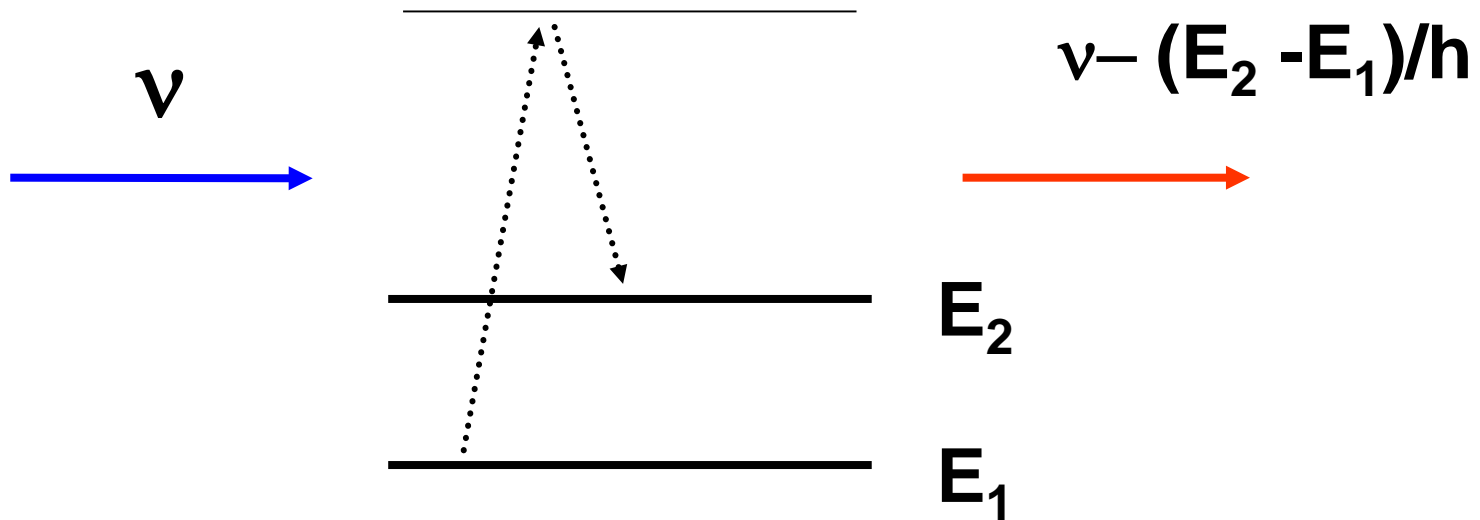
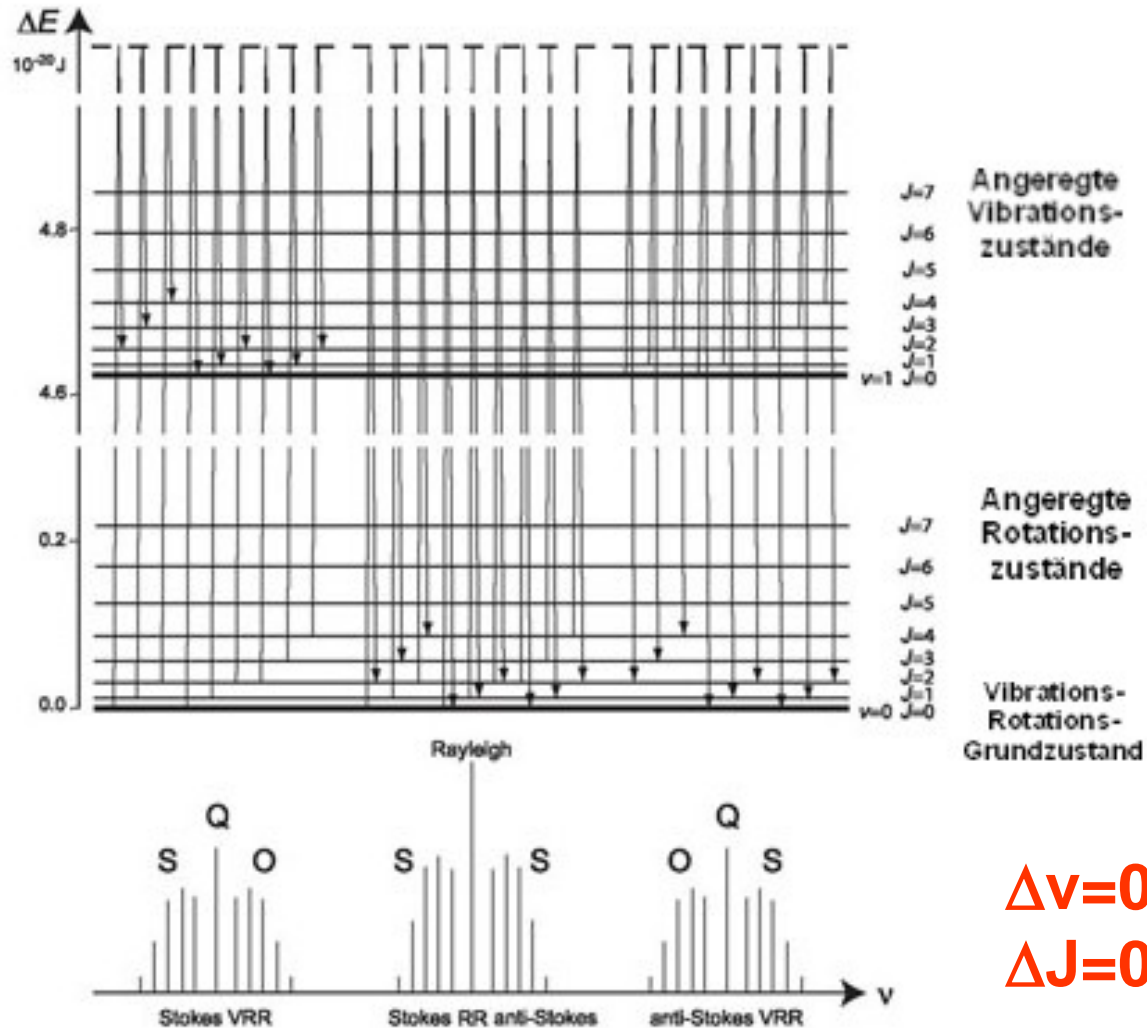


# *Effetto Raman*



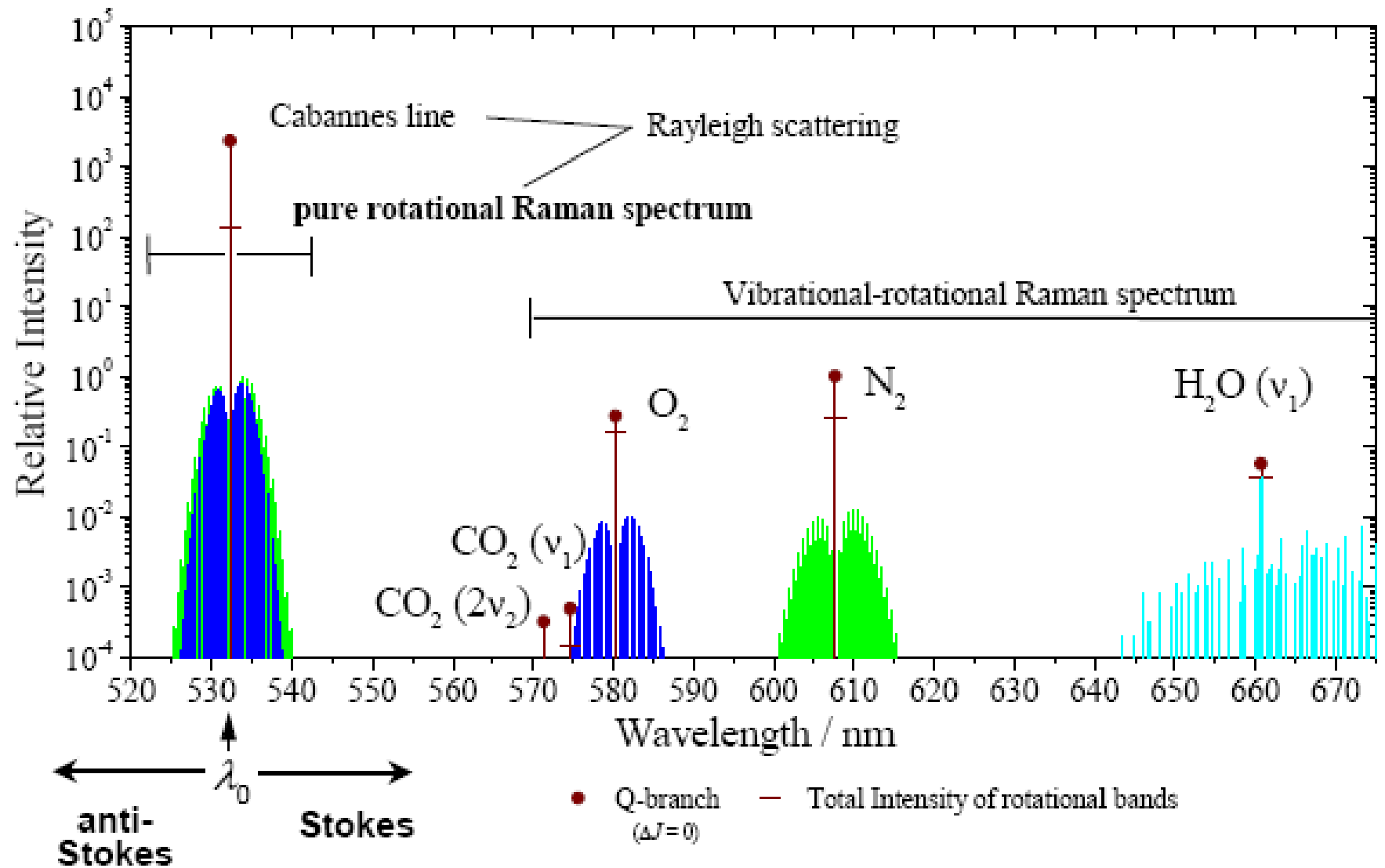
# Effetto Raman rotovibrazionale



$$\Delta v = 0, \pm 1$$

$$\Delta J = 0, \pm 2$$

# Spettro Raman dell'atmosfera



1% H<sub>2</sub>O  
 $T = 300\text{K}$  (for PRRS)

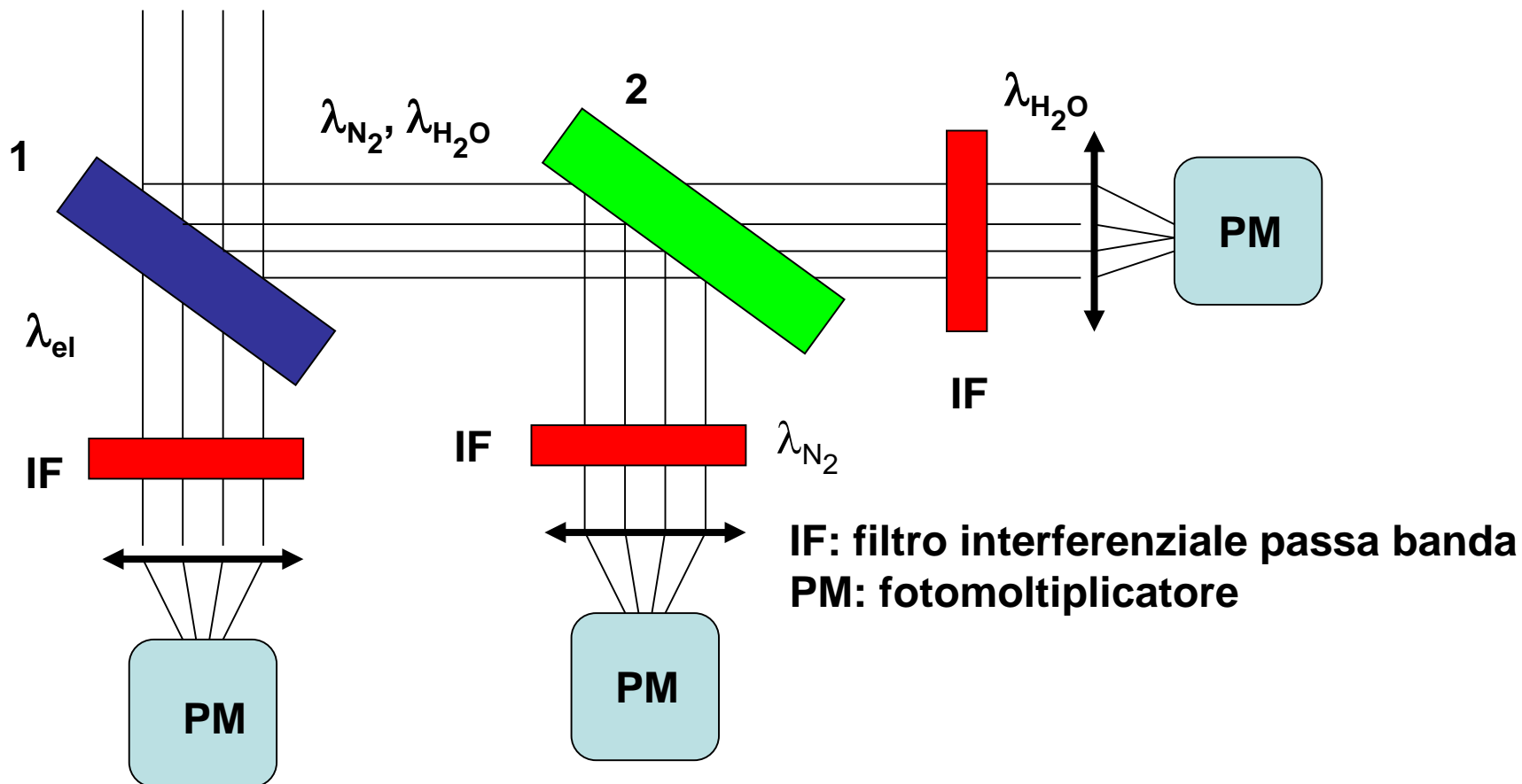
# Schema sperimentale

Dal telescopio

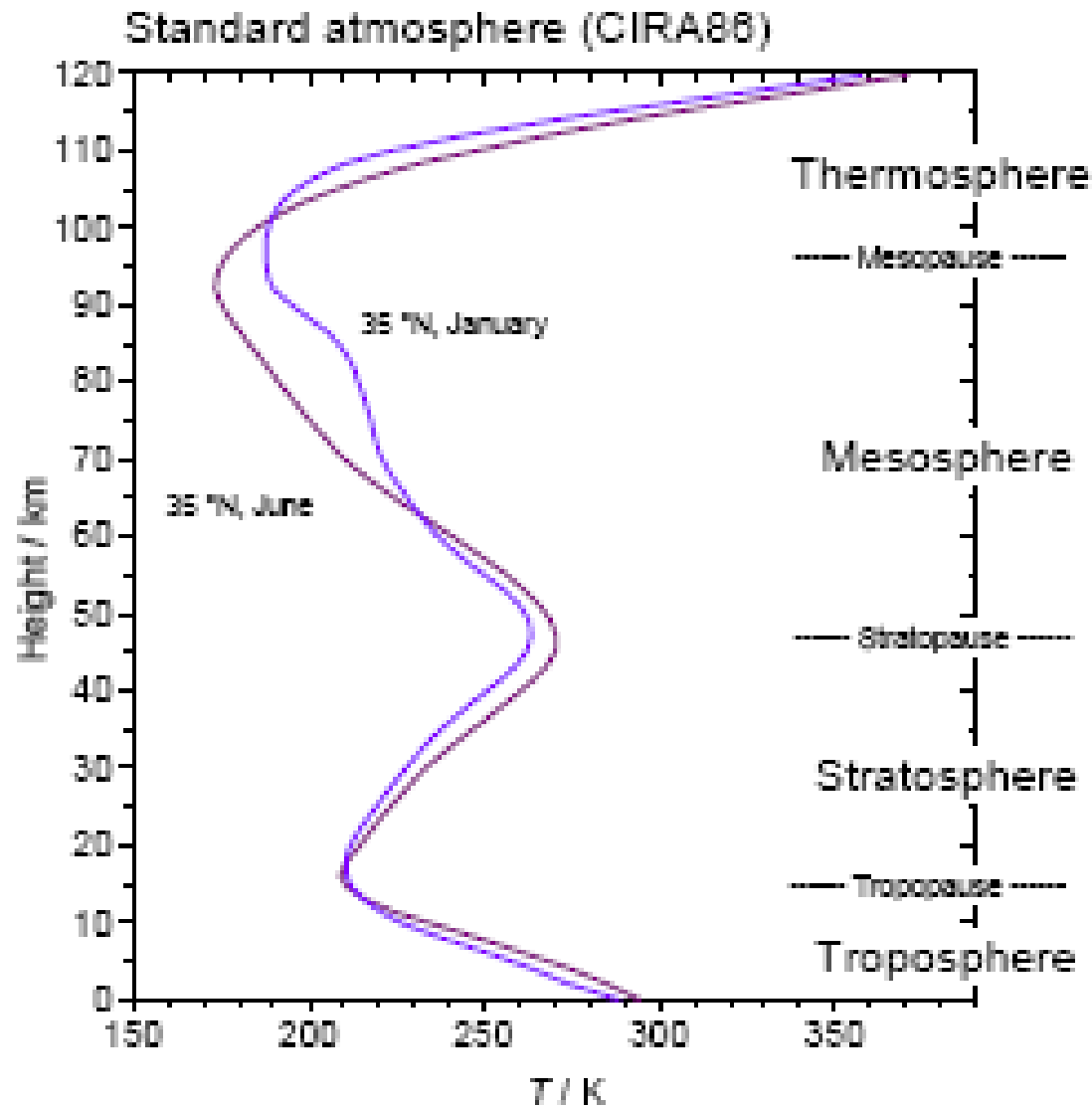
$(\lambda_{el}, \lambda_{N_2}, \lambda_{H_2O})$

1) Specchio dicroico passa basso

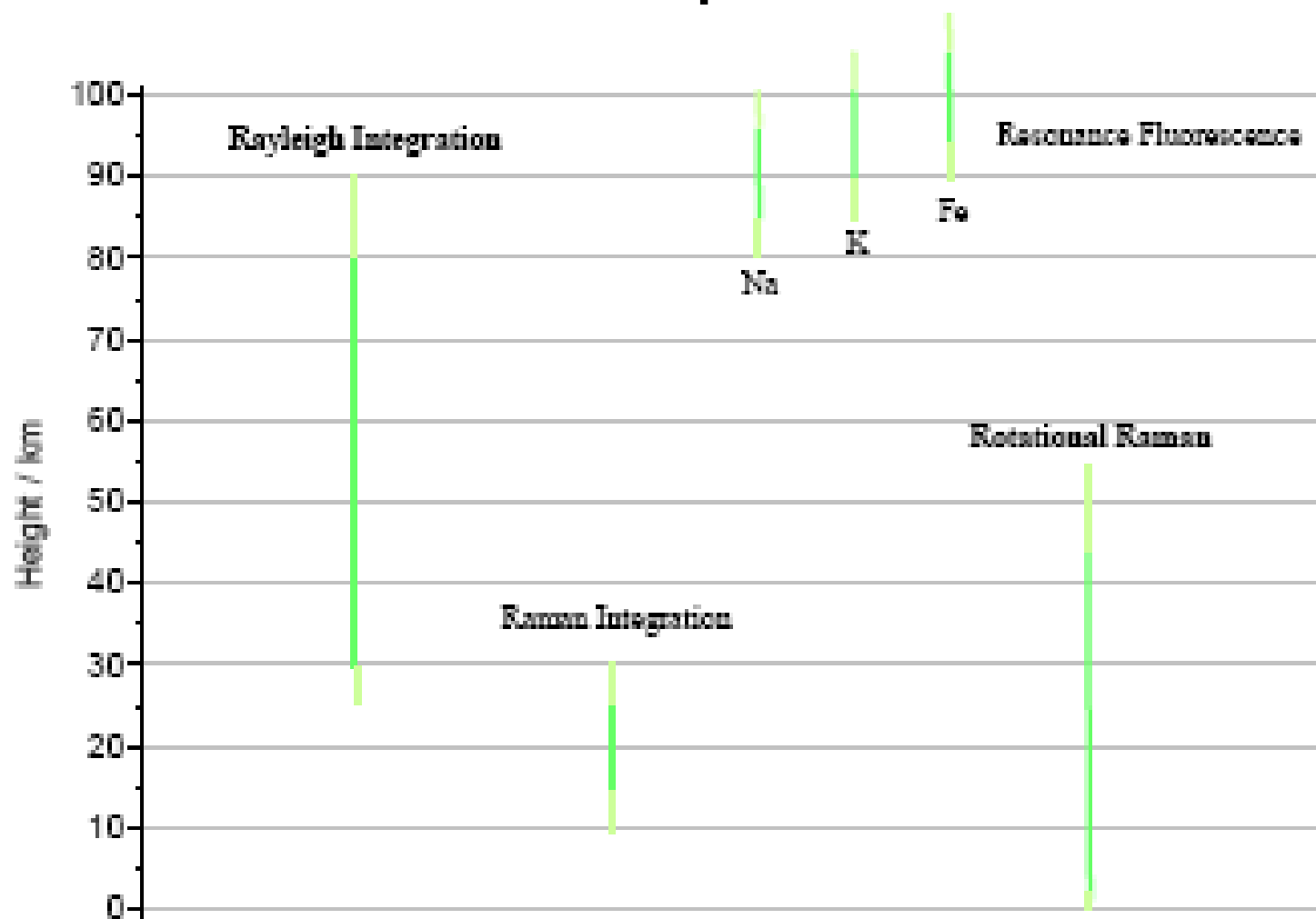
2) Specchio dicroico passa alto

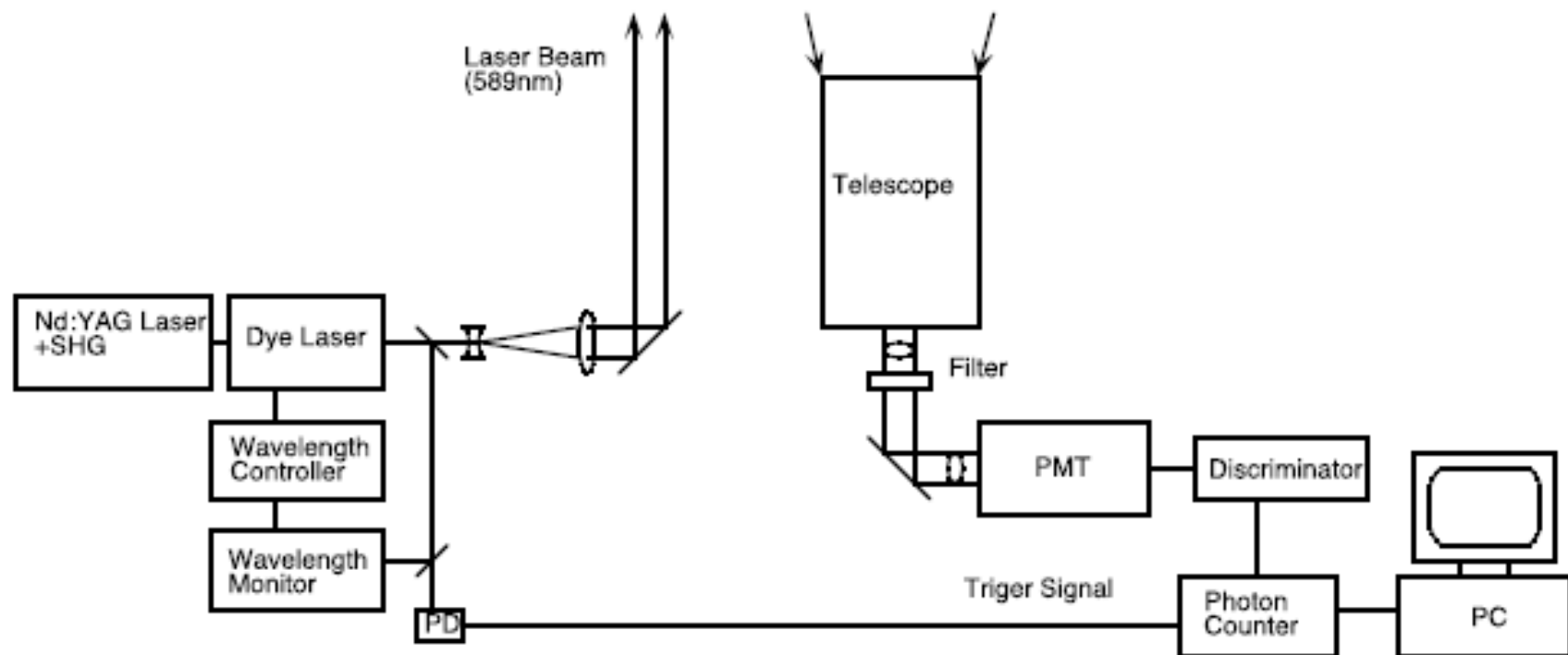


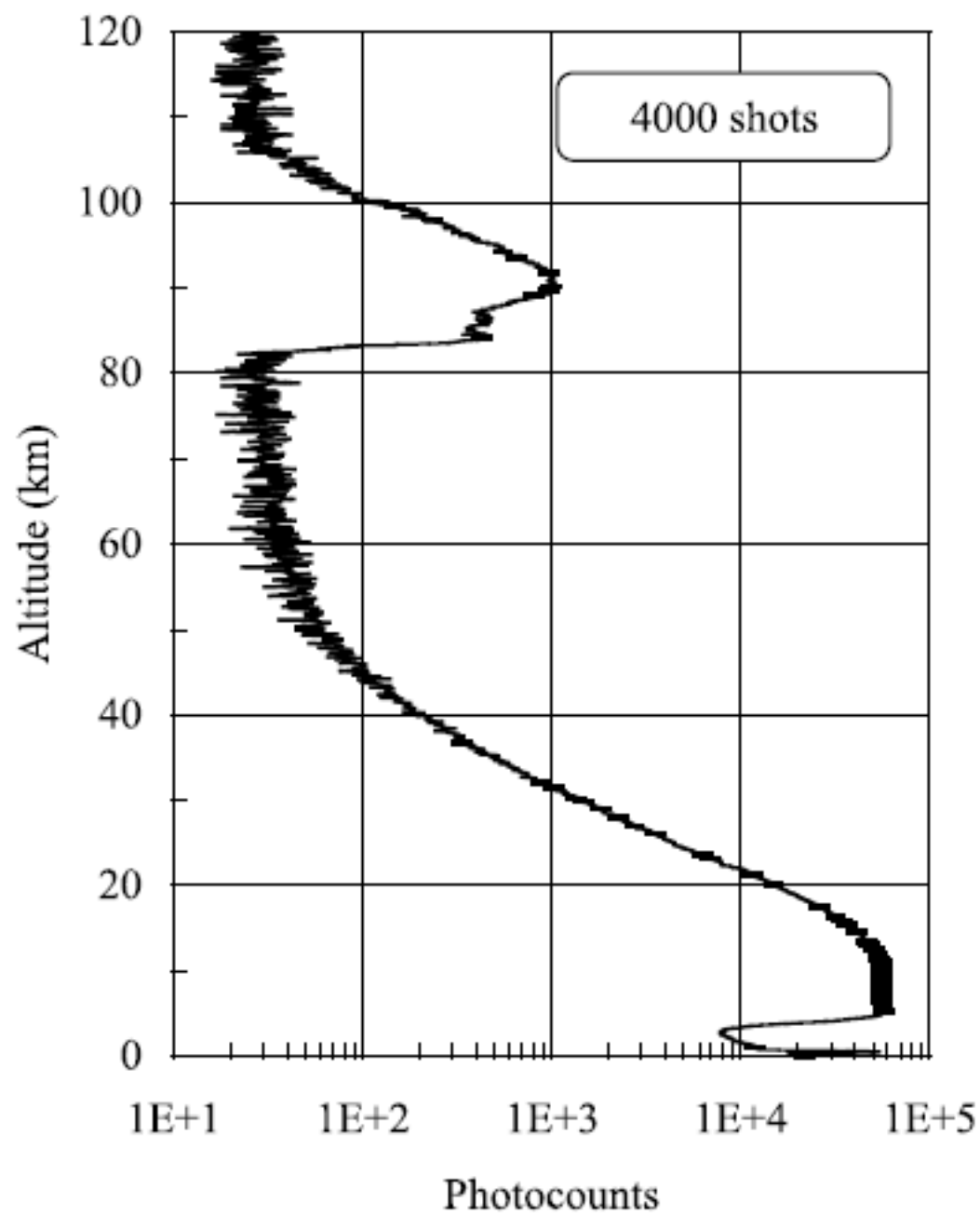
# Variazione della temperatura in atmosfera



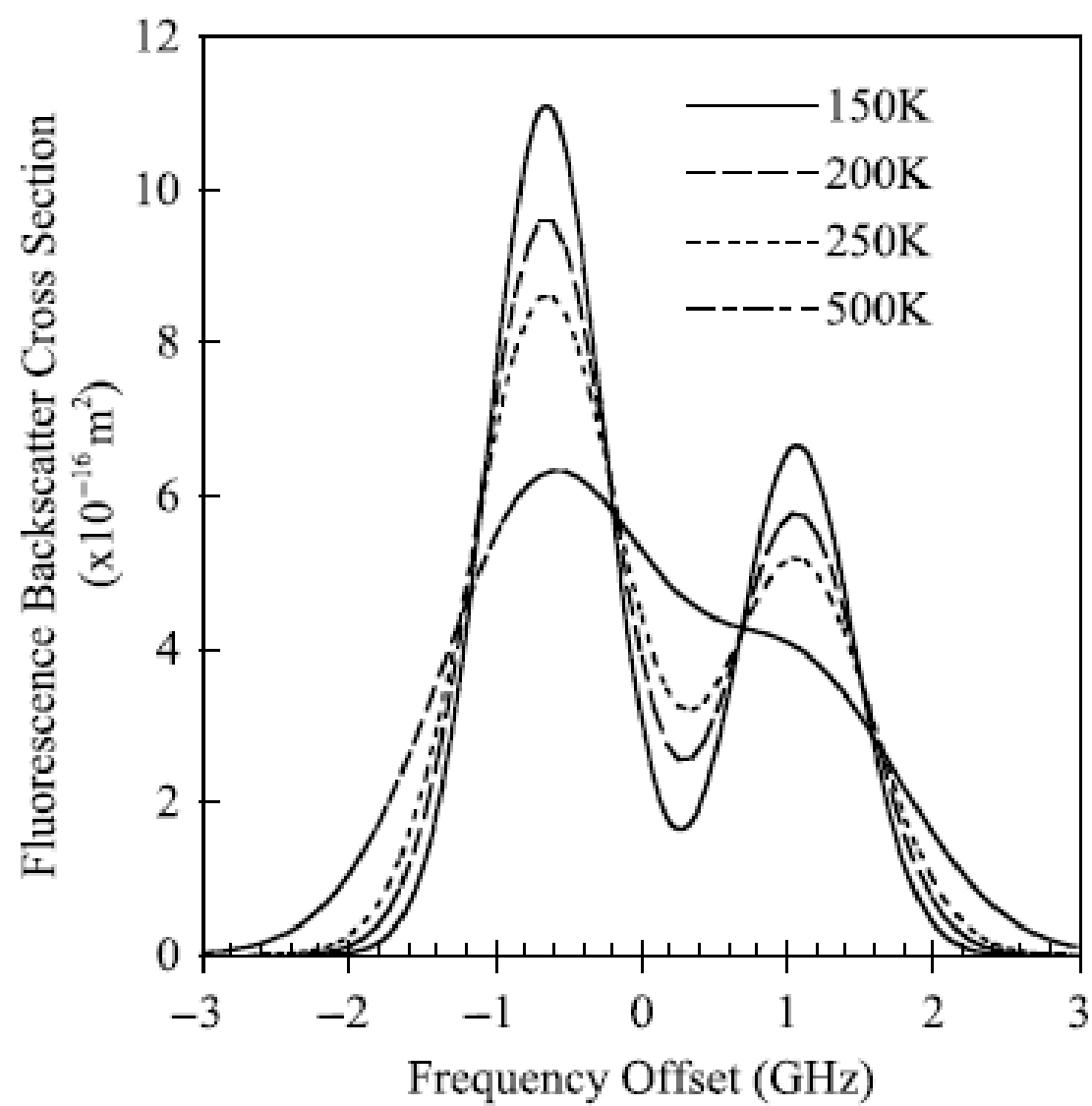
# Metodi lidar per la misura della temperatura

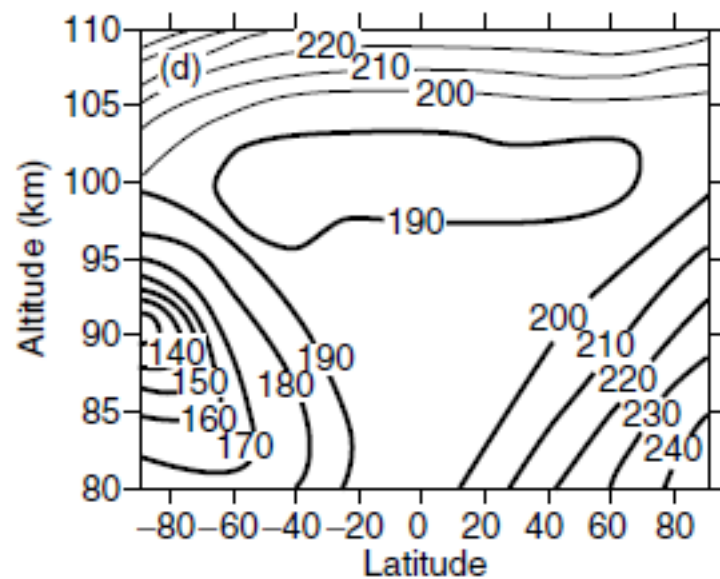
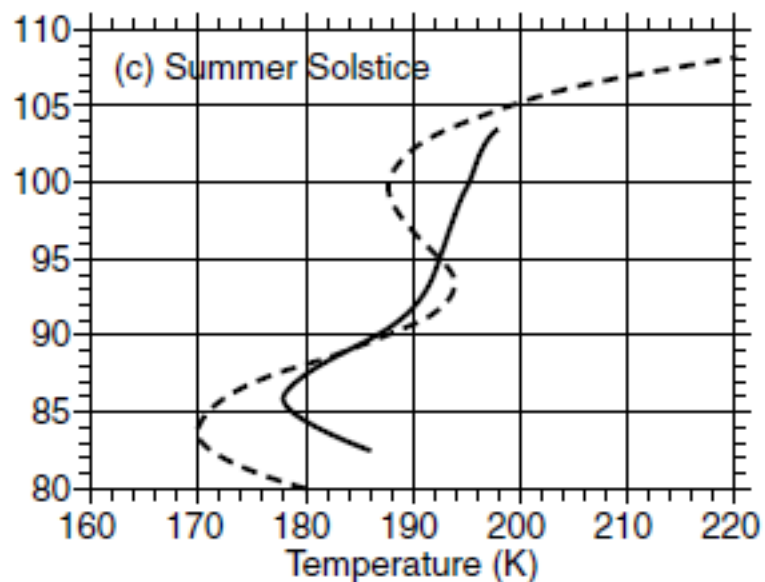
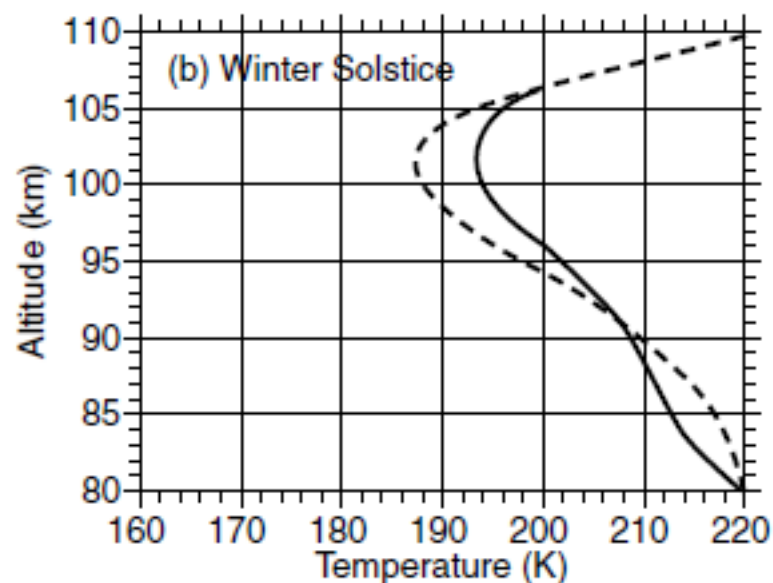
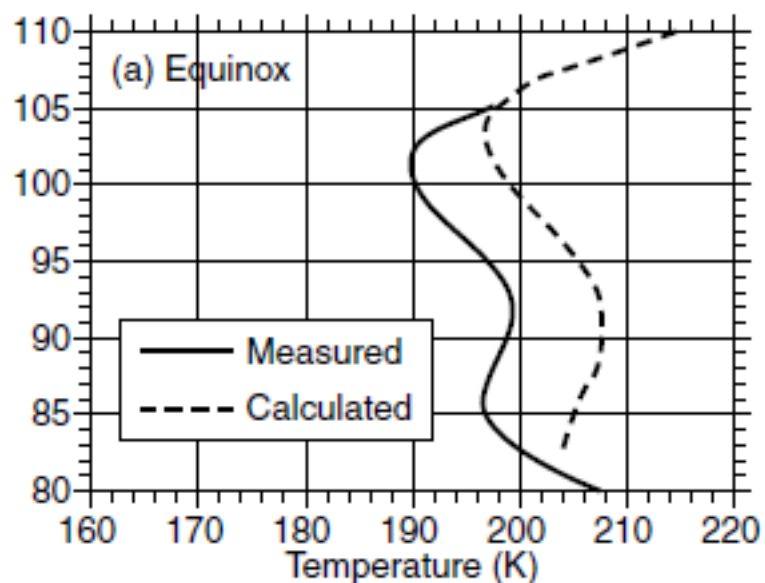












$$N(z) = \frac{C \, S(z) \, (z - z_0)^2}{\tau(z_0, z)^2}.$$

$$N(z) = \frac{N(z_{\text{ref},1}) \, S(z) \, (z - z_0)}{S(z_{\text{ref},1}) \, \tau(z_{\text{ref},1}, z)^2 \, (z_{\text{ref},1} - z_0)^2},$$

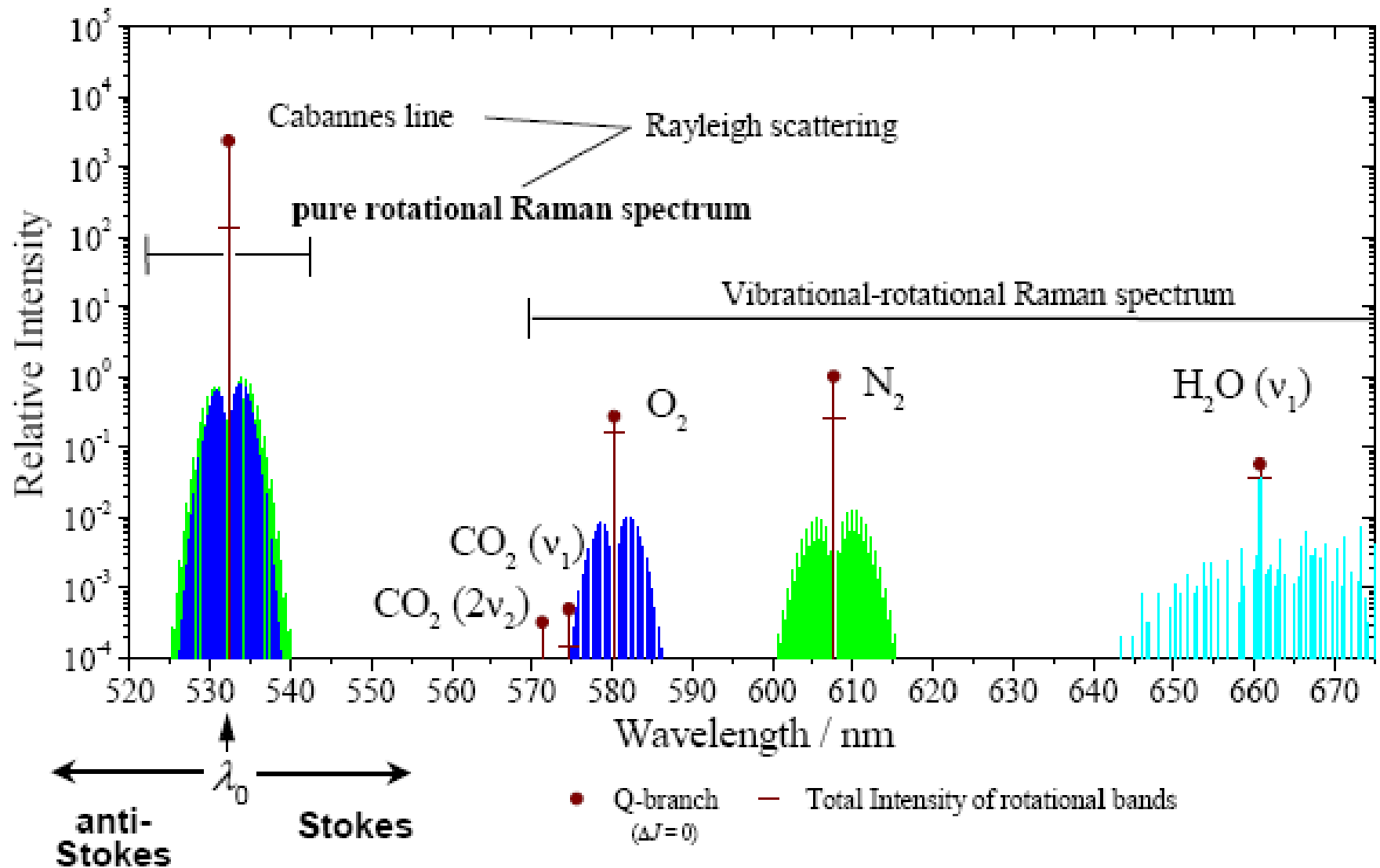
$$p(z) = k N(z) T(z)$$

$$\mathrm{d} p(z) = -\rho(z) g(z) \mathrm{d} z$$

$$\rho(z) = N(z) M$$

$$T(z) = \frac{N(z_{\text{ref},2})}{N(z)} T(z_{\text{ref},2}) + \frac{M}{k N(z)} \int_{z_{\text{ref},2}}^z g(\zeta) N(\zeta) \mathrm{d} \zeta.$$

# Misura della temperatura (effetto Raman puramente rotazionale)



# ***Metodi per misurare la temperatura***

Nell'intervallo di altezze in cui ci aspettiamo che la tecnica Raman funzioni (0-30 km) la temperatura varia di circa 100 gradi

Possiamo trovare degli insiemi di righe rotazionali la cui intensità varia in maniera monotona con la temperatura.

Scegliendo gruppi che hanno un andamento opposto, si può prendere il rapporto tra i due segnali:

1. La funzione di overlap si semplifica
2. La calibrazione è facilitata

Due possibilità:

- a) Estrarre dallo spettro “antistokes” due gruppi di righe corrispondenti a J alti e bassi
- b) Utilizzare righe singole (ad alto e basso J), eventualmente sommare la parte Stokes e Antistokes

$$E_{\text{rot},i}(J) = [B_{0,i}J(J+1) - D_{0,i}J^2(J+1)^2]hc, J = 0, 1, 2, \dots,$$

$$\Delta\nu_{\text{St},i}(J) = -B_{0,i}2(2J+3) + D_{0,i}[3(2J+3) + (2J+3)^3],$$

$$J = 0, 1, 2, \dots \quad (10.18)$$

$$\Delta\nu_{\text{As},i}(J) = B_{0,i}2(2J-1) - D_{0,i}[3(2J-1) + (2J-1)^3] \quad \text{with}$$

$$J = 2, 3, 4, \dots \quad (10.19)$$

$$\left(\frac{d\sigma}{d\Omega}\right)_{\pi}^{\text{RR},i}(J) = \frac{112\pi^4}{15} \frac{g_i(J) h c B_{0,i} (\nu_0 + \Delta\nu_i(J))^4 \gamma_i^2}{(2I_i + 1)^2 k T} \times X(J) \exp\left(-\frac{E_{\text{rot},i}(J)}{kT}\right) \quad (10.20)$$

### Stokes

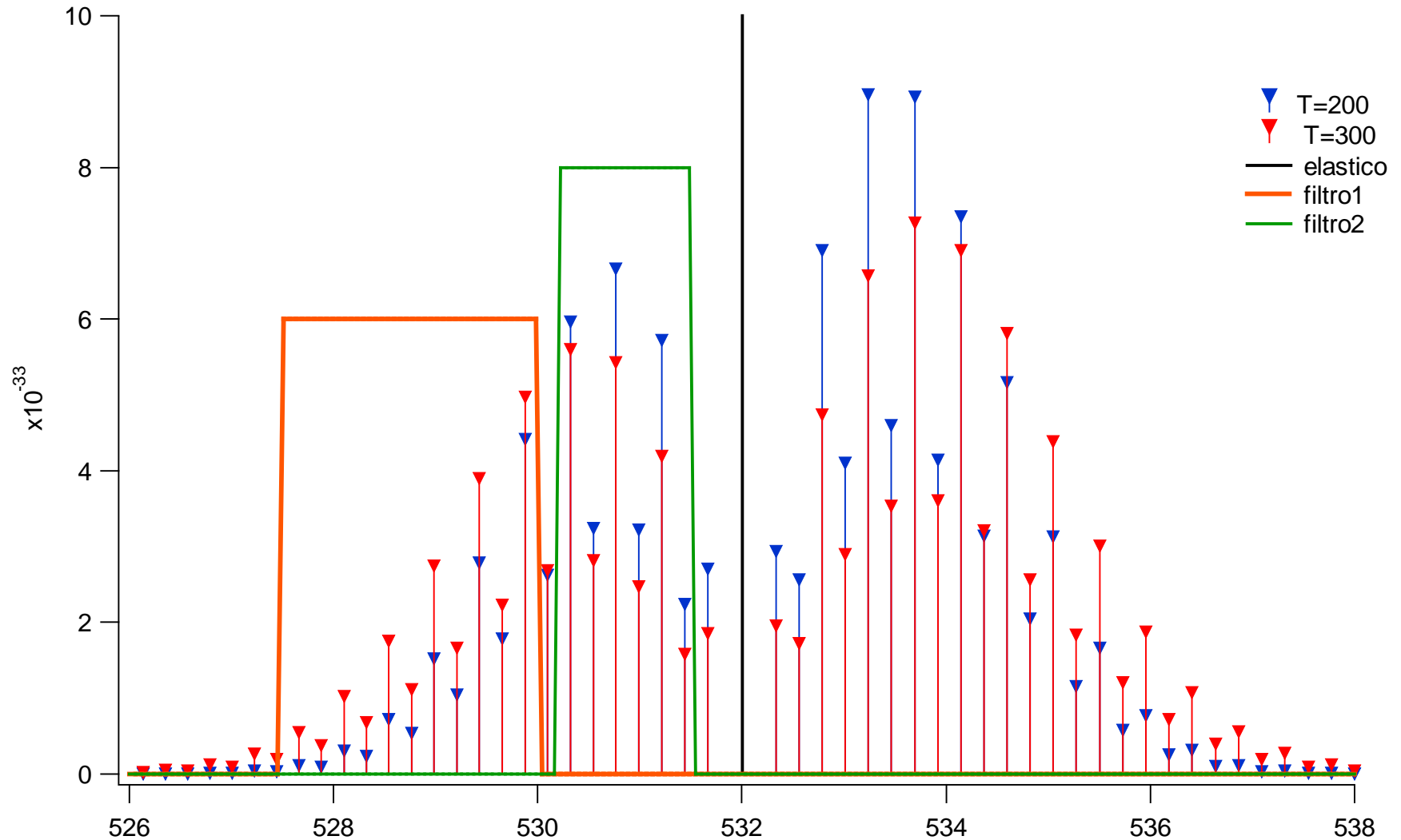
$$X(J) = \frac{(J+1)(J+2)}{2J+3} \quad \text{with } J = 0, 1, 2, \dots$$

### Anti-Stokes

$$X(J) = \frac{J(J-1)}{2J-1} \quad \text{with } J = 2, 3, 4, \dots$$



# Spettro rotazionale N2

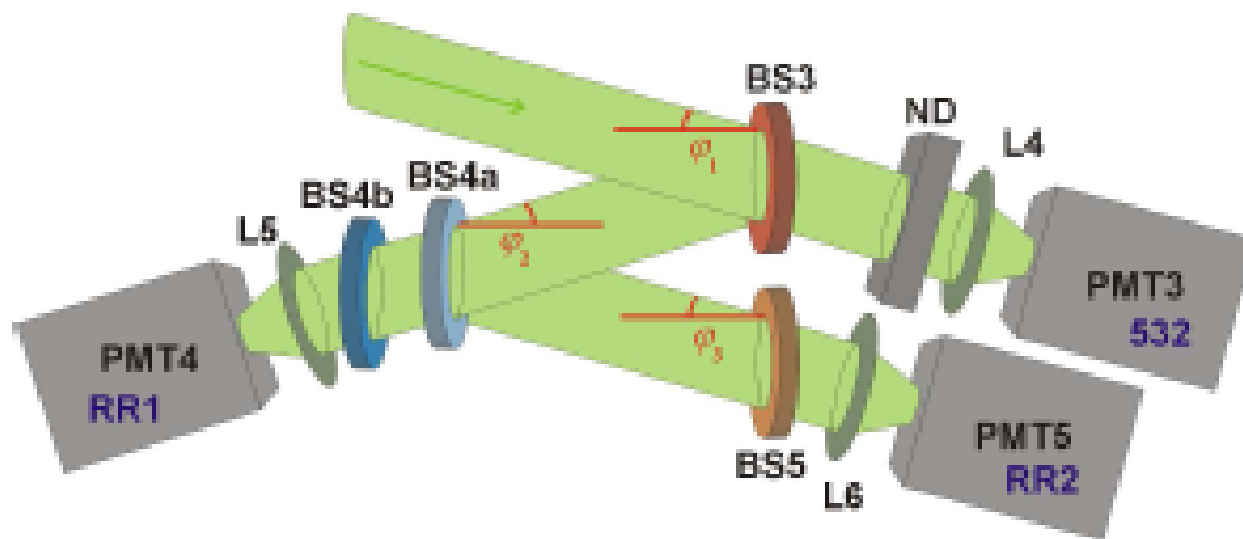


# Somme di gruppi di righe

Prendere la parte antistokes permette di

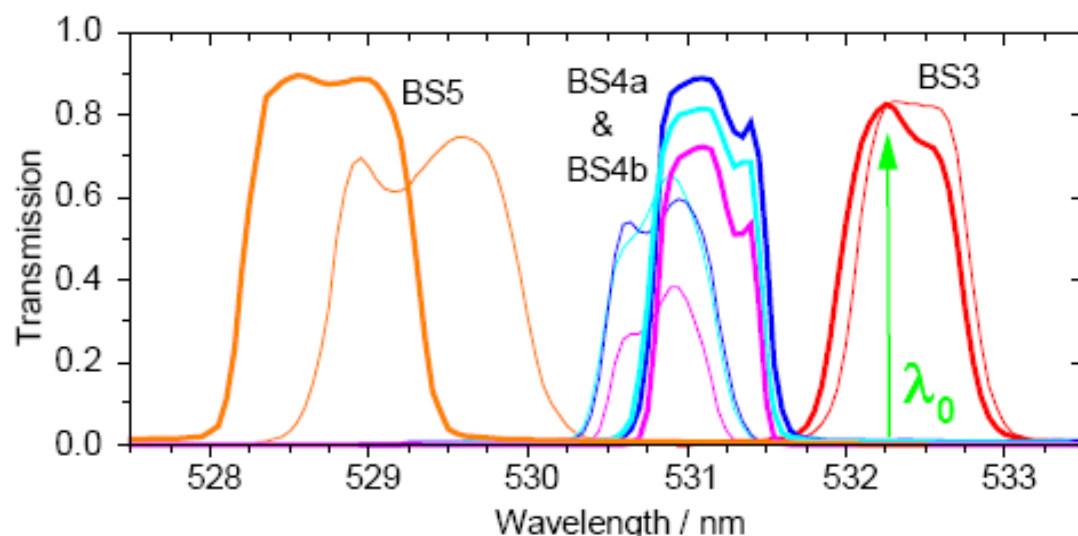
- 1) Eliminare gli eventuali effetti di fluorescenza da parte degli aerosol (bioaerosol)
- 2) Regolare la lunghezza d'onda di max trasmissione dei filtri aumentando l'angolo di incidenza.

# Realizzazione sperimentale



- \* High suppression of the elastic backscatter light ( $OD > 7$ )
- \* Very low losses in the signal separation -> high efficiency  
Reflectivity near 100 %  
Transmission for the rotational Raman channels 0.72 (0.38) and 0.87 (0.75), resp.
- \* Tunability of the filter center wavelengths by changing the angles of incidence  
Adjustment of elastic signal suppression or optimization for certain temperature ranges

# Interference filters



GKSS Raman lidar (1997)

— BS3  
— BS4a  
— BS4b  
— BS4a & BS4b  
— BS5

RASC Raman lidar (2001)

— BS3  
— BS4a  
— BS4b  
— BS4a & BS4b  
— BS5

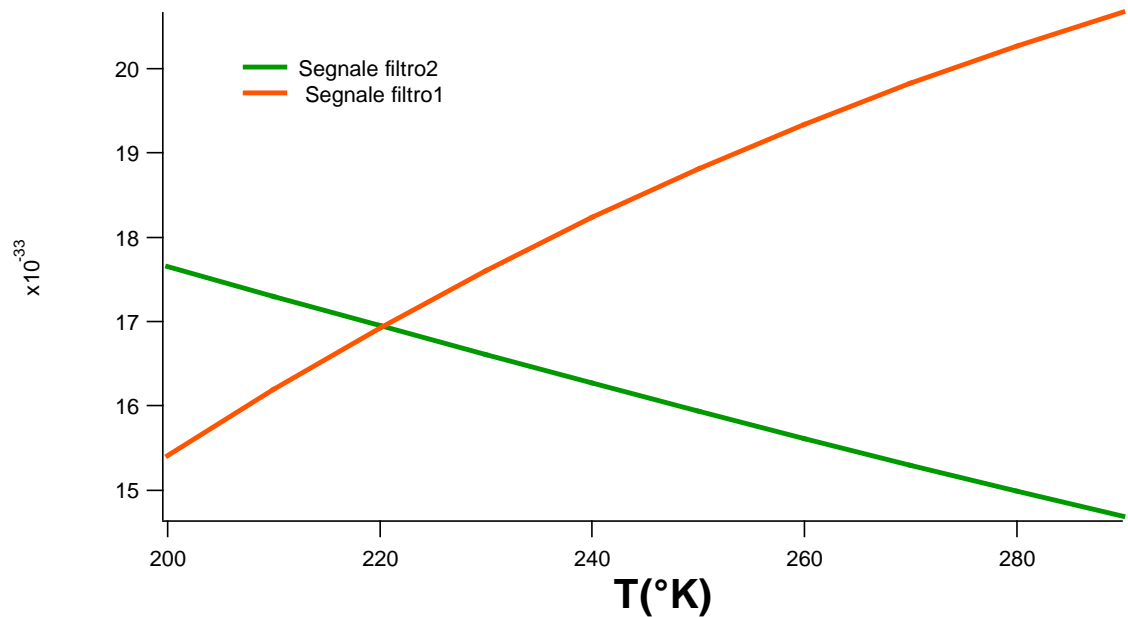
Wavelength, nm	Parameter	BS3	BS4a & BS4b combined	BS5
	AOI, °	4.8	5.0	7.2
	CWL, nm	532.25	531.30	528.70
	FWHM, nm	0.80	0.65	1.10
532.11, p	$\tau$	0.82	$< 10^{-6}$	$< 10^{-6}$
	$\rho$	0.11		
531.10	$\tau$		0.72	$< 2 \cdot 10^{-4}$
	$\rho$	$> 0.95$		
528.50	$\tau$			0.87
	$\rho$	$> 0.96$	$> 0.96$	

IF1a, IF2a, IF2b:

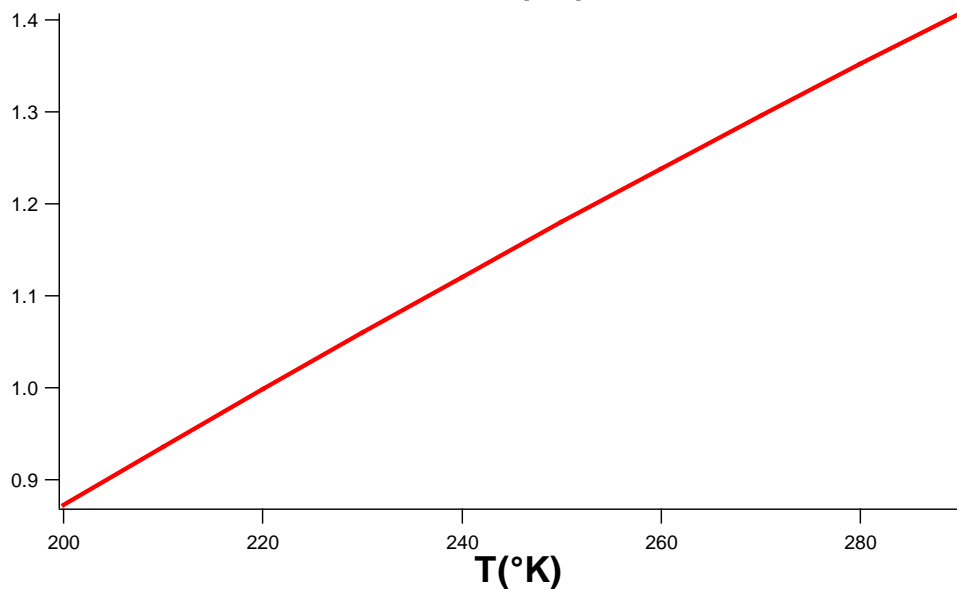
3-cavity interference filters

IF3: 6-cavity interference filters

Diameter 50 mm



Segnali in  
funzione della  
temperatura



Rapporto in  
funzione della  
temperatura

# Andamento del segnale

