A Glossary to some General (Astro)Physical terms

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Abstract

This is a simple document which will hopefullyeventually be a pretty complete list/glossary of various (astro)Physical terms and 'what they mean'. There will be some overlap here with my other Research Notes, e.g. the Emission Line document...

A

Advection Dominated Accretion Flows

The Eddington accretion rate is the accretion rate for which the black hole radiates at the Eddington luminosity:

$$\dot{M}_{\rm Edd} = L_{\rm Edd}/\epsilon c^2. \tag{1}$$

It is generally thought that when the accretion rate is $\sim 0.01 - 11\dot{M}_{\rm Edd}$ thin disk accretion is a reasonable approximation. With a high accretion rate, the gas density is high, so the gas is able to radiate efficiently and stay geometrically thin.

However, if the gas density is low, the gas may be unable to radiate energy at a rate that balances viscous heating. In this case, the heat generated by viscosity will be "advected" inwards with the flow instead of being radiated. The disk becomes hot, hence geometrically thick (though perhaps optically thin), hence low density, and radiatively inefficient. Such "Advection Dominated Accretion Flows" (ADAFs) were studied by Lightman & Eardley, Rees, and others in the 1970s. They were revived in the 1990s by the work of Narayan & Yi and others.

At superEddington accretion rates, in which the large optical depth of the inflowing gas traps most of the radiation and carries it inward, or advects it, into the central black hole. This solution is referred to as an optically thick advectiondominated accretion flow (optically thick ADAF).

B

Bondi Accretion

BA is spherical accretion onto a compact object traveling through the interstellar medium. It is generally used in the context of neutron star and black hole accretion. To achieve an approximate form of the Bondi accretion rate, accretion is assumed to occur at a rate

$$\dot{M} \simeq \pi R^2 \rho v \tag{2}$$

where ρ is the ambient density, v is either the velocity of the object or the sound speed c_s in the surrounding medium if the object's velocity is lower than the sound speed, and the Bondi radius R provides an effective area. The effective radius is acquired by equating the object's escape velocity and the relevant speed, i.e.

$$\sqrt{\frac{2GM}{R}} \simeq c_s, \tag{3}$$

or

$$R \simeq \frac{2GM}{c_s^2}. \tag{4}$$

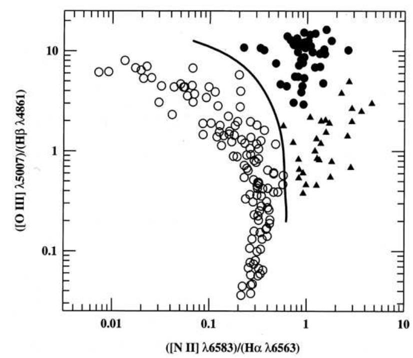

Figure 1:

The accretion rate therefore becomes

$$\dot{M} \simeq \frac{\pi \rho G^2 M^2}{c_s^3}. \tag{5}$$

These are only scaling relations rather than rigorous definitions. A more complete solution can be found in Bondi's original work and two other papers.

AGN Accrete from the ISM, Via Bondi accretion:

$$\dot{M} \simeq (1.4 \times 10^{11} \mathrm{g/s}) \left(\frac{\mathrm{M}}{\mathrm{M}_\Theta}\right) \left(\frac{\rho}{10^{-24}\ \mathrm{g/cm^3}}\right) \left(\frac{\mathrm{c_s}}{10\mathrm{km/s}}\right)^{-3} \tag{6}$$

M_Θ should be $M_\odot$??!!

BPT diagram

Straight from:: Level 5 BPT essay::

"Baldwin, Phillips & Terlevich" (BPT) diagrams demonstrate how LINERs can be distinguished from normal H II regions and normal AGNs (Seyferts and QSOs) on the basis of their [O III] λ5007 / Hβ, [N II] λ6583 / Hα, and [S II] $\lambda\lambda$6716, 6731 / Hα flux ratios. Here it is seen that the Seyfert 2s have high values of each ratio. H II regions define a locus of lower values which does not overlap with the region of parameter space occupied by the Seyferts. The LINERs can be distinguished from the Seyfert 2s by their low values of [O III] λ5007 / Hβ relative to [N II] λ6583 / Hα, and from the H II regions by their larger values of [N II] λ6583 / Hα.

[O III]/[O II] is sensitive to ionization parameter (how ionized is the gas). [O I]/ H α is sensitive to hardness of the radiation field.

C

Covering Factor

The fraction of sight-lines to the AGN centre obscured by dust (e.g., Roseboom et al., 2013).

Compton scattering

Compton scattering (discovered by Arthur Holly Compton) is the inelastic scattering of a photon by a charged particle, usually an electron. It results in **a decrease in energy (increase in wavelength) of**

the photon (which may be an X-ray or gamma ray photon), called the Compton effect. Part of the energy of the photon is transferred to the recoiling electron.

Comption Thick

Objects, or systems, that have column densities exceeding $N_{\mathrm{H}} \simeq 1.5 \times 10^{24}$ cm^{-2}, the value corresponding to unity optical depth for Compton scattering.

Straight from: Comastri, astro-ph/0403693:: The spectrum of the hard X-ray background records the history of accretion processes integrated over the cosmic time. Several pieces of observational and theoretical evidence indicate that a significant fraction of the energy density is obscured by large columns of gas and dust. The absorbing matter is often very thick, **with column densities exceeding $N_{\mathrm{H}} \simeq 1.5 \times 10^{24}$ cm^{-2}, the value corresponding to unity optical depth for Compton scattering**. These sources are called "Compton thick" and appear to be very numerous, at least in the nearby universe. Although Compton thick Active Galactic Nuclei (AGN) are thought to provide an important contribution to the overall cosmic energy budget, their space density and cosmological evolution are poorly known. The properties of Compton thick AGN are reviewed here, with particular emphasis on their contributions to the extragalactic background light in the hard X-ray and infrared bands.

Comption Thin

Objects, or systems, that have column densities in the range $N_{\mathrm{H}} \simeq \times 10^{22} - 10^{24}$ cm^{-2}. These can still be (kinda confusingly known as) "obscured systems".

D

Duty cycle

The fraction of the time that an AGN/QSO is active.

E

Extinction

Extinction is the absorption and scattering of electromagnetic radiation by dust and gas between an emitting astronomical object and the observer.

H

Hard X-rays

See:: X-rays, Hard.

I

Inverse Compton scattering

Inverse Compton scattering involves the scattering of low energy photons to high energies by ultrarelativistic electrons **so that the photons gain and the electrons lose energy**. The process is called inverse because the electrons lose energy rather than the photons.

e.g., in X-ray astronomy, the accretion disc surrounding a black hole is presumed to produce a thermal spectrum. The lower energy photons produced from this spectrum are scattered to higher energies by relativistic electrons in the surrounding corona. This is surmised to cause the power law component in the X-ray spectra (0.2-10 keV) of accreting black holes (Wikipedia link).

Also, e.g., CMB photons are scattered to higher energies by the electrons in this gas, resulting in the Sunyaev-Zel'dovich effect. Observations of the Sunyaev-Zel'dovich effect provide a nearly redshift-independent means of detecting galaxy clusters.

L

LINERS

Straight from Sturm et al. (2006):
Since their identification as a class of galactic nuclei more than 25 years ago (Heckman, 1980), the nature of low-ionization nuclear emission-line regions (LINERs) has remained controversial. *Their optical spectra are characterized by enhanced narrow emission lines of low-ionization species*, quite distinct from those of both H II regions and classical active galactic nuclei (AGNs). They are found in one-third to one-half of all types nearby galaxies (e.g., Ho et al., 1997). In many LINERs the emission is concentrated near the nucleus (a few times 100 pc; e.g, Pogge et al., 2000), but in others it extends over larger regions, up to a few kiloparsecs Veilleux et al. (1995). There is substantial evidence that many LINERs are powered by accretion onto massive black holes and that these objects, due to low accretion rates, constitute the low-luminosity end of the AGN class (Quataert, 2001; Kewley et al., 2006). If many LINERs at low and high redshifts are indeed low-luminosity AGNs, this would have a significant impact on major issues in astronomy such as the growth history of central black holes and the relation of AGNs to galaxy formation and evolution.

R

Reddening

Reddening occurs due to the light scattering off dust and other matter in the interstellar medium. Reddening preferentially removes shorter wavelength photons from a radiated spectrum while leaving behind the longer wavelength photons (in the optical, light that is redder), leaving the spectroscopic lines unchanged.

In any photometric system interstellar reddening can be described by color excess, defined as the difference between an object's observed color index and its intrinsic color index (sometimes referred to as its normal color index). An object's intrinsic color index is the theoretical color index which it would have if unaffected by extinction. In the UBV photometric system the color excess E_{B-V} is related to the B-V colour by: $E_{B-V} = (B-V)_{\rm observed} - (B-V)_{\rm intrinsic}$.

Reflection-dominated

Reprocesessing

Reprocesessing, thermal

The thermal reprocessing hypothesis in AGN is where EUV/X-ray photons are reprocessed by the accretion disc into optical/UV photons.

Rosseland opacities

(from scienceworld.wolfram.com/physics/RosselandMeanOpacity.html)
The Rosseland mean opacity $\langle\kappa\rangle$ is defined as

$$\frac{1}{\kappa} = \frac{1}{B}\int_0^\infty \frac{B_\nu}{\kappa_\nu} d\nu \tag{7}$$

where B is the total brightness (intensity), B_ν is the specific brightness, and κ_ν is the specific opacity.

(from Wikipedia)
It is customary to define the average opacity, calculated using a certain weighting scheme. Planck opacity uses the normalized Planck black body radiation energy density distribution, $B_\nu(T)$ as the weighting function, and averages κ_ν directly:

$$\kappa_{Pl} = \frac{\int_0^\infty \kappa_\nu B_\nu(T) d\nu}{\int_0^\infty B_\nu(T) d\nu} \tag{8}$$

$$= \left(\frac{\pi}{\sigma T^4}\right) \int_0^\infty \kappa_\nu B_\nu(T) d\nu, \tag{9}$$

where σ is the Stefan-Boltzmann constant.

The Rosseland opacity (after Svein Rosseland), on the other hand, uses a temperature derivative of the Planck distribution,$u(\nu,T) = \partial B_\nu(T)/\partial T$ as the weighting function, and averages κ_ν^{-1},

$$\frac{1}{\kappa} = \frac{\int_0^\infty \kappa_\nu^{-1} u(\nu,T) d\nu}{\int_0^\infty u(\nu,T) d\nu}. \tag{10}$$

The photon mean free path is $\lambda_\nu = (\kappa_\nu \rho)^{-1}$. The Rosseland opacity is derived in the diffusion approximation to the radiative transport equation. It is valid whenever the radiation field is isotropic over distances comparable to or less than a radiation mean free path, such as in local thermal equilibrium. In practice, the mean opacity for Thomson electron scattering is:

$$\kappa_{\rm es} = 0.20(1+X)\,{\rm cm}^2\,{\rm g}^{-1} \tag{11}$$

where X is the hydrogen mass fraction. For nonrelativistic thermal bremsstrahlung, or free-free transitions, assuming solar metallicity, it is:

$$\kappa_{\rm ff}(\rho,T) = 0.64\times 10^{23}(\rho[{\rm g\ \ cm}^{-3}])(T[{\rm K}])^{-7/2}\,{\rm cm}^2\,{\rm g}^{-1}.[1] \tag{12}$$

The Rosseland mean attenuation coefficient is:

$$\frac{1}{\kappa} = \frac{\int_0^\infty (\kappa_{\nu,\rm es} + \kappa_{\nu,\rm ff})^{-1} u(\nu,T) d\nu}{\int_0^\infty u(\nu,T) d\nu}] \tag{13}$$

S

Salpeter time

$$t_S = M/\dot{M} = 4.5\times 10^7 \left(\frac{\epsilon}{0.1}\right)\left(\frac{L}{L_{\rm Edd}}\right)^{-1} \tag{14}$$

where $\epsilon = L/\dot{M}c^2$ is the radiative efficiency for a QSO radiating at a fraction $L/LEdd$ of the Eddington luminosity. Commonly accepted values of these two key parameters for luminous QSOs are $\epsilon = 0.1$ and $L/LEdd = 1$. Martini, P. (QSO Lifetimes; http://adsabs.harvard.edu/abs/2004cbhg.symp..169M).

This critical accretion rate, [the Eddington mass accretion rate], is proportional to the mass of the accreting object, which implies that the mass of an object that is growing at the maximal (Eddington) accretion grows exponentially on a timescale known as the Salpeter time,

$$t_{Sal} = \frac{\epsilon\sigma_T c}{4\pi G m_p} \approx 45\epsilon_{0.1}10^6\,\text{years} \tag{15}$$

from “Massive Black Hole Growth and Formation” from Paolo Coppi.

Soft Xrays

See:: X-rays, Soft.

Soltan Argument

$$\frac{\epsilon}{1-\epsilon}\rho_{\rm BH}c^2 = \int e(z)(1+z)dz \tag{16}$$

$e(z)dz$: present energy density from AGN in redshift range z to $z+dz$.
$\rho_{\rm BH}$: mean cosmic density of nuclear black holes.
η: radiative efficiency
The Soltan argument works approximately for η ≈0.1, so observed AGN must account for most of nuclear black hole growth.

Refs:
www.aei.mpg.de/ pau/conf_vid/Miralda.pdf
www.bo.astro.it/ vignali/PhD.../Merloni_PhD_Bologna_Tuesday.pptx www.astro.yale.edu/coppi/pubs/bhgrowth4.pdf
http://ned.ipac.caltech.edu/level5/March02/Ferrarese/Fer2.html

Synchrotron Radiation

Synchrotron Self-Absorption

Aaron Parsons video

Synchrotron Self-Compton

Electrons undergoing synchrotron radiation create a photon bath which other electrons will then interact with via inverse Compton scattering. Recall that for original (unprocessed) synchrotron radiation, that F_ν, between some minimum and maximum frequency cut-off, goes as $K\nu^\alpha$, and that the number of photons per γ is $\frac{dN}{d\gamma} = N_0\gamma^s$, where $\alpha = \frac{1+s}{2}$. These frequency cut-offs were set by $\gamma^2_{\rm min}\nu_{\rm cyc}$ and $\gamma^2_{\rm max}\nu_{\rm cyc}$. After this radiation is processed by SSC, approximately every photon is upscattered to a new energy $\frac{4}{3}\gamma^2\nu$.

T

Thomson cross-section*

$N_{\rm H} \geq \sigma_{\rm T}^{-1} \simeq 1.5 \times 10^{24}$ cm^{-2}.

For an electron:

$$\sigma_{\rm T} = \frac{8\pi}{3}\left(\frac{\alpha\hbar c}{mc^2}\right)^2 = 0.6652 \times 10^{-24}\ {\rm cm}^{-2} \tag{17}$$

Thomson scattering

Thomson scattering is the elastic scattering of electromagnetic radiation by a free charged particle. It is just the low-energy limit of Compton scattering: the particle kinetic energy and photon frequency are the same before and after the scattering. This limit is valid as long as the photon energy is much less than the mass energy of the particle: $\nu \ll mc^2/h$.

X

X-rays, Hard

X-rays, Soft

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