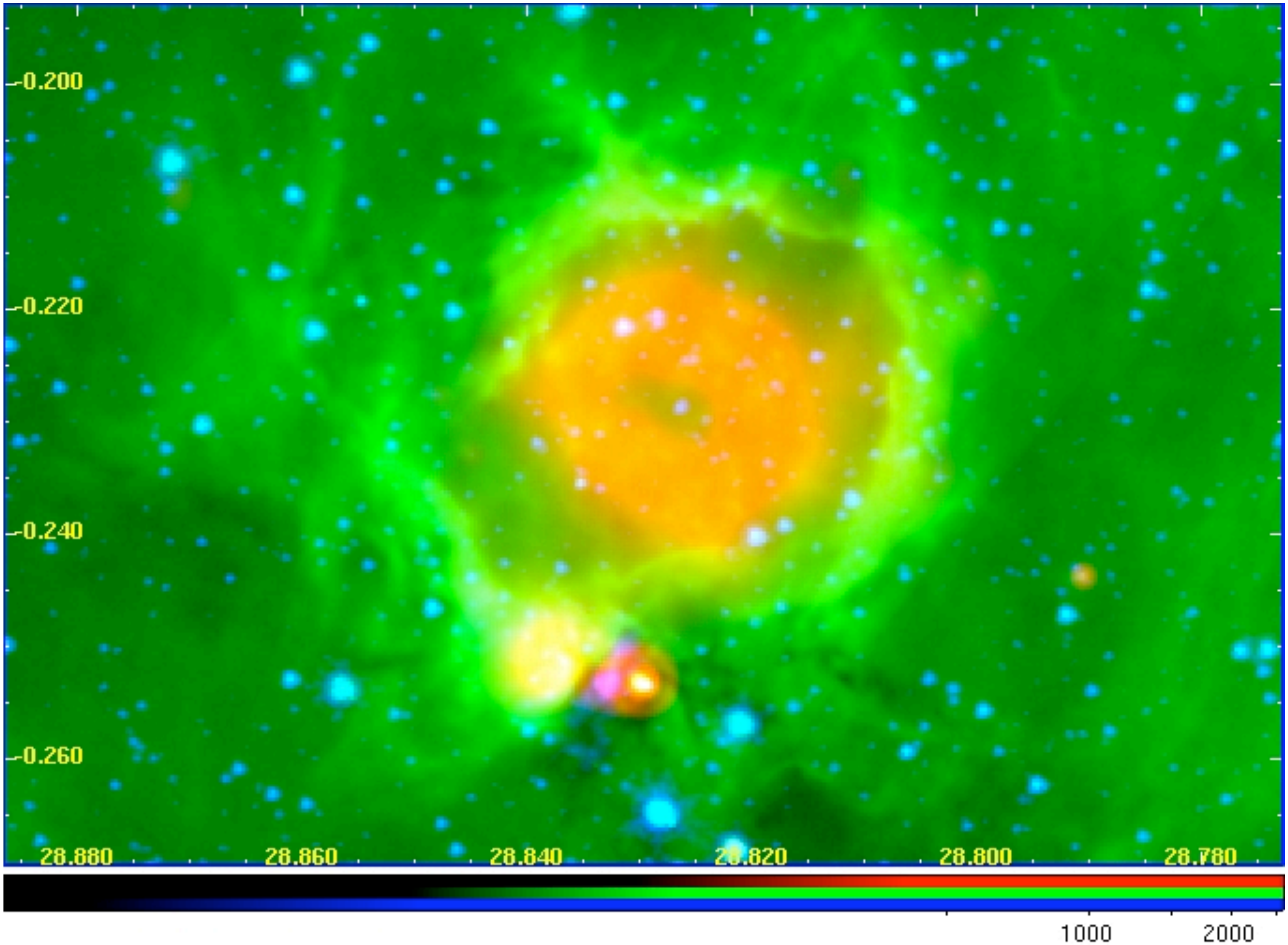
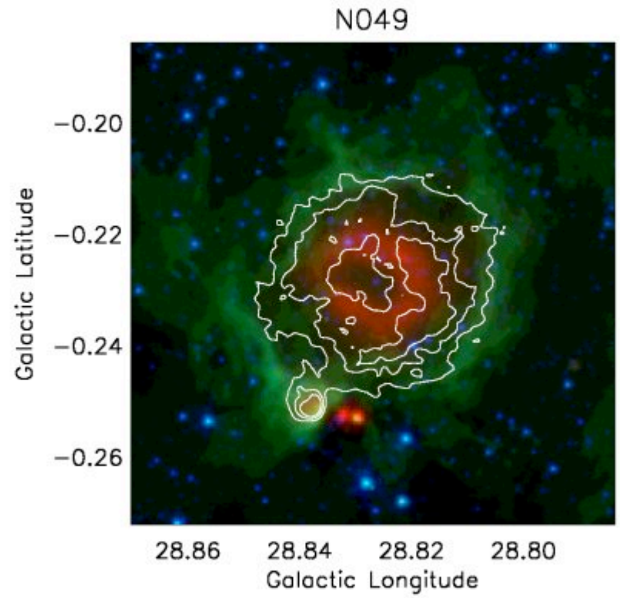
Outline
N49-A Wind-Blown Bubble

- Dust observed within this wind-blown bubble
  - MIR/Radio Image
  - Relative Broadband Brightnesses
- Modeling the dust: Why does dust survive?
- Importance of grains on bubble properties
- Summary

N49 4.5(B), 8.0(G), 24(R) μm Image



N49 IR/Radio Image



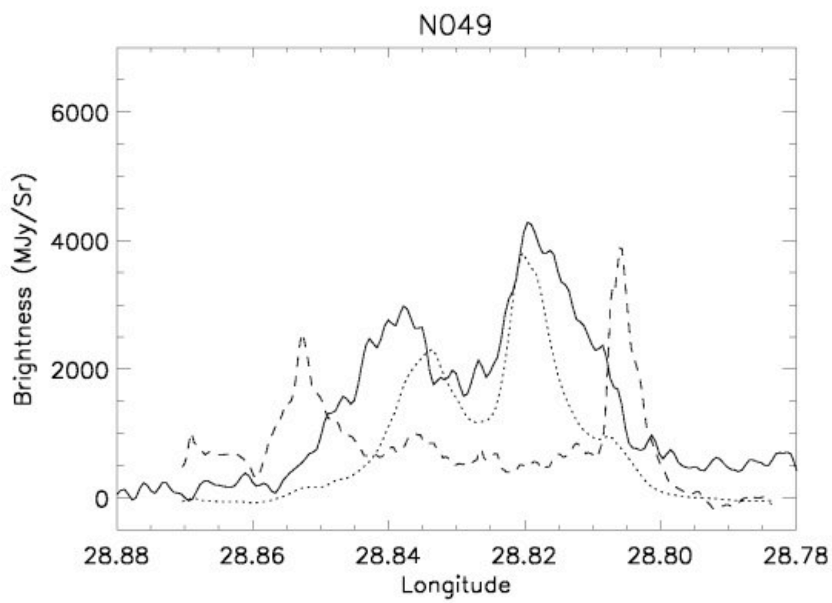
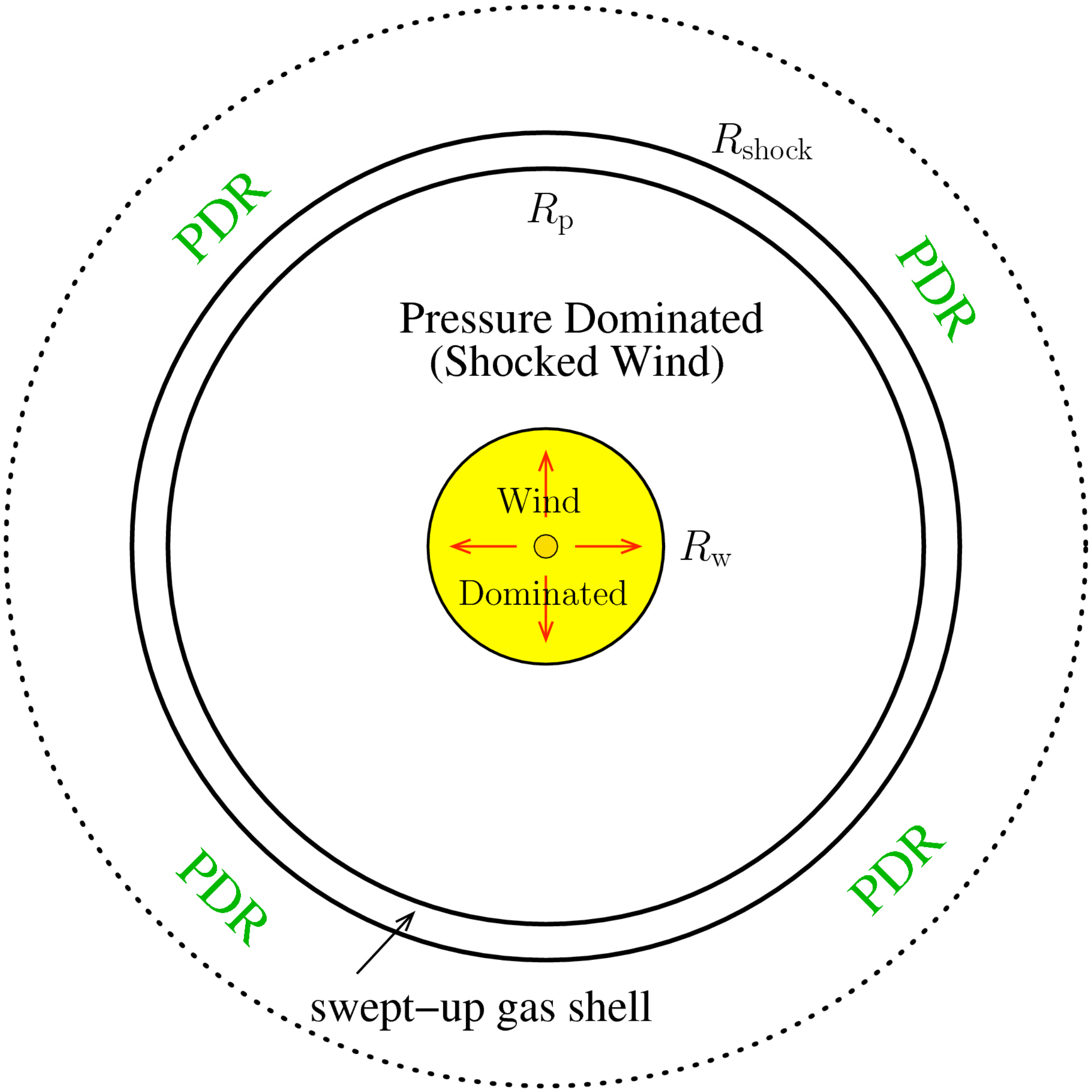
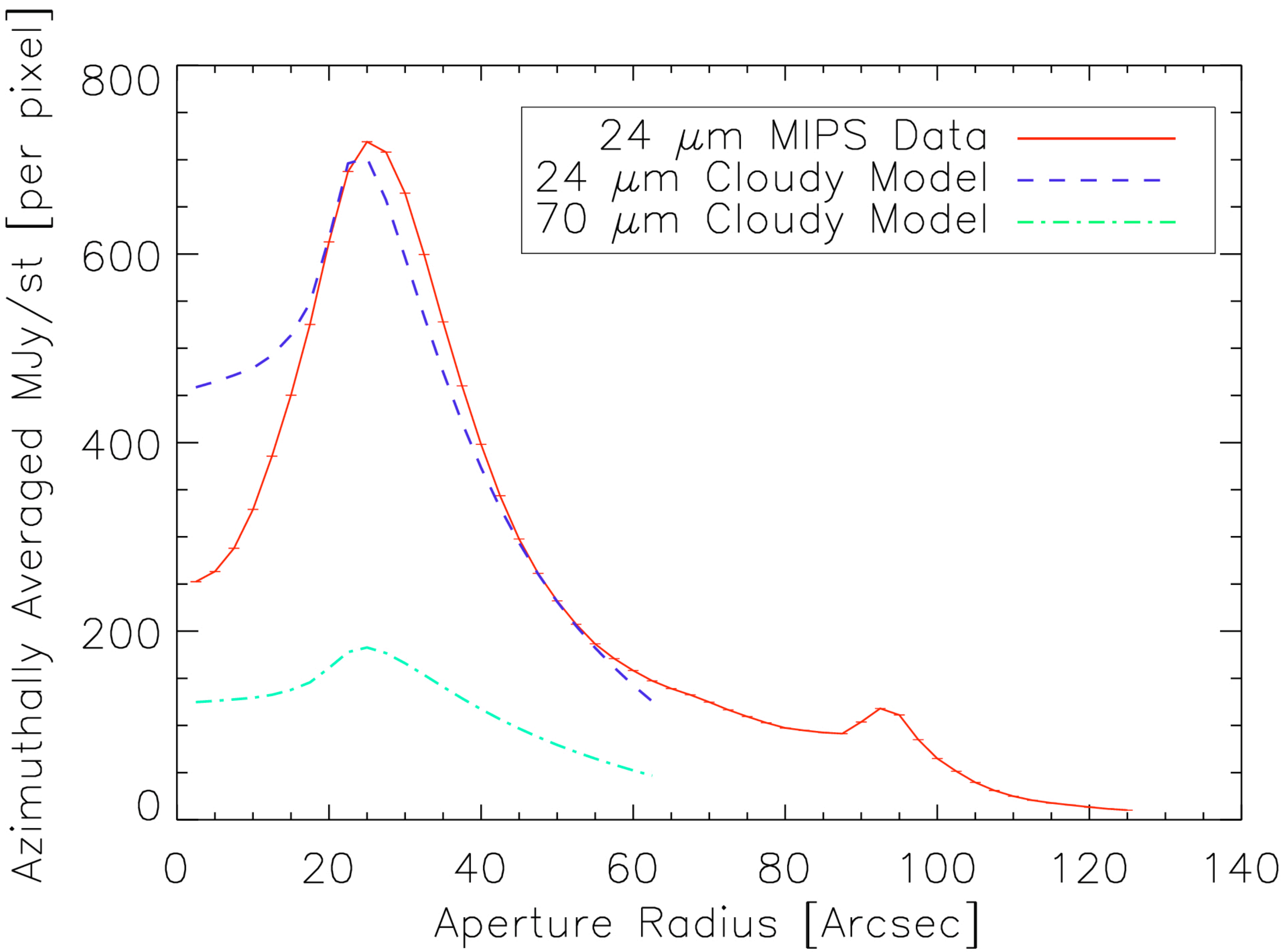


Image of Wind-Blown Bubbles a la Weaver et al. 1977



Dust models approximately fit the data: 24/70μm Brightness Distributions



Dust Model Properties

As a first approximation, we model N49 as a static, uniform-temperature, dusty bubble using Cloudy (Ferland, 1998) and Cloudy_3D (Morisset, 2004). Key parameters for the models are:

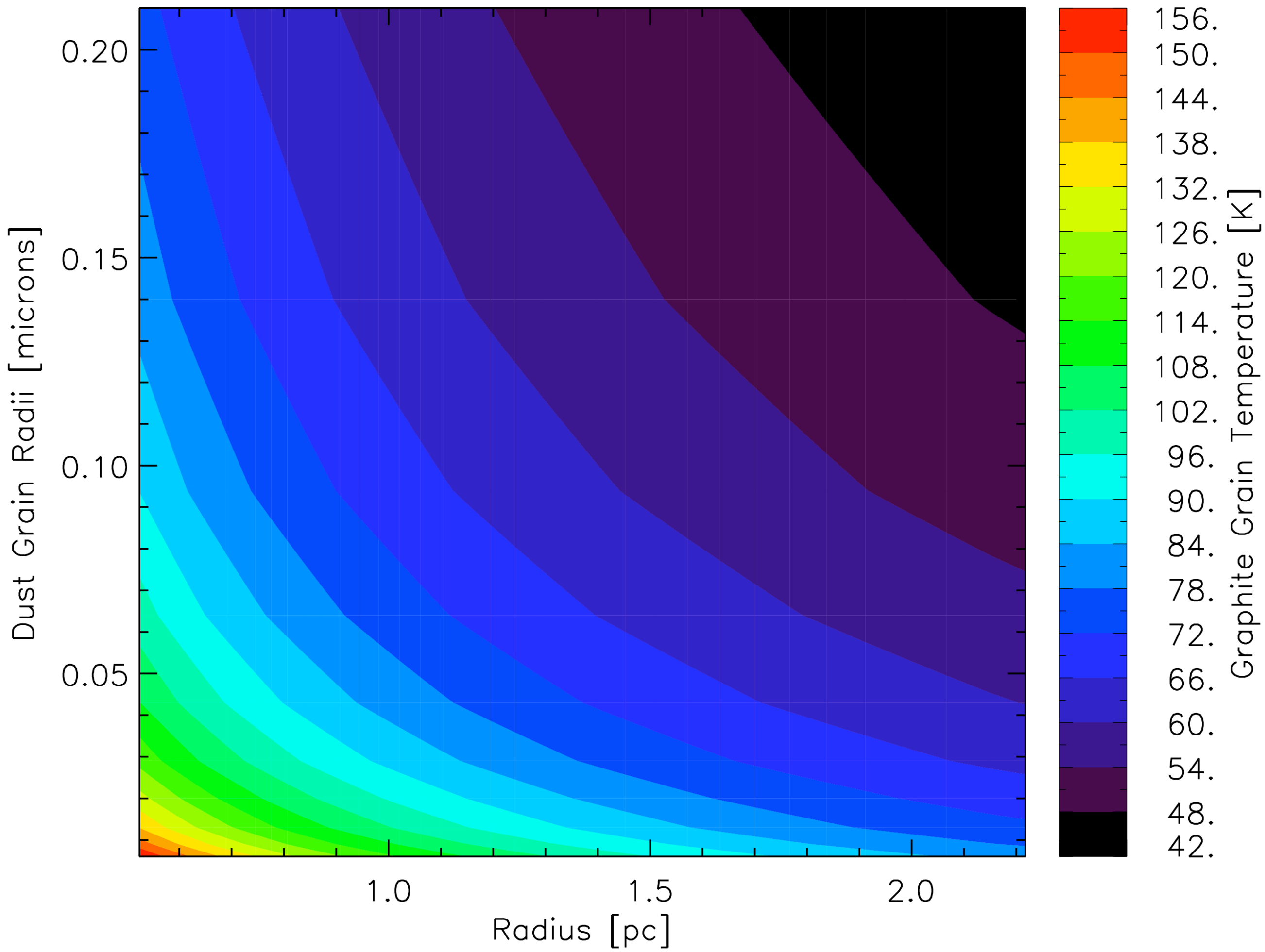
Parameter	*Value*	*Reference*
$T_{e,\mathrm{bubble}}$	10^7 K	Freyer et al. (2003)
central star	O6V	Watson et al. (2008)
Distance	5.7 kpc	Churchwell et al. (2006)
Age	$\sim 10^5$ yrs	Watson et al. (2008)
n_{inner}	11.2 cm^{-3}	(Best-Fit Result)
r_{inner}	0.6 pc	(Best-Fit Result)
r_{outer}	2.2 pc	(Best-Fit Result)
Dust	ISM grain distribution	van Hoof et al. (2004)

O5V star; n_{inner}~0.01 cm^{-3}; age~10^6 yr

Can Dust Survive in the Bubble?
Dust Properties in Wind-Blown Bubbles

- Grain Temperatures
- Sputtering Timescales
- Grain Residence times
- Average Grain Charge
- Dust Cooling Fraction

Grain Temperatures: Little Sublimation

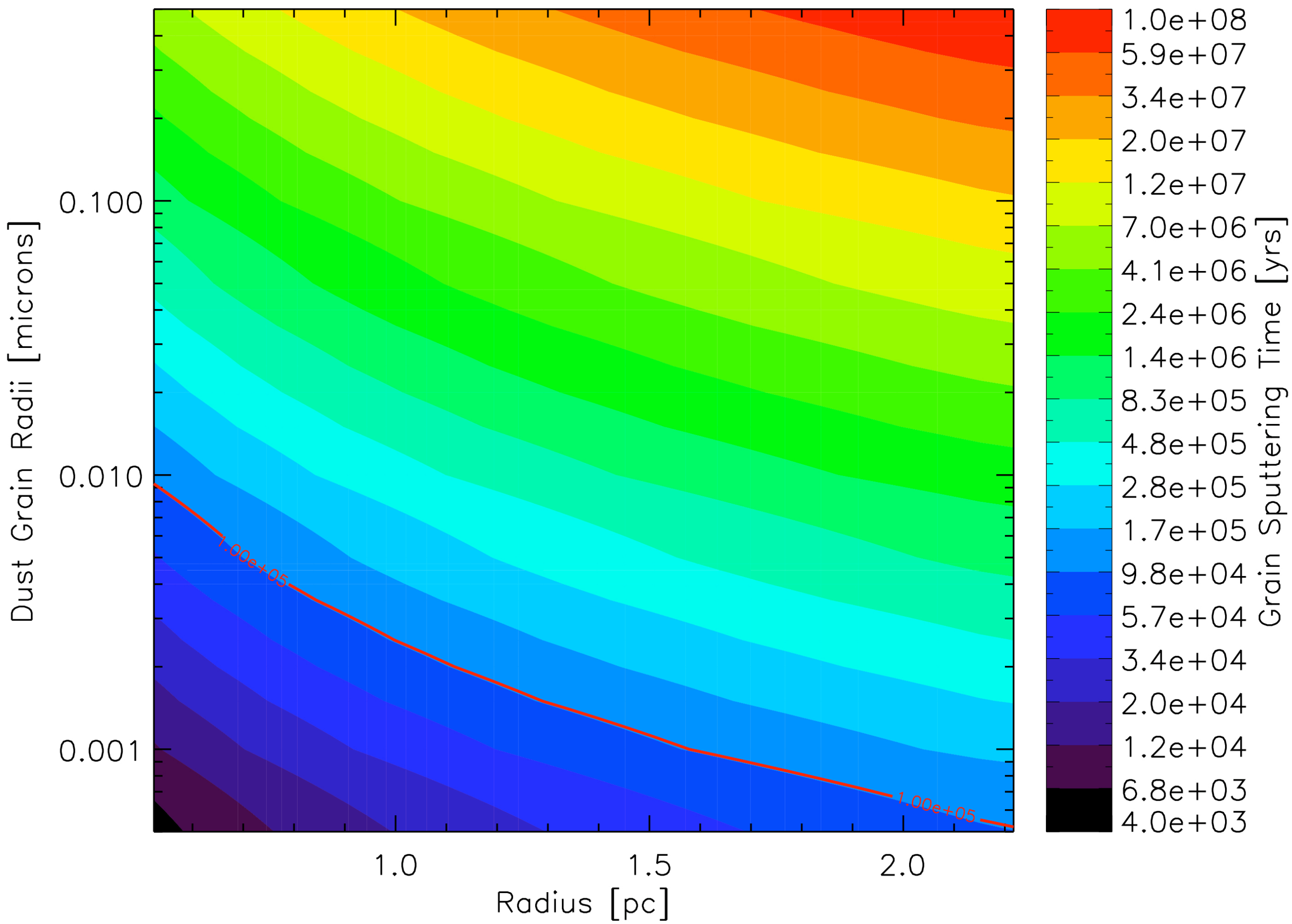


Graphites slightly warmer than the silicates at same radius and grain size

Larger grains cooler than smaller grains at same radius and grain size

Decrease in temp with radius only ~50%

Sputtering: Destroying Small Grains

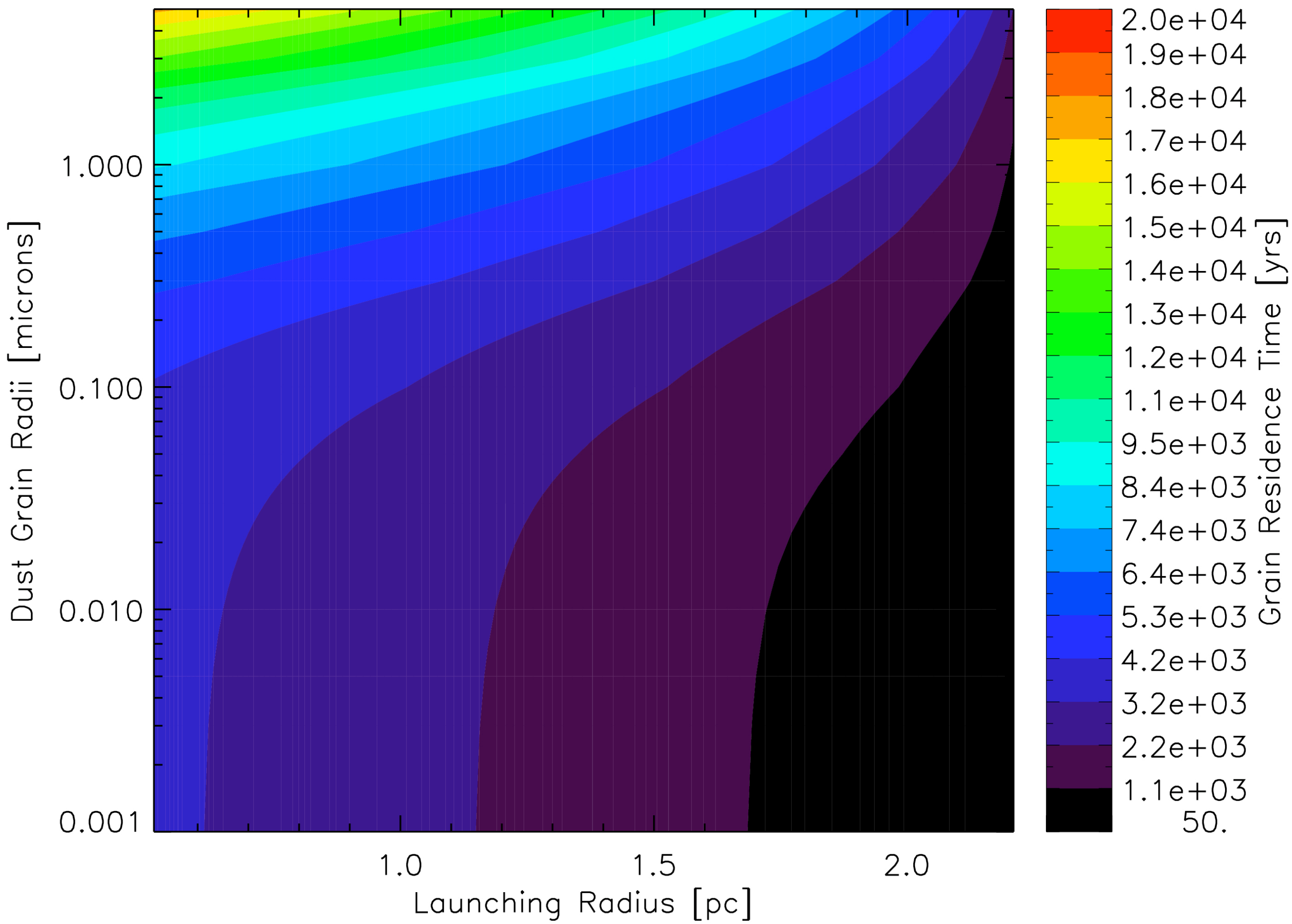


Sputtering timescales about same for graphite & silicates

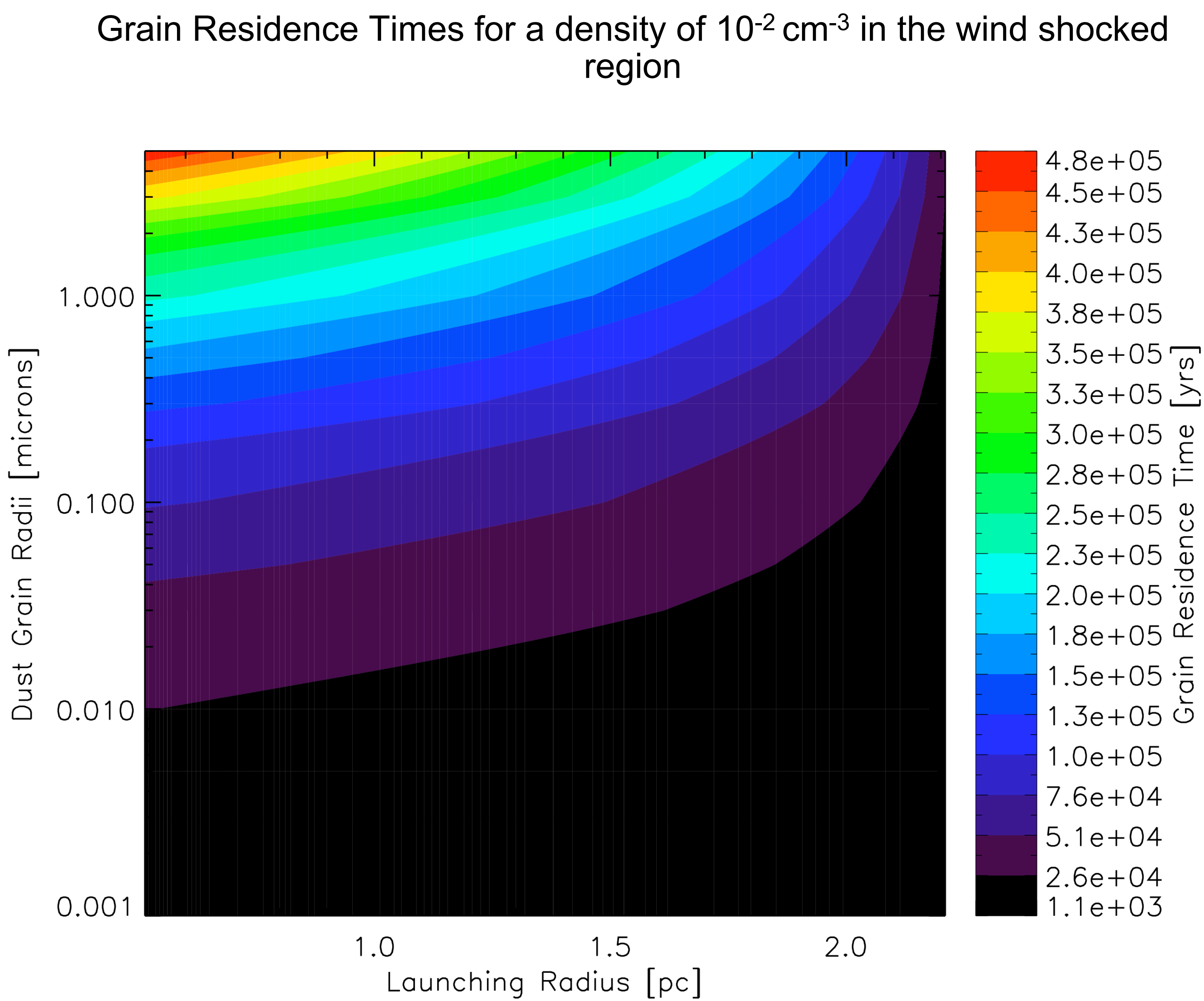
Grains ≤0.1 μm have lifetimes shorter than HII lifetimes

Sputtering timescales increase by ~10 from 0.5 to >2 pc

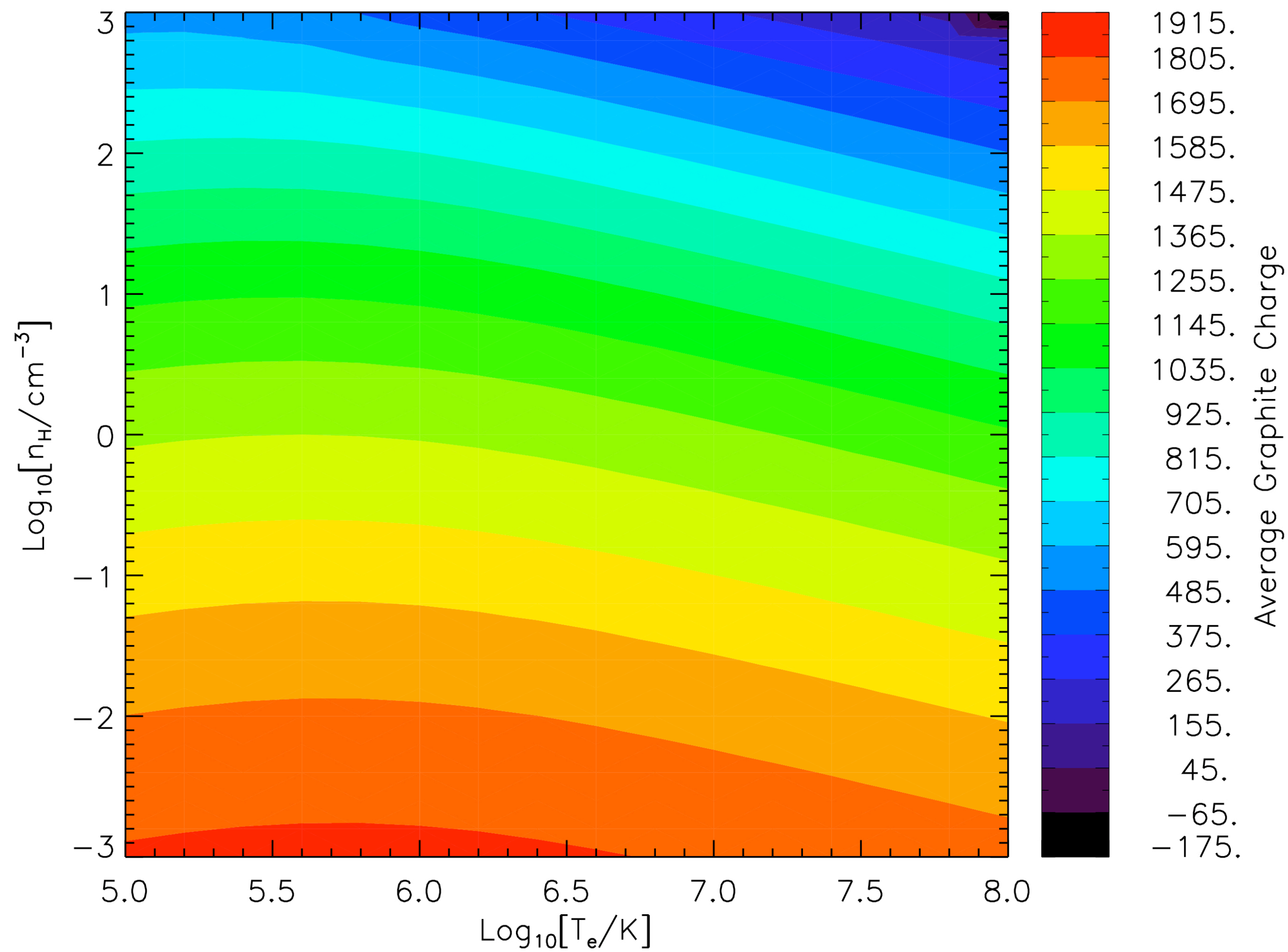
Wind/Dust Friction: Driving Grains Out



For a density of 11 cm^{-3} in wind-shocked region

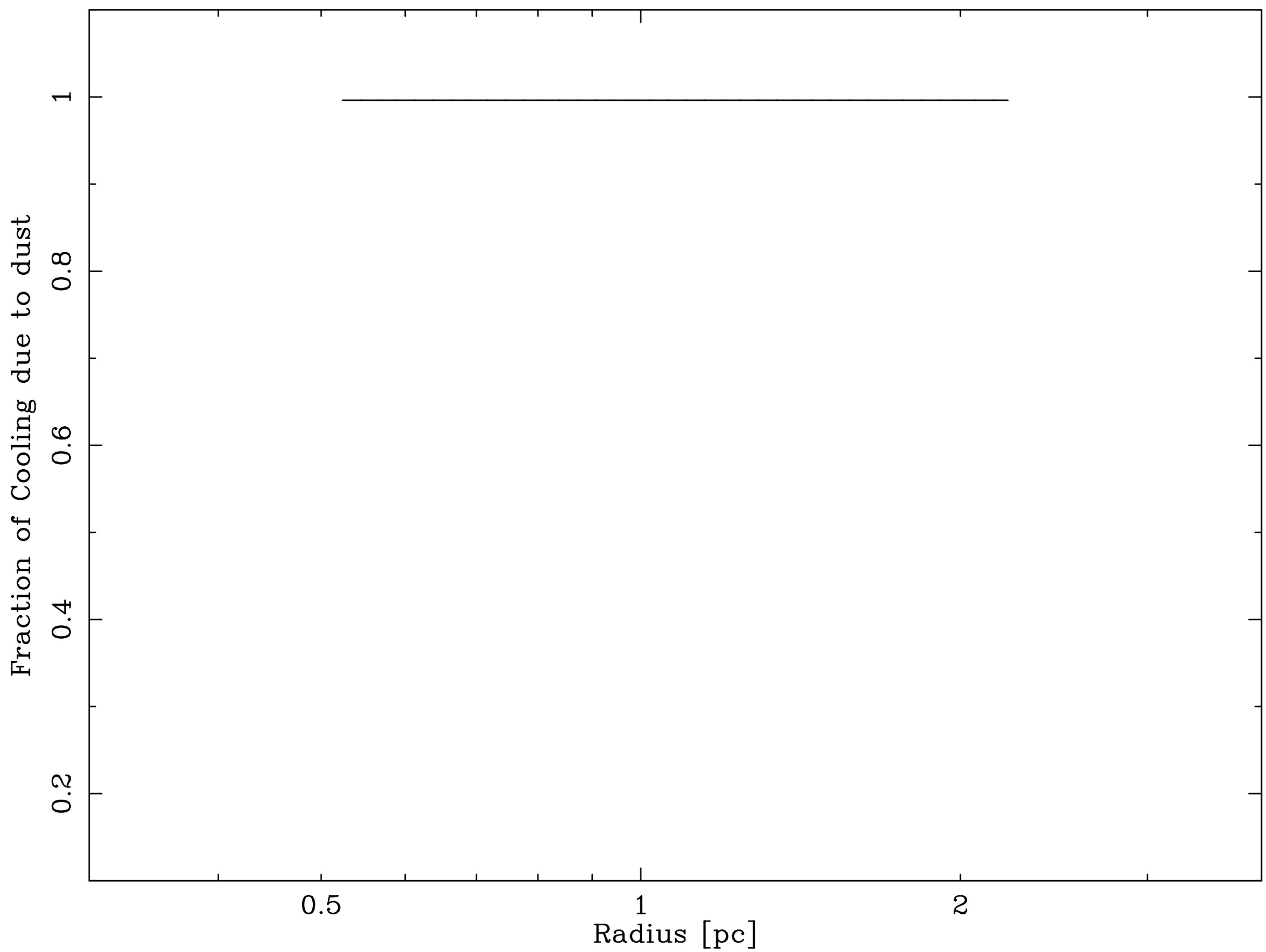

Grain Residence Times for a density of 10^-2 cm^-3 in the wind shocked region
Dust Grain Radii [microns]
1.000
0.100
0.010
0.001
1.0
1.5
2.0
Launching Radius [pc]
4.8e+05
4.5e+05
4.3e+05
4.0e+05
3.8e+05
3.5e+05
3.3e+05
3.0e+05
2.8e+05
2.5e+05
2.3e+05
2.0e+05
1.8e+05
1.5e+05
1.3e+05
1.0e+05
7.6e+04
5.1e+04
2.6e+04
1.1e+03
Grain Residence Time [yrs]

Grains have high positive charge in wind-shocked zone

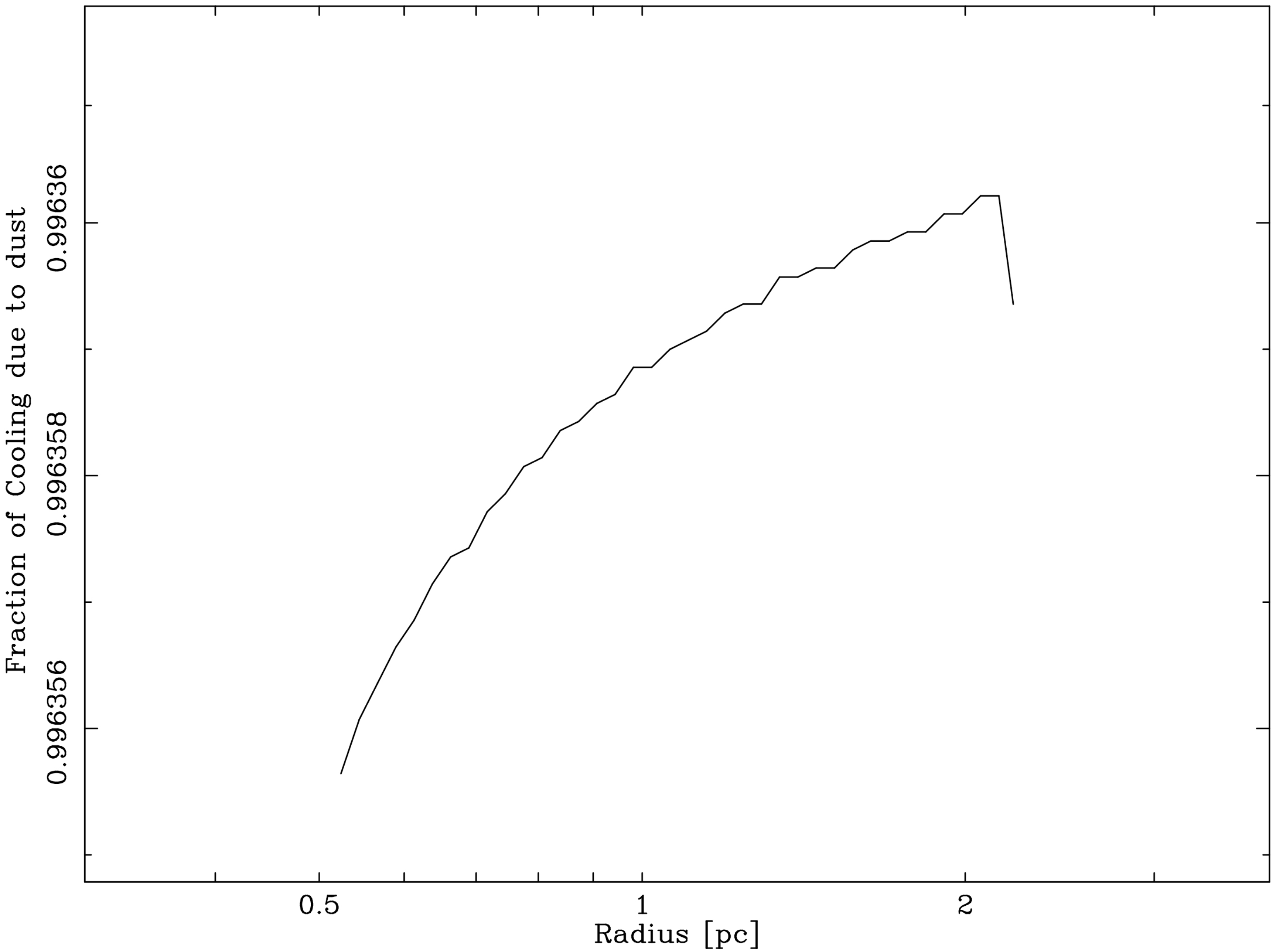


Charge depends most strongly on density as long as $T>10^5$ K

Dust Cooling Fraction



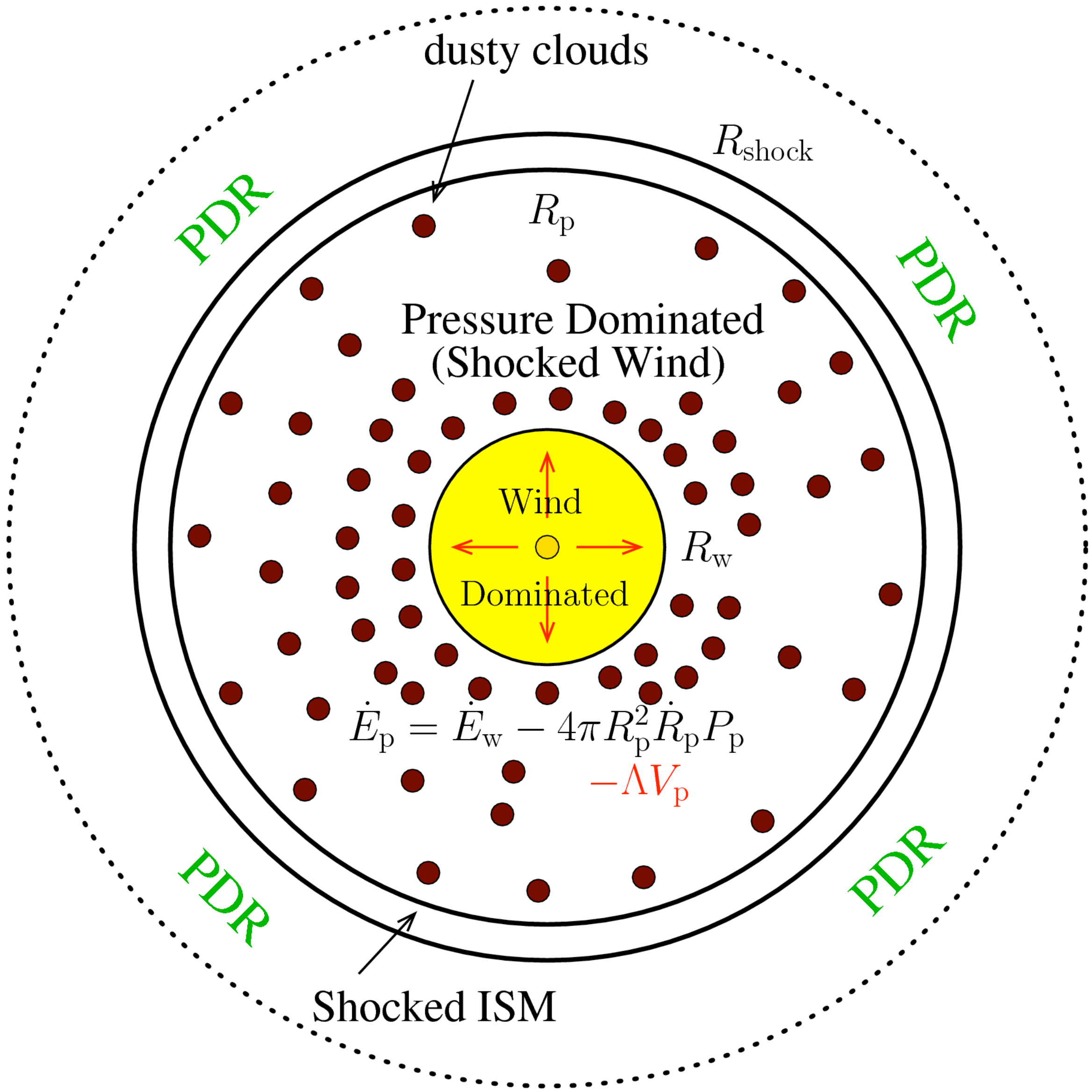
Dust Cooling Fraction: Zoomed



Issues

- 24µm emission => Dust exists within HII regions
- Dust residence timescales are small relative to the age of bubbles =>Why are grains in HII regions?
  - Need a continuous source of grains
    - Perhaps from embedded neutral condensations?
    - Entrainment of neutral condensations from the PDR of the HII region?

Diagram of a Dusty Wind-Blown Bubble



What can ALMA Contribute?

- High spatial resolution, sensitive, mm-submm images of bubbles will be important to determine:
  - the extent of warm dust in HII regions for comparison with cm and 24 μm emission. Probably different dust components dominate at each wavelength.
  - the total luminosity of the central star(s)
  - the location of the ionizing stars and measure their mass loss rates
- High resolution molecular line probes will provide:
  - the kinematics and structure of associated PDR regions
  - constrain chemical models of PDRs
  - temperature and density structure of PDRs
- Radio recomb lines will:
  - provide density structure of H+ gas
  - locate and define the structure of shocks and ionization fronts in HII regions
  - determine bubble expansion velocities which will
    - Verify that they are what we think they are
    - Provide distance estimates independent of a Galactic rotation model
  - determine kinematic distances
  - internal velocity structure of bubbles

Summary

- Dust Impacts on wind-blown HII regions
  - Dominates cooling
  - Temperatures lower than in absence of dust
  - Radii smaller for age and ambient density than expected in absence of dust => age estimates not simply related to size and initial ambient ISM density
  - Ionization structure => looks like a cooler central star than the actual star
  - MIR-FIR brightness much greater than in absence of dust
  - Theoretically only grains of size ≥ 0.2μm survive long enough to play an important role, however the 24/70μm seems to require some small grains
  - Kinematic impacts due to dust?
    - Relative dust drift velocities are fairly large

Comparison:[NeII], [NeIII], PAH(11.3μm)