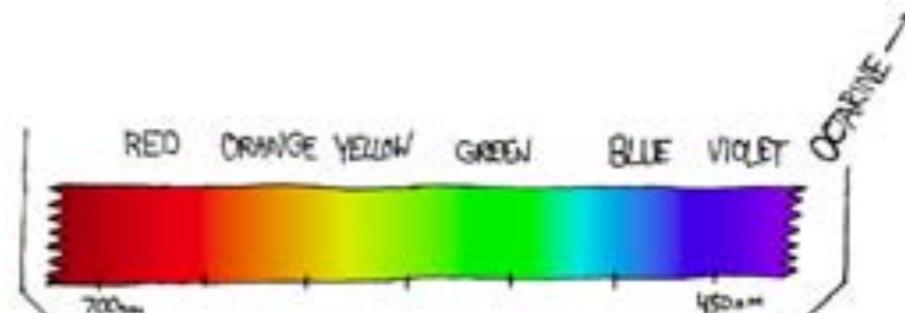
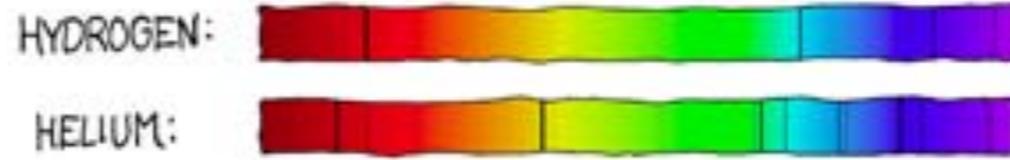


GAMMA DECAY

THE ELECTROMAGNETIC SPECTRUM

THESE WAVES TRAVEL THROUGH THE ELECTROMAGNETIC FIELD. THEY WERE FORMERLY CARRIED BY THE AETHER, WHICH WAS DECOMMISSIONED IN 1897 DUE TO BUDGET CUTS.

ABSORPTION SPECTRA:



VISIBLE LIGHT

OTHER WAVES:

SLINKY WAVES

SOUND WAVES
20 kHz
AUDIBLE SOUND
20 Hz
THAT HIGH-PITCHED NOISE IN EMPTY ROOMS

THE WAVE

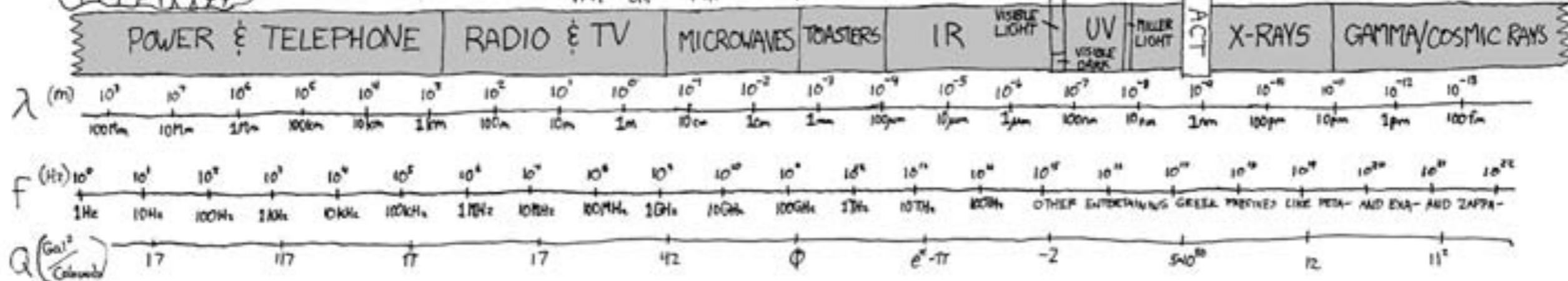
SHOUTING CAR DEALERSHIP COMMERCIALS

CIA (SECRET) HAM RADIO KOSHER RADIO

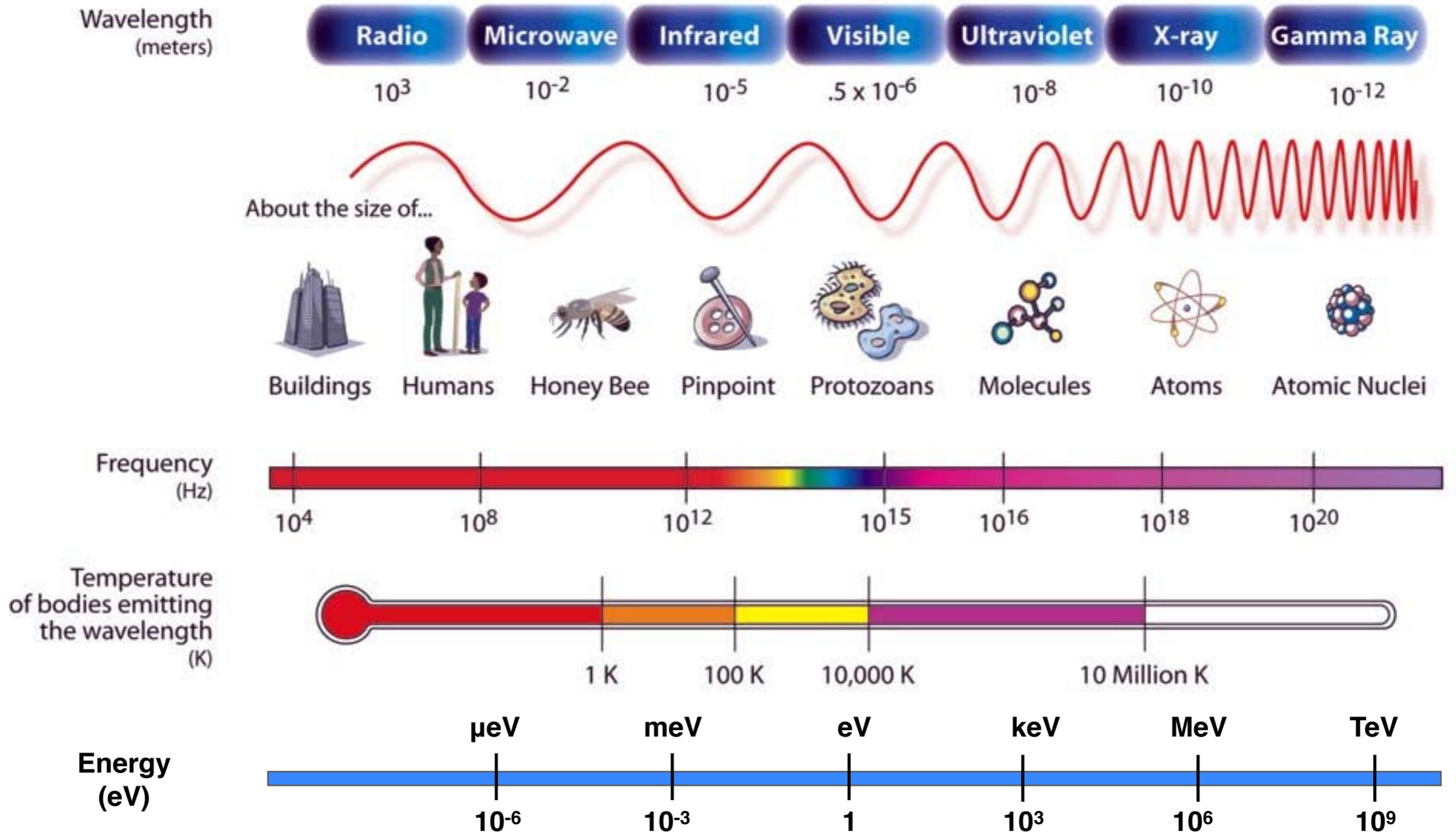
SPACE RAYS CONTROLLING STEVE BALLMER
99.3 "THE FOX"
101.5 "THE BADGER"
106.3 "THE FRIGHTENED SQUIREL"
24 1/2 NPR PLEDGE DRIVES
CELL PHONE CANCER RAYS
ALIENS SETI
WIFI BRAIN WAVES
SOLANESI
SUPERMAN'S HEAT VISION
JACK BLACK'S HEAT VISION
GRAVITY

POTATO
BLOGORAYS
MAIL-ORDER X-RAY GLASSES
SINISTER GOOGLE PROJECTS

CENSORED UNDER PATRIOT ACT



ELECTROMAGNETIC SPECTRUM



DIPOLE RADIATION

- Rate from Fermi's Golden Rule + Density of states:

$$W = \frac{2\pi}{\hbar} |\langle \psi_f | \hat{V} | \psi_i \rangle|^2 \rho(E_f) = \frac{\omega^3}{2\pi c^3 \hbar} |\langle \hat{r} \rangle|^2 \sin^2 \theta d\Omega$$

- Integrating over angles:

$$\lambda(E1) = \frac{4}{3} \frac{e^2 \omega^3}{\hbar c^3} |\langle r \rangle|^2$$

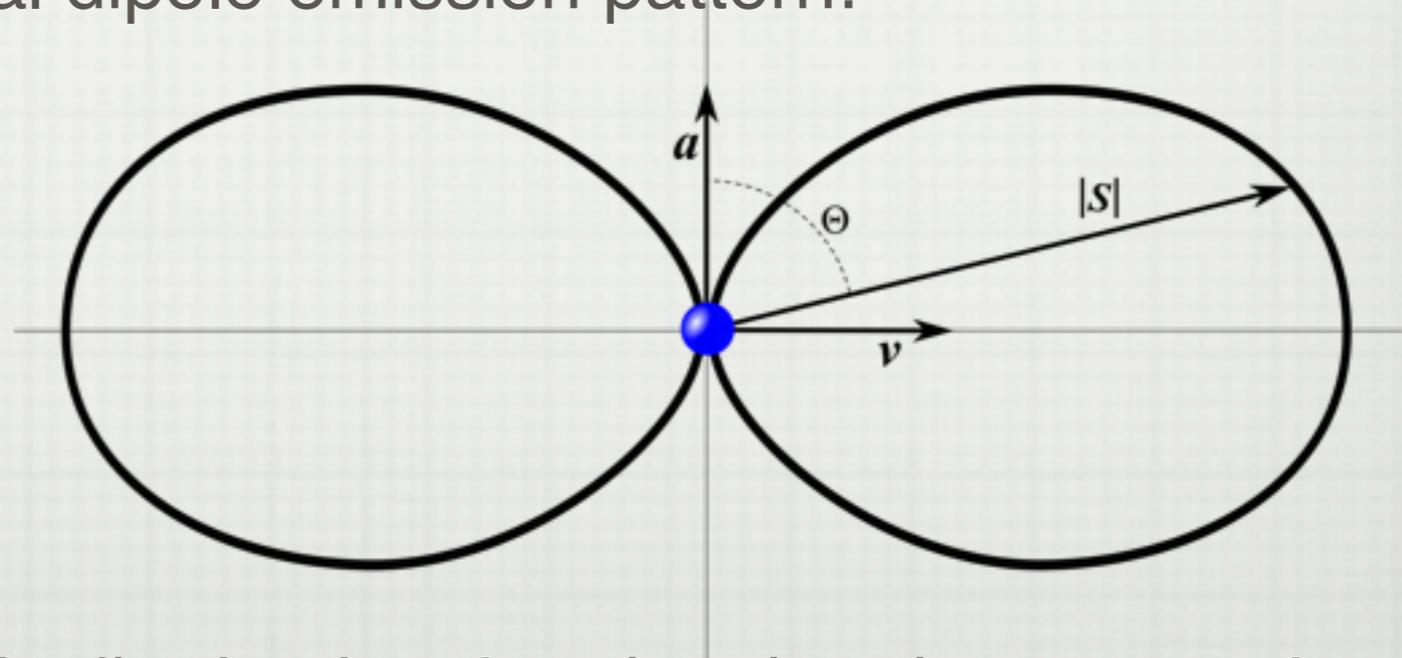
DIPOLE APPROXIMATION

- In deriving the dipole emission formula we only kept lowest order expansion:

$$\vec{A} \propto a_k^\dagger e^{i\vec{k}\cdot\vec{r}} \vec{\epsilon}_k \approx a_k^\dagger (1 + i\vec{k}\cdot\vec{r} + \dots) \vec{\epsilon}_k \rightarrow a_k^\dagger \vec{\epsilon}_k$$

- This yields the typical dipole emission pattern:

$$W \propto \sin^2 \theta d\Omega$$



- In QM the angular distribution is related to the photon angular momentum

BEYOND THE DIPOLE

- Higher order terms in the expansion give rise to gamma emission
 - with different angular-dependence pattern
 - and higher angular momentum for the gamma photon emitted

$$\vec{A} \propto a_k^\dagger e^{i\vec{k}\cdot\vec{r}} \vec{\epsilon}_k \approx a_k^\dagger \sum_{\ell} \frac{(i\vec{k}\cdot\vec{r})^\ell}{\ell!} \vec{\epsilon}_k$$

- Each ℓ term contributes to a different decay rate.

MULTIPOLE RADIATION

- Electric multipole

$$\lambda(E\ell) = \frac{8\pi(\ell + 1)}{\ell[(2\ell + 1)!!]^2} \frac{e^2}{\hbar c} \left(\frac{E}{\hbar c}\right)^{2\ell+1} \left(\frac{3}{\ell + 3}\right)^2 c \langle |\hat{r}| \rangle^{2\ell}$$

$$\langle |\hat{r}| \rangle \approx R_0 A^{1/3}$$

- Rates: $\lambda(E1) = 1.0 \times 10^{14} A^{2/3} E^3$

$$\lambda(E2) = 7.3 \times 10^7 A^{4/3} E^5$$

$$\lambda(E3) = 34 A^2 E^7$$

$$\lambda(E4) = 1.1 \times 10^{-5} A^{8/3} E^9$$

MULTIPOLE RADIATION

- Magnetic multipole

$$\lambda(M\ell) = \frac{8\pi(\ell + 1)}{\ell[(2\ell + 1)!!]^2} \frac{e^2}{\hbar c} \frac{E^{2\ell+1}}{\hbar c} \left(\frac{3}{\ell + 3}\right)^2 c \langle |\hat{r}| \rangle^{2\ell-2} \left[\frac{\hbar}{m_p c} \left(\mu_p - \frac{1}{\ell + 1} \right) \right]$$

- Rates:

$$\lambda(M1) = 5.6 \times 10^{13} E^3$$

$$\lambda(M2) = 3.5 \times 10^7 A^{2/3} E^5$$

$$\lambda(M3) = 16 A^{4/3} E^7$$

$$\lambda(M4) = 4.5 \times 10^{-6} A^2 E^9$$

WHICH TRANSITION?

- The lowest multipole dominates:
 - Lower multipoles decay faster (higher rates)
 - Electric multipoles are faster than magnetic multipoles

- ➔ Why don't we always only observe electric dipole (E1) radiation?

SELECTION RULES

- The multipole ℓ is related to the gamma angular momentum
 - the angular momentum must be conserved in gamma decay
- Possible ℓ : $|I_f - I_i| \leq \ell_\gamma \leq I_f + I_i$
- Parity: $(-1)^\ell$ for Electric and $(-1)^{\ell-1}$ for Magnetic: parity must be conserved, $\Pi_\gamma = \Pi_i \Pi_f$

Multipolarity	Angular Momentum l	Parity Π	Multipolarity	Angular Momentum l	Parity Π
M1	1	+	E1	1	-
M2	2	-	E2	2	+
M3	3	+	E3	3	-
M4	4	-	E4	4	+
M5	5	+	E5	5	-

WHICH TRANSITION?

- The lowest **permitted** multipole dominates
- Electric multipoles are more probable than the same magnetic multipole by a factor 100
$$\frac{\lambda(E\ell)}{\lambda(M\ell)} \approx 10^2$$
- Emission from the multipole $\ell+1$ is 10^{-5} times less probable than the ℓ -multipole emission

$$\frac{\lambda(E, \ell + 1)}{\lambda(E\ell)} \approx 10^{-5}, \quad \frac{\lambda(M, \ell + 1)}{\lambda(M\ell)} \approx 10^{-5}$$

WHICH TRANSITION?

- Combining the two rules:

$$\frac{\lambda(E, l + 1)}{\lambda(Ml)} \approx 10^{-3}, \quad \frac{\lambda(M, l + 1)}{\lambda(El)} \approx 10^{-7}$$

- Thus E2 competes with M1
- But M2 does not compete with E1

INTERNAL CONVERSION

- In some cases energy is not released in the form of gamma photons, but carried away by an electron:



- This process is called Internal Conversion
- It is the only process possible, when selection rules do not allow any of the multipole transitions:
 - e.g. even-even nuclides, decay from a 0^+ level
 - the photon cannot have zero angular momentum.

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