Jacopo Fritz, IRyA - UNAM

DataCubes in Astrophysics

Lesson 7

Optical (MUSE) datacubes

Optical (MUSE)

- We will use observations of galaxies with MUSE to extract as much information as possible;
- we will calculate:
  1. the spatially-resolved and total SFR;
  2. the s-r and tot. stellar mass and SFH;
  3. the s-r dust extinction;
  4. gas density;
  5. more…

The theory and Physics behind

- Stellar and gas dynamics;
- dust extinction;
- stellar population synthesis.

Stellar and gas dynamics

Spirals

Ellipticals

How are these dynamically supported?

One step back

The Doppler effect

The Doppler effect is the change in frequency (wavelength) of ANY wave in relation to an observer who is moving RELATIVE to the source

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The Doppler Effect

Mathematically…

$$\nu_{obs} = \left(\frac{c \pm v_r}{c \pm v_s} \right) \nu_{em}$$

Relation between observed and emitted frequency: v_r is the velocity of the observer (receiver), v_s is the velocity of the source, and c is the velocity of the wave.

In the limit where: v_s and $v_r << c$:

$$\nu_{obs} = \left(1 - \frac{\Delta v}{c} \right)$$

The frequency (wavelength) change is proportional to the (relative) velocity

Measuring the Doppler Effect

A reference frequency is needed!

Emission lines are easier, but any reference line can be used.

Now back to the dynamics!

Ellipticals (and spheroidals)

Velocity dispersion

Ellipticals (and spheroidals)

How do we measure this?

1. What are elliptical galaxies (mainly) made of?
2. What is the effect of different velocities components along the line of sight?

The velocity dispersion

Spiral galaxies

Rotation

+

Velocity dispersion

Spiral galaxies

How do we measure this?

1. Spheroidal component: velocity dispersion;
2. Disk component: rotation;
3. In this case, where gas is also present, it is possible to derive the dynamics of the two components: stars and gas;
4. These kind of studies can reveal very interesting phenomena.

Rotation velocity

Rotation velocity

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- Note that when measuring a rotation velocity, a certain degree of widening is also observed;
- optical lines are nice, but sometimes atomic hydrogen is even better!

Interstellar dust

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- Catalyst for molecular hydrogen formation;
- Shields molecular clouds from UV radiation;
- Reprocesses about 50% of stellar light.

What is it made of?

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- Circumstellar : signatures of CO, silicon carbide, amorphous silicate, polycyclic aromatic hydrocarbons, water ice, polyformaldehyde;
- Silicate and Carbon are more common in the interstellar medium.

The effect of dust

Dust has a dual effect

- Absorbs very efficiently UV and optical light;
- is (usually) transparent at IR wavelength;
- by absorbing light it gets heated up;
- it emits in thermal equilibrium (or not…) as a black body.

Extinction and wavelength

Barnard 68

B V I

K H J

Extinction and wavelength

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Extinction and wavelength

Barnard 68

Interstellar Extinction

- Starlight extinction is the first and most prominent manifestation of the presence of dust;
- in the simplest case, a source is attenuated by a foreground screen:

$$I_\lambda = I_{\lambda,0}\, e^{-\tau_\lambda}$$

Interstellar Extinction

- Extinction is generally expressed in magnitude (optical depth is used at longer wavelengths);
- in the optical-UV, extinction is conventionally characterised by the *color excess:*

$$E(B-V) = A_B - A_V$$

- where, in general:

$$A_\lambda = m_\lambda - m_\lambda^0$$

Exercise: find the conversion factor between optical depth and monochromatic extinction

Interstellar Extinction

Extinction curves

Characterised by the parameter R_V, defined as:

$$R_V = \frac{A_V}{E(B-V)}$$
$$= \frac{A_V}{A_B - A_V}$$

How to correct for dust absorption

- Dust is the main catalyst for the formation of molecular gas;
- star forming regions are rich in molecular gas;
- the location of star formation is likely to be surrounded by more or less high dust amounts;
- geometry of gas, dust and stars plays a major role.

How to correct for dust absorption

- The effect of dust is <u>differential</u> and non-linear with respect to λ;
- the properties of dust are, **<u>MORE OR LESS</u>**, similar in all galaxies;
- extinction curves are derived for many cases/regions/environment/galaxy types;
- <u>attenuation</u> curves are available as well.

How to correct for dust absorption

- Extinction in magnitudes: $m_{obs} = m_{em} + A_\lambda$;
- extinction in flux: $F(\lambda)_{obs} = F(\lambda)_{em} \cdot 10^{-0.4 \cdot A_\lambda}$;
- an extinction curve (in *mag*!!!) gives NO absolute scale;
- we need to find 2 observables at different λ with a known flux ratio (e.g. from theoretical considerations);
- recombination lines very well comply to this requirement!

How to correct for dust absorption

$$\frac{F(H\alpha)}{F(H\beta)} = 2.86$$

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(how to correct for dust extinction)

How to correct for dust absorption

$$m_\lambda^o = m_\lambda^e + A_\lambda$$

Extinction in magnitudes

$$F_\lambda^o = F_\lambda^e \cdot 10^{-0.4 \cdot A_\lambda}$$

Extinction in flux

$$F_\alpha^o = F_\alpha^e \cdot 10^{-0.4 \cdot A_\alpha}$$

Extinction at Hα wavelength

$$F_\beta^o = F_\beta^e \cdot 10^{-0.4 \cdot A_\beta}$$

Extinction at Hβ wavelength

$$\frac{F_\alpha^o}{F_\beta^o} = \frac{F_\alpha^e}{F_\beta^e} \cdot 10^{-0.4 \cdot (A_\alpha - A_\beta)}$$

$$\frac{F_\alpha^o}{F_\beta^o} = 2.86 \cdot 10^{-0.4 \cdot (A_\alpha / A_V - A_\beta / A_V) A_V}$$

A_α / A_V and A_β / A_V is given in the extinction curve

Summary

- Stellar and gas kinematics in galaxies: spheroidal and disk systems;
- interstellar dust;
- dust extinction;
- how to correcto for dust extinction.