# AGNAGN Seminar Sec.1

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# 1.1 Introduction

**Topics in astrophysics:**
**①physics of ionized gas**
**②interpretation of emission line spectra from ionized gas**

**Attractive targets:**
1. **HII region**(to prove the evolution of the elements and SFH)
2. **Planetary nebulae**(to see the outer remaining envelopes of dying stars)
3. **Supernova remnants**(to observe materials from the burned out dee interiors of exploded)

Starburst galaxies, Quasars, …

# 1.2 Gaseous Nebulae

- Bright extended objects
- Brightness: most of nebulae are faint
  (can be imaged on long exposures with appropriate filters)
- Size: ~30° (Maximum, Gum nebula)
  limit of resolution of the largest nebulae(Minimum)
- Surface brightness: independent of distance
  ⇒nearest nebulae tend to be studied

## Emission line from gas nebulae

- Permitted line
  Hα, Hβ, Hγ, HeI(weak), HeII(weak)…

- Forbidden line
  [OIII], [NII], [NeII]…

## Continuum from gas nebulae

- Atomic component
  - Emitted by free-bound transition
  - Paschen continuum(@<3646 Å), Balmer continuum(@912~3646 Å)
- Reflection component
  - Consist of starlight scattered by dust

# Radio continuum/emission line from gas nebulae

Origins:

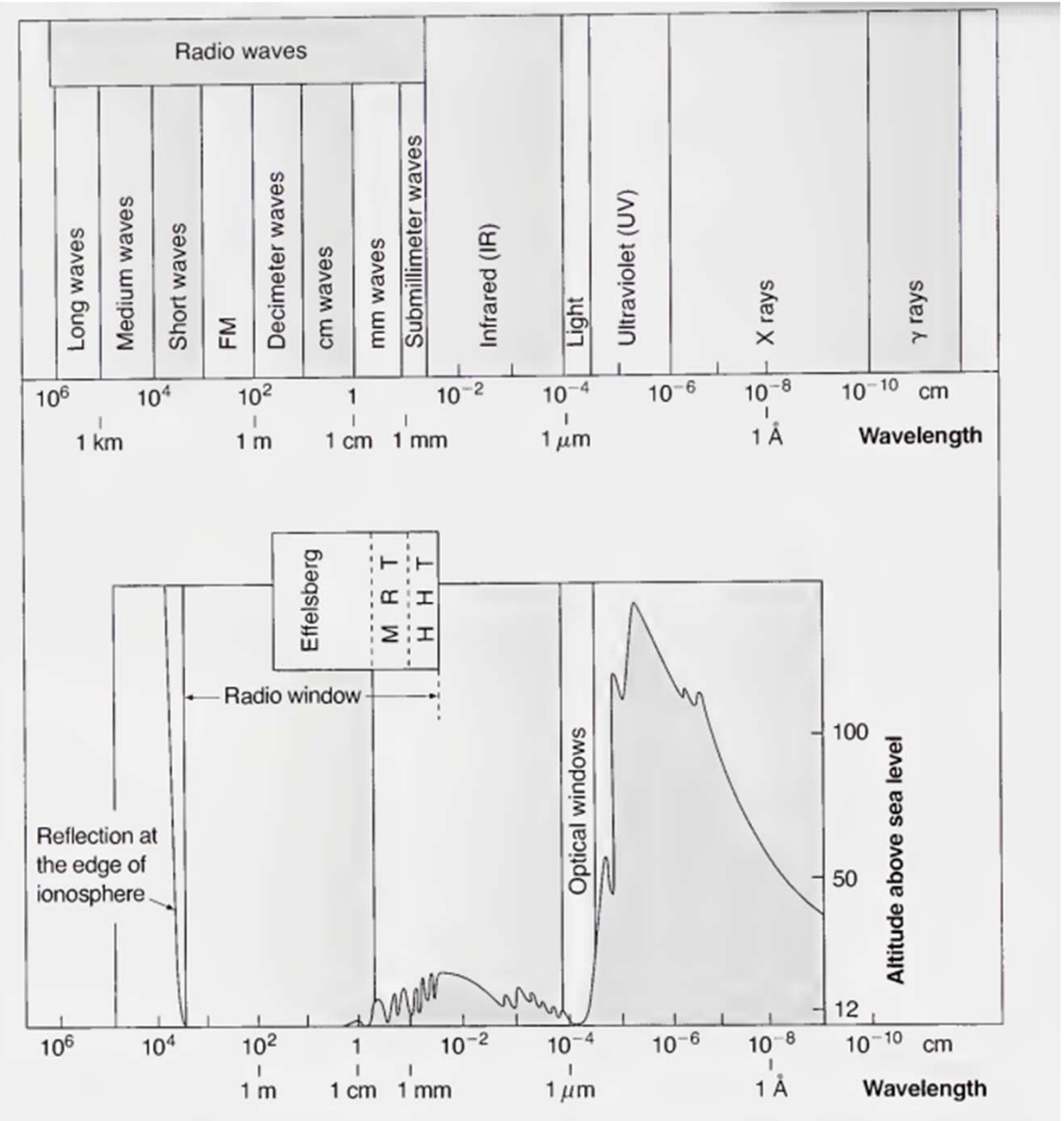
- Free-free emission
- Bremsstrahlung of thermal electron accelerated on Coulomb collisions with protons

- (weak emission lines by bound-bound transitions between high levels of H)
- (weak recombination lines of He)

# 1.3 Observational Material

Nebulae emits various radiation, but we can only observe optical, infrared and radio from ground

(we have to use space telescope, balloon, etc.)



# 1.3.1 Ground Based Optical

**Telescope:**

- Light gathering power is proportional to the size of the primary mirror⇒Larger telescopes have advantages
- Spatial resolution: ~1”(limited by seeing)
- AO observation can improve spatial resolution

**Origins of optical radiation from nebulae:**

① **Emission lines: ionized gas**
② **Continuum: atomic process, scattering of light from the photospheres of stars**
③ **Absorption lines: Ions or atoms of ISM, background stars**

## 1.3.2 Ultraviolet

- Only observed from space with balloons, sounding rockets, orbital missions
- Origins of UV emission:
  - Emission lines: warm ionized gas
  - Continuum: hot stars, atomic process
  - Absorption lines: various elements in ISM

## 1.3.3 X-ray

- Observed with orbital missions
- Resolutions of early missions were limited by technology
  ⇒achieved resolutions similar to optical observation
- Origins of X-ray emission
  - Emission lines: atomic processes of heavy element ions
  - Continuum: very hot material or non-thermal processes

## 1.3.4 Infrared

- Some wavelengths can be observed from the ground (other wavelength can be observed only from space)
- Instrument for orbital missions must be cooled to minimize thermal emission
- Resolution is limited due to technology level
- Possible to penetrate through dusty region
  ⇒useful to observe dusty region

- Origins of infrared emission:
  - Emission lines: various atoms and ions, and molecular rotational and vibrational transition
  - Continuum: cool thermal emission from grains

## 1.3.5 Radio

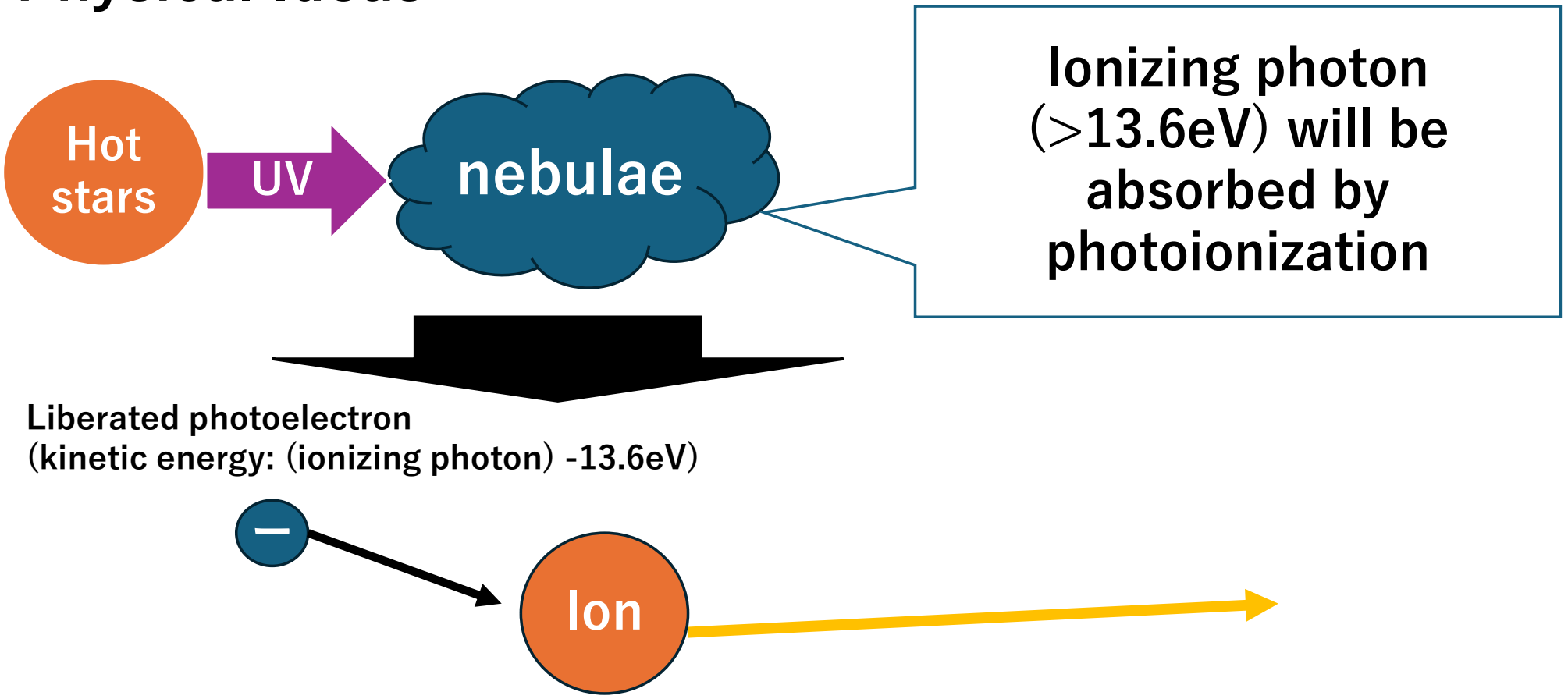
- Most of the wavelength(except very long waves) can be observed from the ground
- Absorbed by water vapor⇒studied from dry mountain-top sites
- Very poor refraction limits⇒interferometers

## 1.3.6 Returned Data

Digital data⇒(reduction process)
⇒final products(image, emission line fluxes, continuum…)

Archived data:
Consisted of past observation data
It can be carried out to start new projects

# 1.4 Physical Ideas



## Origins of the spectrum from nebular

1. High ionization collision line
   Observed from nebulae with especially hot stars
2. Recombination lines(H, He, C…)
   Radiated by excited atoms through transition to lower and lower levels
   (He and C recombination lines are very weak)
3. Continuum
   Emitted from dust heated by central stars

# Type of nebular

①diffuse nebulae/HII region
②planetary nebulae
(③ shells of nova)
(④ supernova remnant)

Physical process are similar, but these are different in origin, mass, evolution…
⇒We will examine each of these types of object

# 1.5 Diffuse Nebulae(HII region)

- **Regions of interstellar gas with the exciting star or OB type stars** (like NGC1499)
- **H is ionized, He is singly ionized, and other elements are mostly singly or doubly ionized**
- **Density of electron: 10-100($cm^{-3}$, typical)**
- **It shows strong HI recombination lines and collisionally excited lines([NII], [OII], [OIII])**
- **Some of the strength of lines depend on the temperature of central stars**
- **Useful to trace the structure of spiral arms, measure the radial velocity, and get the information on the kinematics of Pop I stars**

# 1.6 Planetary Nebulae

- Isolated nebular formed by the death of solar-like stars
- Temperature of central star: about 50000K
  (that of typical HII region: 30000~50000K)
  ⇒tends to be high ionized(He+⇒He++)
- We can detect HeII, strong [OIII] and [NeIII], [NeV] lines
- Luminosity: very weak(Mv=-3~+5)⇒hard to observe
- Density: 100~10000 $cm^{-3}$
- Mass:0.1~1 $M_{\odot}$

- Useful to derive velocity and abundance, and to solve the stellar evolution

# 1.7 Nova and Supernova Remnants

**Nova:** surrounded by small, faint shell=photoionized nebulae
**Supernova remnants:** some of nebular are SNR, with strong non-thermal radio spectra

- **Filamentary nebulae:** radiates strong non-thermal radio spec
  ⇒identified as older SNR

**Crab Nebula: one of the famous SNRs**

- Remnant of SN of A.D.1054
- **Synchrotron radiation** is observed from radio to optical
  ⇒**Source of ionization photons(Photoionization)**

**Source of ionization photons in other SNR:**

- Photoionization source is not detected⇒**Collisional ionization?**

$$\begin{cases} photoionization \\ collisional\ ionization \end{cases}$$ ⇒**thermal electron⇒collisional excitation**

# 1.8 Active Galactic Nuclei

Starburst galaxies/Extragalactic HII region:

- Galactic nuclei with characteristic nebular emission line
- Many galaxies have this type nuclei
- Seems to be giant HII region/cluster of HII region

**AGN:**

**①Seyfert galaxy:**

- **Emission line spectrum with a wide range of ionization**
- **Grater range of velocities than starburst galaxies**

**②Quasars/QSOs**

- **Similar galaxies with Seyfert galaxy(radio-loud/quiet analogues)**

# Ionization in AGN

- Much of the ionized gas appears to be photoionized
- Ionization source: high energies of the featureless continuum(not a hot star), emitted by accretion disk around a black hale or magnetic field associated with BH
- Physical law is same with HII region, but special physical process is important because of the difference of the numbers of high-energy photons

# 1.9 Star Formation in Galaxies

**Newly born OB type stars⇒photoionization of ISM**
**⇒create large emission-line diffuse nebulae or huge regions of nebulosity**

**Starburst galaxies(like infrared luminous galaxies):**
Galaxies that have high SFR and strong emission lines

**Origins of starburst galaxies:**
**Interactions and mergers of gas-rich spirals**
**Gas in ISM falls towards the merger nuclei⇒star formation**
**⇑**
**Obscured by dust**
**=we need infrared observation to observe directly**