A Research Note into Dust, Quasar and Host galaxy...

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Abstract

This is a Research Note into the properties, observations and physical processess associated with dust in Quasars and their host galaxies.

1 Motivation

"Dust" - to be defined in due course, is a key astrophysical entity, responsible for aiding star formation, emitting mid-infrared electromagnetic radiation and for obscuring optical light. In particular, we are interested in the dust that contributes to an obscuring medium, possibly a torus in a Active Galactic Nucleus central engine. We are also keen to related this AGN/QSO dust to that of the AGN host galaxy.

2 Glossary of Terms

Term	Definition	Units	Ref
$A(V)$	total extinction	magnitudes	Wikipedia
	total absorption in magnitudes at V	mags	[1]
$E(B-V)$	(interstellar) Reddening	unitless	
	Color Excess		Wikipedia
	$A(B)-A(V)$		
$R(V)$	$A(V)/E(B-V)$		Wikipedia
	ratio of total to selective absorption at V		[1]
"low reddening"	$E(B-V) \lesssim 0.2$	–	Ross et al. (2009)

Table 1: [1] https://ned.ipac.caltech.edu/help/extinction_law_calc.html

3 Setting up the Problem

astro.berkeley.edu/ay216/Lecture05-08.pdf

The (general) extinction A_λ can also be written in terms of the brightness in magnitudes of a source, but this requires knowing its distances and luminosity.:

$$m_\lambda = M_\lambda + 4 \log d - 5 + A_\lambda. \tag{1}$$

Instead we use the distance independent "selective extinction", which is the additional color excess due to extinction:

$$E(B-V) = A(B) - A(V) \tag{2}$$
$$= (B-V) - (B-V)_0 \tag{3}$$

The "normalized selective extinctio" at any wavelength is also a common measure of extinction:

$$E(\lambda, V)/E(B-V) \tag{4}$$

The "normalized extinction": $1/R_V$, measures the steepness of the extinction curve:

$$R_V = A(V)/[A(B) - A(V)] \tag{5}$$
$$= A(V)/E(B-V) \tag{6}$$

It is steep in the diffuse ISM: $RV = 3.10.2$, shallower in dark clouds: RV

4 Definition of Dust

Draine (2003) will be our guide...
For our purposes we define "dust" as...

4.1 Other Key references

Pei (1992)

5 Dust Laws

"One of the main tools used in the study of dust grain properties is extinction curves, particularly ultraviolet (UV) extinction curves." (**?**).

From e.g. (among others!!) Gordon et al. (2003); Glikman et al. (2012)::
SMC
LMC
Milky Way
Calzetti94

Extinction Curve Data	R_V value	Reference
SMC Bar Sample	2.74±0.13	Gordon et al. (2003)
SMC Wing Sample	2.05±0.17	Gordon et al. (2003)
LMC LMC2 Supershell Sample	2.76±0.09	Gordon et al. (2003)
LMC LMC2 Supershell Sample	3.41±0.06	Gordon et al. (2003)
SMC Bar (AzV 18)	3.60±0.73	Gordon & Clayton (1998)
SMC Bar (AzV 214)	2.75±0.55	Gordon & Clayton (1998)
SMC Bar (AzV 398)	2.87±0.40	Gordon & Clayton (1998)
SMC Wing (AzV 456)	2.66±0.16	Gordon & Clayton (1998)

Table 2: Notes: Average from Table 2 for the Gordon et al. (2003) values; "Adopted" values from Gordon & Clayton (1998).

6 AGN Dust

7 "Level 5" Dusty Disks and the Infrared Emission From AGN

In "The Central Engine of Active Galactic Nuclei", ASP Conference Series, Vol. 373, Xi'an, China, 16-21 October, 2007, eds. L. C. Ho and J.-M. Wang http://ned.ipac.caltech.edu/level5/Sept07/Li2/Li_contents.html

8 Sublimation and the Temperature Gap

Published in Theory of Accretion Disks, 1989
E. Sterl Phinney
http://ned.ipac.caltech.edu/level5/Phinney/Phinney6.html

The rate of sublimation of a dust grain at temperature T is given (in g cm−2 s−1) by

$$Q = \sum_i (p_{si}(T) - p_i) S_i(T) \sqrt{\frac{m_i}{2\pi kT}} \tag{7}$$

where the index i runs over all equilibrium gas-phase species (e.g. C, C2, CO, etc. for graphite grains), pi is the partial pressure of species i, Si(T)   1 is the sticking fraction for molecules colliding with the grain surface, and p_{si} is the saturation vapor pressure for species i. The saturation vapor pressure is given by

$$p_{si} = \zeta_i(T) kT \frac{(2\pi m_i kT)^{3/2}}{h^3} \exp\left[-\frac{h_0}{kt} - \Delta\right] \tag{8}$$

where ζ_i is the product of the rotational, vibrational, and electronic partition functions for the gas-phase species i, and h0 is the heat of sublimation at zero temperature, on a per atom basis. Delta(T) is a complicated expression involving integrals of the specific heat of the solid (Reif 1965, p. 367). Graphite (h0 / k = 8.58 x 104 K to C, h0 / k = 9.82 x 104 K to C2, h0 / k = 9.45 x 104 K to C3, Kelley 1973) is the most refractory substance (with the exception of Tungsten!); silicate grains have h0 / k appeq 6.6 x 104 K. We have fitted the thermodynamic data and sublimation measurements of graphite in vacuum (Kelley 1973), and find that the saturation vapor pressure of the dominant gas-phase constituent is well fitted by

$$p_s = 6 \times 10^{15} \exp\left[-92200/T\right] \mathrm{dyncm}^{-2} \tag{9}$$

The gas pressure in an alpha accretion disk is

$$\begin{aligned} p &= \frac{GM\dot{M}}{4\pi r^3 \alpha c_s} && (10) \\ &= 0.01\, M_S\, \dot{m}\, r_{\mathrm{pc}}^{-3} \alpha^{-1}\, T_3^{-1/2} \mathrm{dyn\,cm}^{-2} && (11) \end{aligned}$$

This pressure is comparable to the pressure   10-2 dyn cm-2 in broad-line clouds. Since the solar abundance of carbon, C/H = 4 x 10-4, the partial pressure of carbon, were it all in the gas phase, would be

$$p_C = 10^{-5}\, M_S\, \dot{m}\, r_{\mathrm{pc}}^{-3} \alpha^{-1}\, T_3^{-1/2} \mathrm{dyn\,cm}^{-2} \tag{12}$$

At radii   1 pc, grains grow at an impressive rate: a / adot   5n9 (a / 0.1 m) yr; in fact the temperatures and densities are quite similar to those in red-giant winds where interstellar dust is believed to form. [But here the grain and gas temperatures need not be equal: the ratio of a grain's radiative cooling luminosity to the rate at which it exchanges energy with gas via collisions is L/H = 10n11-1 Tg,35 / TH,33/2, where the grain temperature is 103 Tg,3 K and the gas temperature and density are 103 TH,3 and 1011 n11 cm-3, respectively]. However, comparing with equation (7) and equation (9), we see that when the grain temperatures Tg exceed 2000 K, graphite grains will certainly begin to sublimate rather than grow. For Tg ¿ 2100 K, the timescale for sublimation of a 1 m graphite grain becomes shorter than 103 yr, the timescale on which in could be replenished by inflow. From figure 1, we see that this temperature is reached at   0.3 pc in our fiducial quasar.

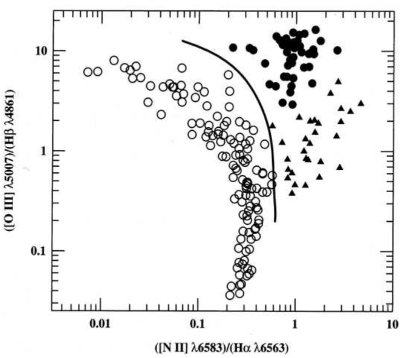

Figure 1:

When the dust sublimates, the gas loses its primary opacity and coolant. As the temperature rises above 3000 K, most common molecules are destroyed, and the opacity drops precipitously by several orders of magnitude (Alexander et al. 1983). The gas in the interior of the disk is then unable to remain in thermal equilibrium at temperatures 2000 ltapprox T ltapprox 7000 K, and must inevitably heat. Above 104 K, the opacity rises abruptly to near its former level as hydrogen is ionized, providing the gas with a new thermal equilibrium state. Unless there is no warp (or down-scattering of radiation onto the disk from electrons or a jet), the transition disk at r ¡ 0.3 pc is thus constrained by the heating from the central source to be optically thin, with T 104 K, until r ltapprox 0.02 pc, when the incident flux can be carried by optically thick thermal emission, and the temperature will begin to rise above 104 K in the accretion disk. The absence of thermalized emission from material with temperatures 2000 ltapprox T ltapprox 7000 K provides a natural explanation for the minimum in nuLnu at nu = 1014.5 Hz (lambda = 1 m) observed in almost all quasars (Neugebauer et al. 1989). [The reader may mentally add an accretion disk spectrum to the right of figure 2]. Since in this interpretation the frequency is a universal constant, determined (up to very slowly varying logarithms) by the heats of sublimation and dissociation of dust and molecules, and by the ionization of hydrogen, the minimum in the reradiated nuLnu will always be present, and observable unless filled in by starlight or a non-thermal contribution to the spectrum.

Next

9 Recent Work

http://arxiv.org/abs/1308.6517

$$A_\lambda/A_I \approx f(\lambda; R_V, C_1, C_2, C_3, C_4, \lambda_0, \gamma) \tag{13}$$

However, if there is a significant amount of dust associated with the quasar, then the continuum will take on the form:

$$\begin{aligned} L_\lambda, \mathrm{rest} &\propto \lambda^{\alpha_\lambda}\, e^{-\tau_\lambda} && (14)\\ &\propto \lambda^{\alpha_\lambda}\, 10^{-E(B-V)\, R_\lambda/2.5} && (15)\end{aligned}$$

where $L_\lambda, rest$ is the rest frame luminosity, α_λ is the intrinsic spectral index, τ_λ is the optical depth of the dust, and R_λ is a function that is dependent on the physical properties of the dust.

10 Hugo Messias

RayleighJeans law and cut-off in e.g. Fig. 4 of Nenkova et al. 2008, ApJ, 685, 147.

11 ROE High-z Group: 15th Oct 2014

11.1 Definitions

11.2 Meurer IRX-beta relation

e.g. Calzetti et al. 1994

11.3 Extinction vs. Attenuation

Basically anything outside the MW is Attenuation (and not Extinction!!)

11.4 Meurer IRX-beta relation

12 ROE High-z Group: 03rd Dec 2014 (Loretta Dunne).

12.1 LifeCycle

Average timescale for lifecycle is 10^7 years...
Condensation temperatue of dust ranges $\sim 800 - 2000$K.
(What's the "simplest" type of dust"??!)

12.2 Dust Sinks

Average lifecycle for dust $\sim 10^8$ years...

12.3 Questions

Chemisty of dust! C vs. Si
and/or Size of dust grains, nm to μm to few/several μm
SMG dust properties vs. IMFs vs. sinks and sources (Rowlands'14), Top Heavy IMFs etc.
Dust in high-z gals (SMGs); high-z QSOs ($z \sim 6$)
SNe Explosions, radioactive decay etc. etc. etc.
All this, and how it extrapolates to e.g. the extinction laws...
(really don't know what's going on here!!!)

12.4 References

Rowlands et al. (2014)
Gallo et al. (2011? ,2014??)
Hiroshita...

13 ROE High-z Group: 11 Feb 2015 (Loretta Dunne).

Casey, Narayanan and Cooray arXiv:1402.1456v1

14 Useful URLs

http://etc.stsci.edu/etcstatic/users_guide/1_ref_7_ebv.html

15 References

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