Documentation and report of Astrophysics with Artificial Intelligence(Astropy and AstroML) – UVES Spectroscopy with Astropy

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* **All the information is based on and originated from ‘astropy.org’, ‘atsroml.org’, and ‘wikipedia.org’**

<1> The fundamental knowledge to utilize astropy and astroML for astrophysics

1. Accretion Disk

The accretion disk which is also known as circumstellar disk is the structure which is created by diffuse material in orbital motion around a massive central body. Typically, the central body is the star such as protostar, white dwarf, neutron star, or black hole and also there are theoretical stars such as black dwarf and blue dwarf. The instabilities in the disk causes redistribution of the angular momentum and to move spiral the materials inward toward the central body. In this process, the gravitational energy and frictional forces are converted to the thermal energy by compressing and raising the temperature of the material and this occurs the emission of electromagnetic radiation on the surface of the disk. The range of the frequency of the emission of electromagnetic radiation depends on the central body. For instance, the accretion disk of the protostar radiates the infrared and the neutron star and black hole emit the X-ray.

The equation of the angular momentum

L = r × p = r × mv

(m : mass of the material,

P : linear momentum of the material,

r : position vector from origin 0 to material,

v : velocity of the material)

According to the above principle, when the matter falls inward, the gravitational energy and angular momentum are decreased. However, the total angular momentum has to be sustained as comparable value, which is known as the law of angular momentum conservation. The equation of this:

dL / dt = (dr/dt × p) + (r × dp/dt)

= (v × mv) + (r × F)

# = 𝜏

( : torque(or moment) = r × F)

In other words, the loss of the angular momentum falling inward toward the central body should be compensated by the acquiring of the angular momentum far from the center. In short, angular momentum should be transported outwards from central body for material to accrete. This is because while the airframe of the inner orbit of the disk has rapid angular momentum, the outer one has slow angular momentum. In this process, the transportation of the angular momentum is occurred. According to the ‘Rayleigh stability criterion’,

∂(R2Ω) / ∂R > 0

(Ω : the angular velocity of a fluid element,

R : the distance to the rotation center)

In this, the accretion disk is supposed and expected as a laminar flow.

Plus, if it is needed, the angular momentum can be quantized.

L = nh /2𝝅 = nħ (n = 1, 2, 3, ⋯)

sħ = h / 2𝝅

(h : Planck constant, = 6.626 × 10-34 [J·s],

ħ : Dirac’s constant, = 1.054 × 10-34 [J·s])

When it comes to the radiated energy of the accretion disk, when one of the proton does free falling, the relation between kinetic energy and gravitational energy is

1/2 × mv2 = GMm / r

When the material reaches at the surface of the star(r = R), the kinetic energy is radiated as form of thermal energy. If the proportion of the accretion which the matter accretes to the mass is dm/dt, the ratio of the attenuation of the energy at the surface of the star is 1/2 × dm/dt × v2. Thus, the luminosity of the star is

L = 1/2 × dm/dt × v2 = GMdm / Rdt

=  {\displaystyle \epsilon}εc2 × dm / dt

(ε : accretion efficiency = 2GM / c2R = 1/2 × Rsch/R)

This efficiency(ε) means the one which rest mass energy of the accreting matter converts into the thermal energy. In the above equation, according to the equation of accretion efficiency, the accretion efficiency is directly proportional with the how much the star is compacted.

1. Protostar

The protostar is the young star arose in the initial stage of star evolution which is made by concentrating of the molecular cloud in the interstellar medium. This star is initiated from when the density of the central molecular cloud increases, ended up with the stage of the T tauri star. In the final stage, the T tauri stellar wind is occurred, which epitomizes that the star starts the radiant of the energy at inner point after the stage which the star pulls the mass.

The thermal pressure of the dust grains and molecular which are the components of the molecular cloud and the gravitational restraint energy of the cloud sustain the equilibrium. However, once the derangement such as shock wave occurred by supernova explosion, spiral density wave, or encounter or collision with other molecular clouds effects on the molecular cloud and this derangement is sufficiently strong, the equilibrium is upset and the mass is clustered on the specific point by occurring the gravitational instability. Once the cloud initiates the shrinking, the minimum mass of the molecular cloud for gravitational concentration can be expressed and this is also known as Jeans Instability.

Mj = (9/4) × (1/2𝝅n)1/2 × (1/m2 ) × (kT/G)3/2

(n : the particle number density,

m : average mass of the gas particle in the interstellar cloud,

T : temperature of the gas)