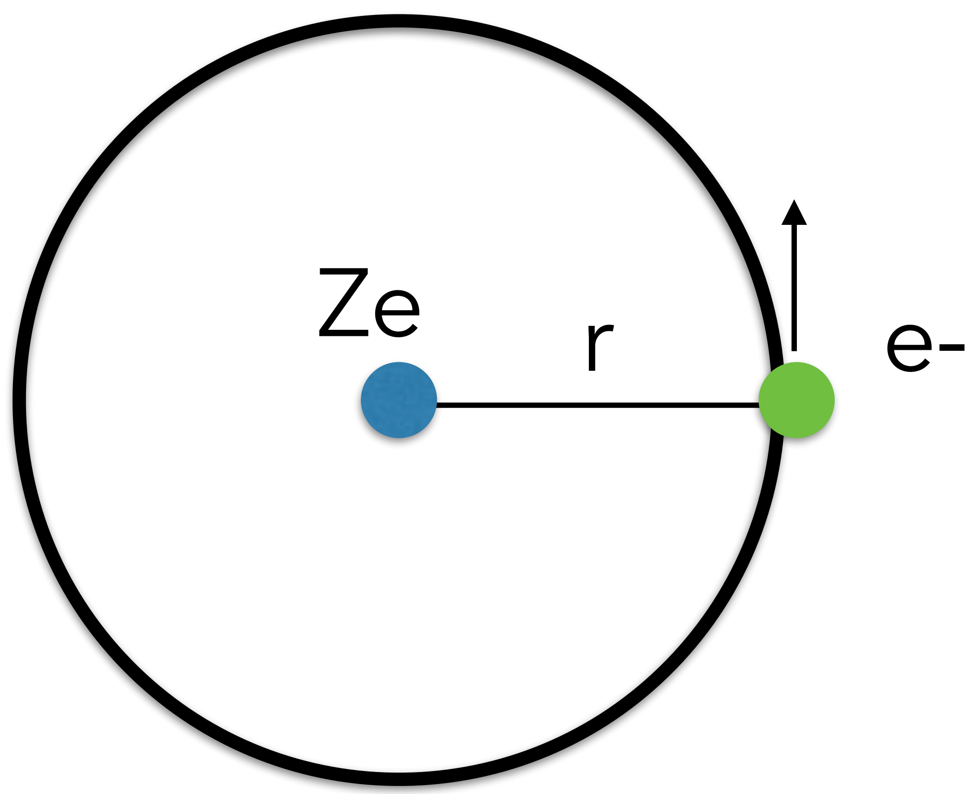
Physics 224
The Interstellar Medium

- Order of Magnitude Energy Levels
- Basics of Proposal Writing
- Scientific Presentation Skills

Order of Magnitude Energy Levels

Classical non-relativistic atom



First "allowed transitions"

Coulomb interactions between e- and nucleus

Order of Magnitude Energy Levels

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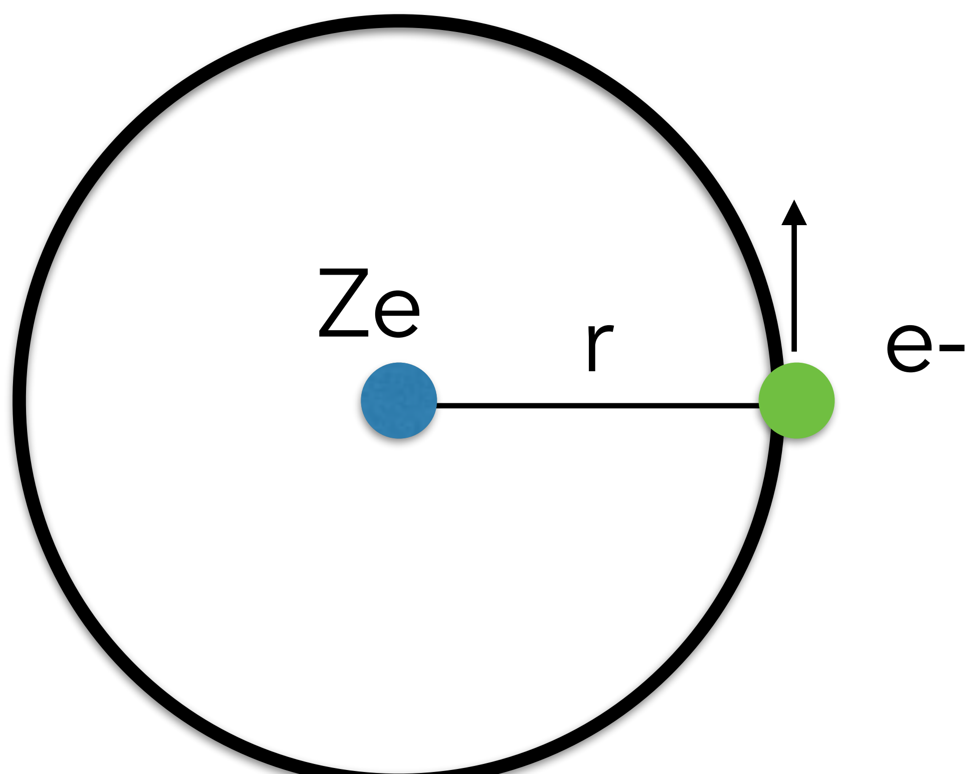

First "allowed transitions"

Coulomb interactions between e- and nucleus

$E \sim 13.6 \text{ eV} (Z^2/n^2)$

Order of Magnitude Energy Levels

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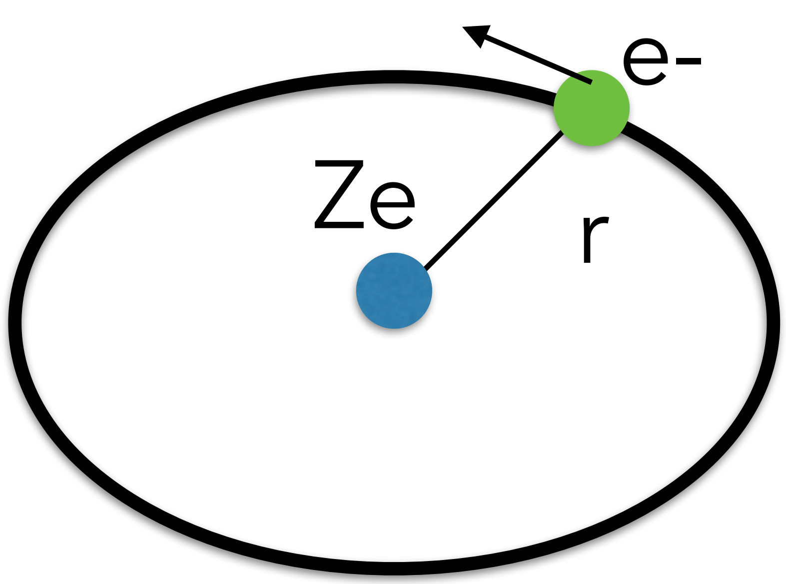
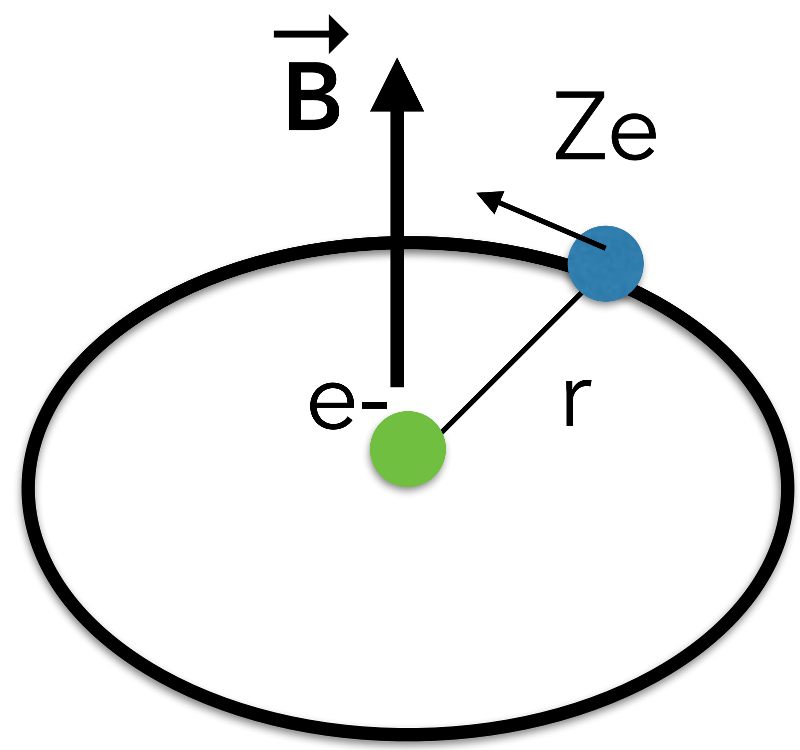


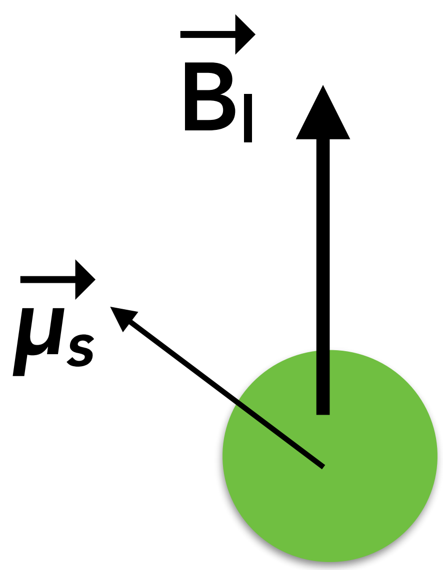
from nucleus's point of view



from e- point of view
orbiting proton generates B-field

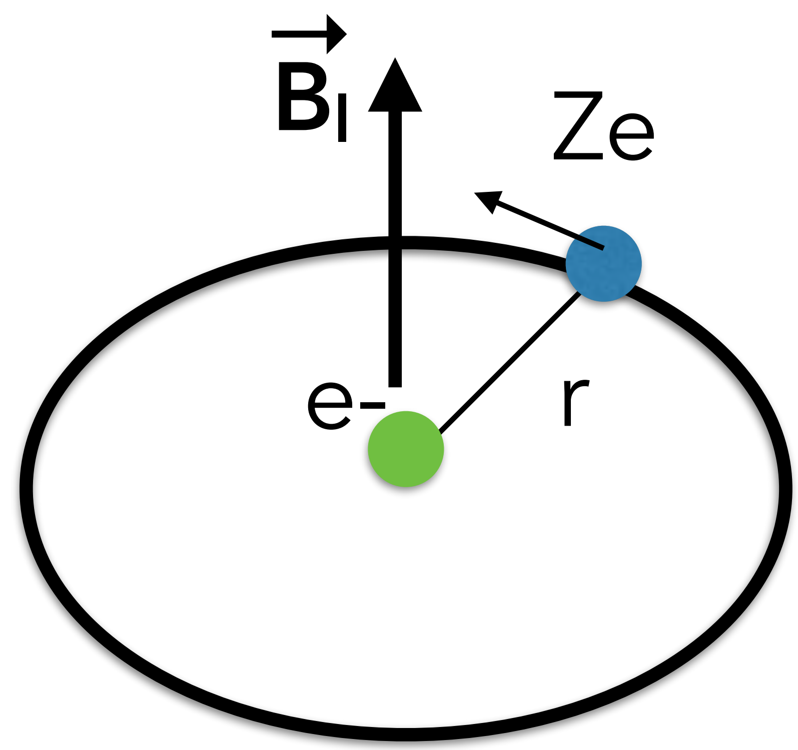
Order of Magnitude Energy Levels

Classical non-relativistic atom



spin magnetic moment of electron interacts with orbit B-field

Spin-Orbit coupling!



from e- point of view orbiting proton generates B-field

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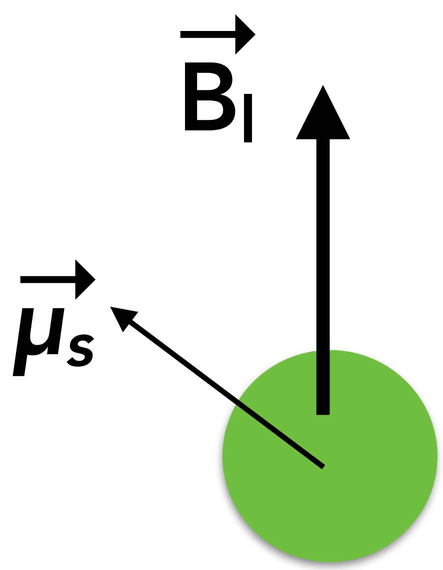


spin magnetic moment of electron interacts with orbit B-field

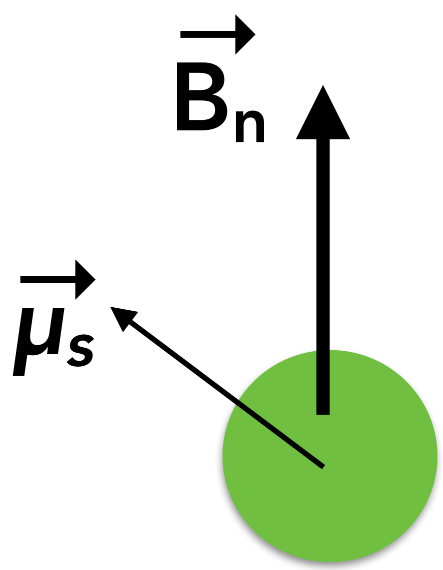
"fine structure" transitions

interaction between spin and angular momentum of e-

$E \sim 13.6\ \text{eV}\ (\alpha^2 Z^4/n^5)$

Order of Magnitude Energy Levels

Classical non-relativistic atom



spin magnetic moment of electron interacts with B-field from nuclear spin

"hyperfine structure" transitions

interaction between magnetic moments of nucleus and e-

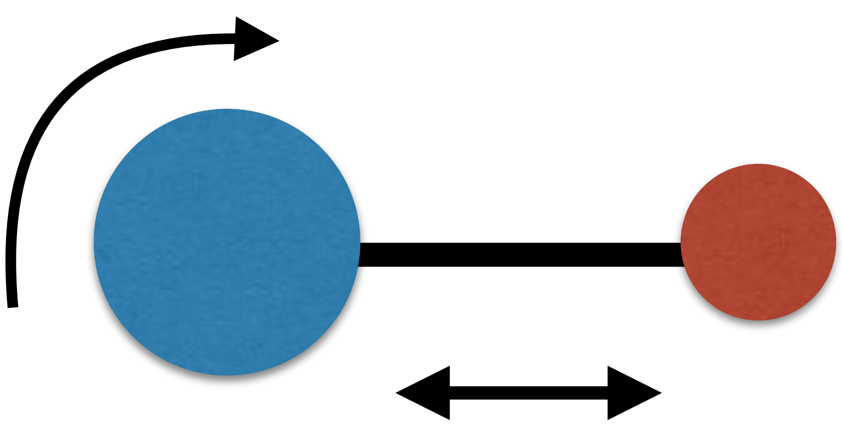
$E \sim 13.6\text{ eV}\,(m_e/m_n)(\alpha^2 Z^4/n^5)$

Order of Magnitude Energy Levels

"Allowed" Electric Dipole	$E \sim 13.6$ eV (Z^2/n^2)
"Forbidden" Fine Structure	$E \sim 13.6$ eV $(\alpha^2 Z^4/n^5)$
"Forbidden" Hyperfine Structure	$E \sim 13.6$ eV $(m_e/m_n)(\alpha^2 Z^4/n^5)$

Order of Magnitude Molecular Energy Levels

Cover diatomic molecules, read Draine ch 5 for more detailed info.



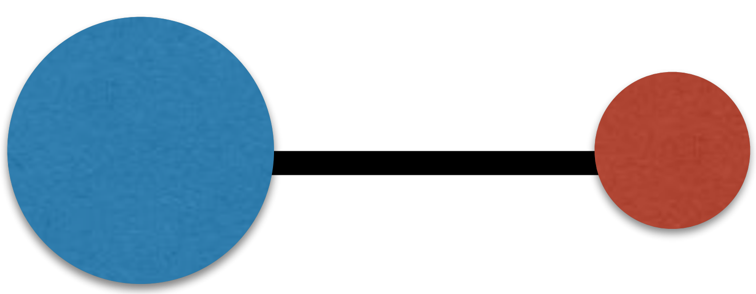
1) Electronic Transitions of e-

2) Rotational Transitions

3) Vibrational Transitions

Order of Magnitude
Molecular Energy Levels

Typical energies

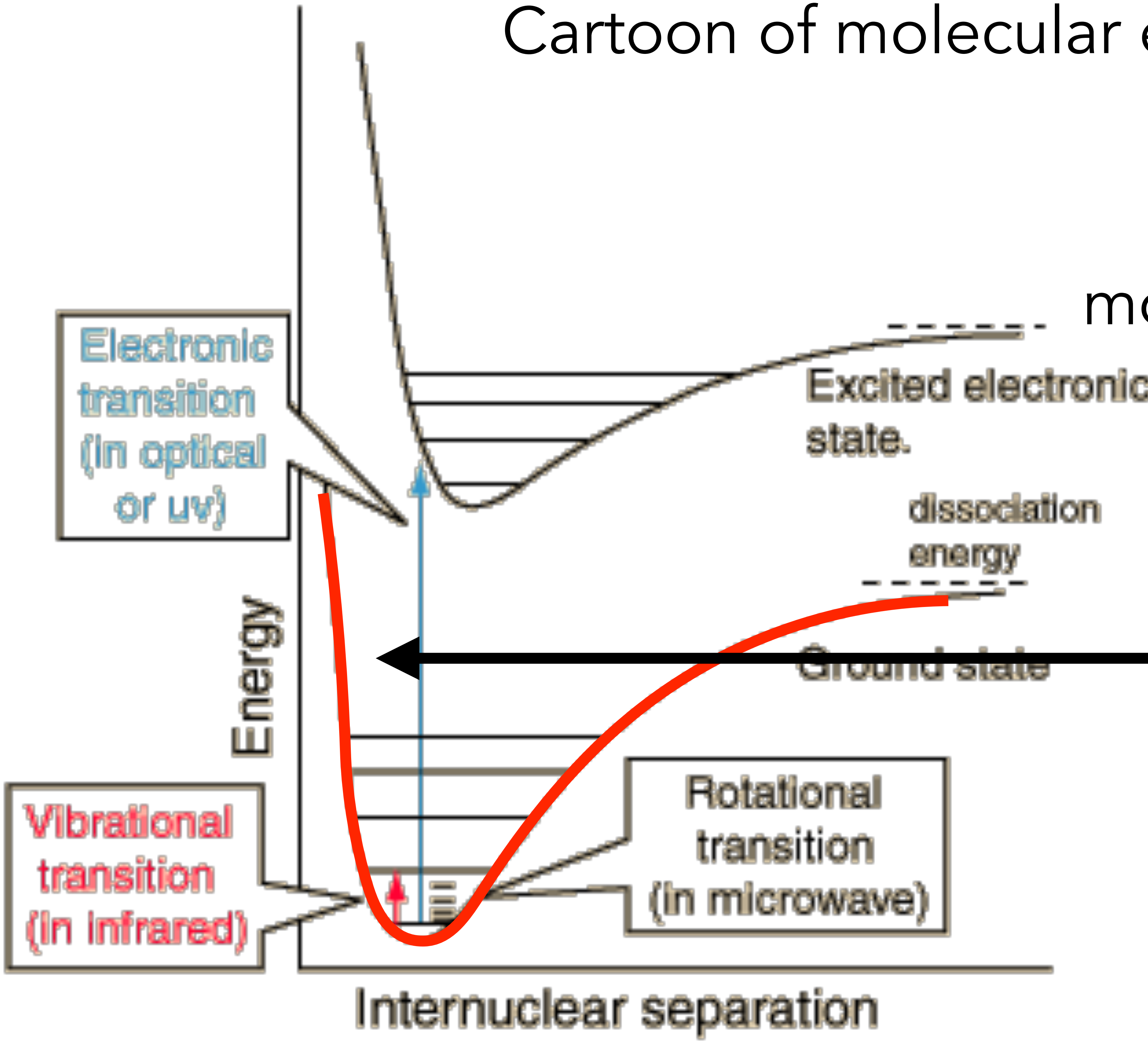


$$E \sim E_{rot} + E_{vib} + E_{el}$$

10^{-3}-10^{-2} eV 10^{-2}-10^{-1} eV   1-10 eV

Electrons move much more quickly than nuclei so for rotation/vibration calculations we can average over the electron transitions (Born-Oppenheimer approximation)

Cartoon of molecular energy levels

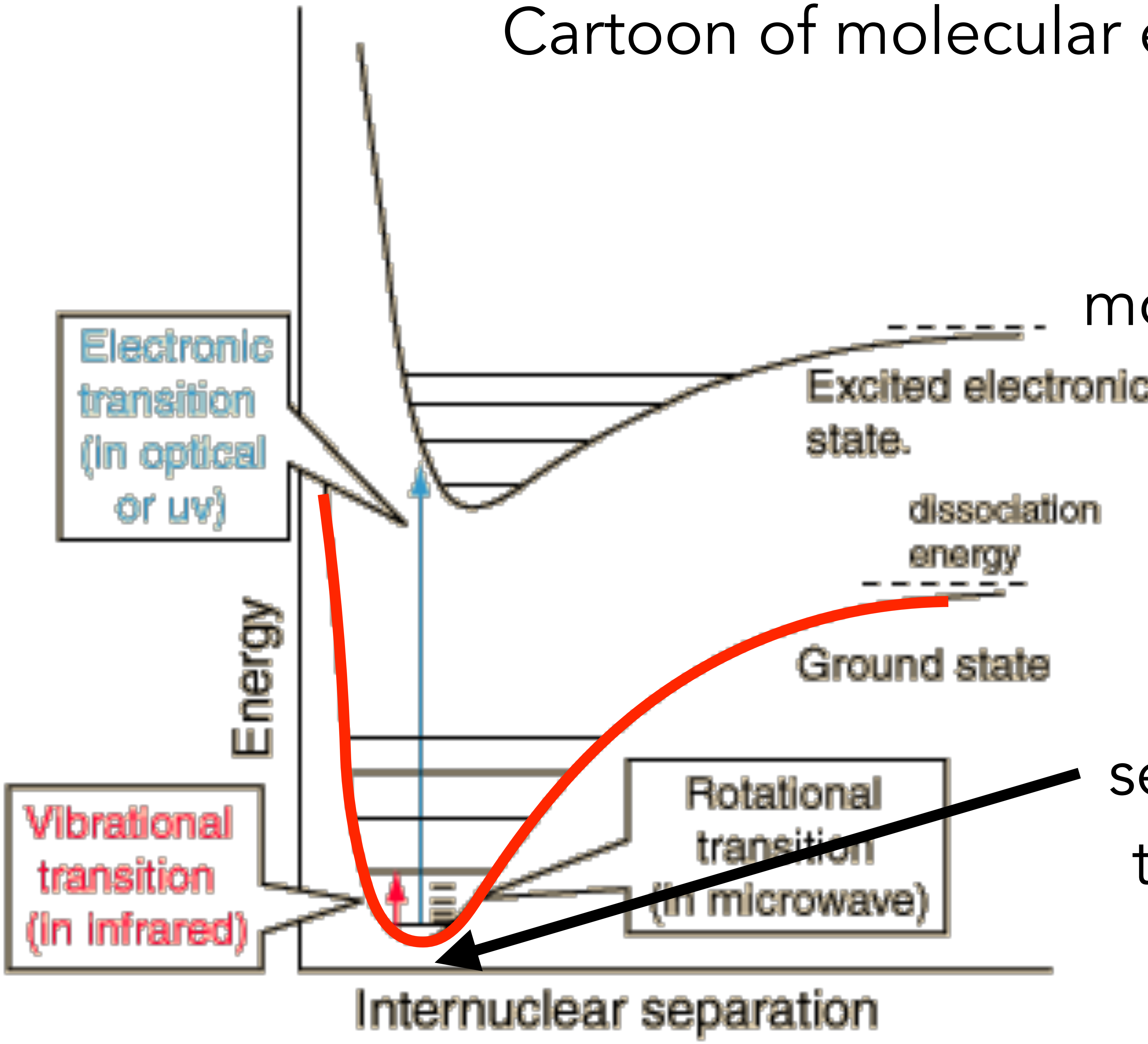


Basic structure of molecule sets this curve

If nuclei get too close together the repel each other, so energy required to make to get R->0 is large.

http://hyperphysics.phy-astr.gsu.edu/hbase/molecule/molec.html

Cartoon of molecular energy levels

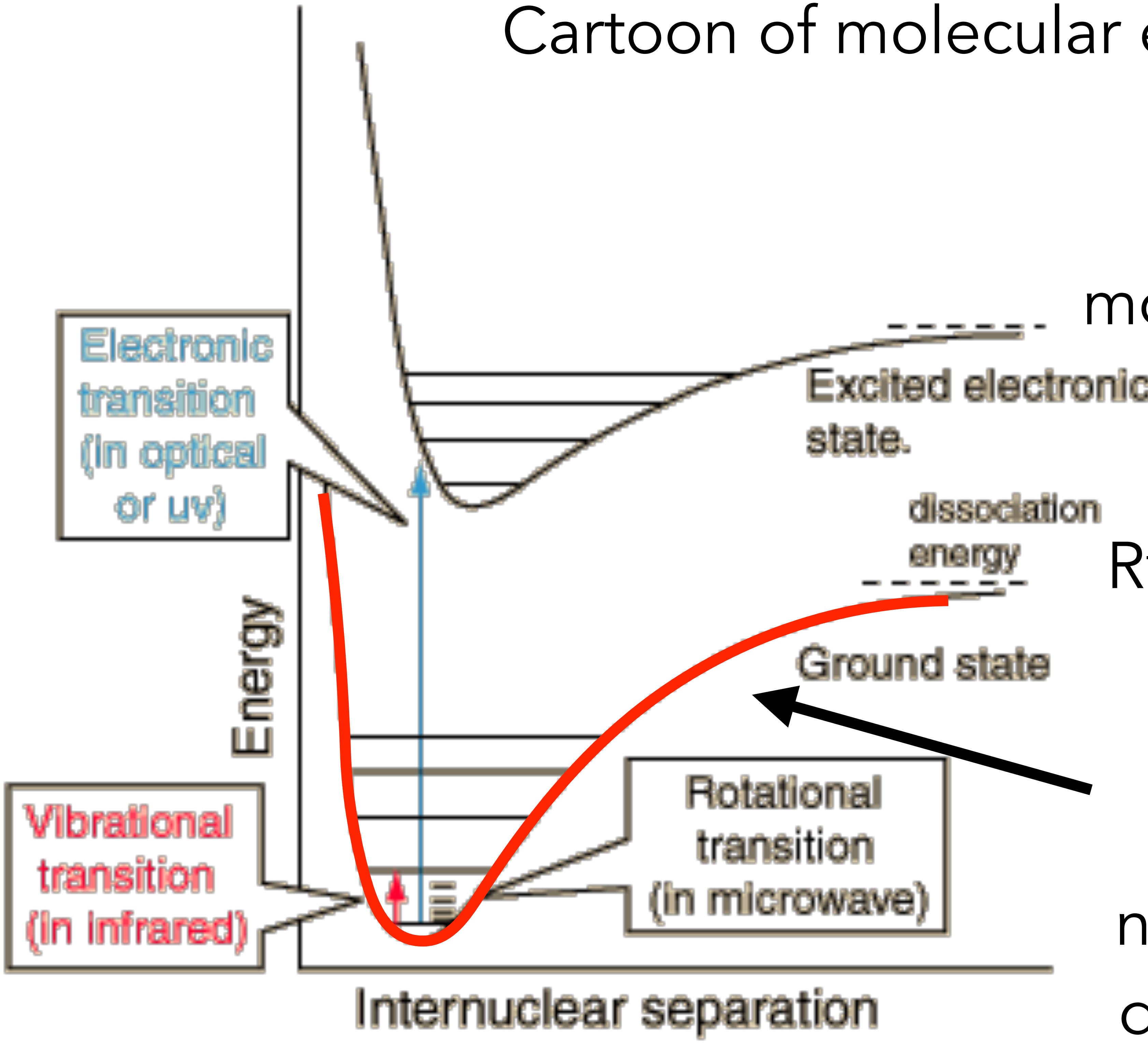


Basic structure of molecule sets this curve

Minimum separation set by the properties of the specific molecular bond.

http://hyperphysics.phy-astr.gsu.edu/hbase/molecule/molec.html

Cartoon of molecular energy levels

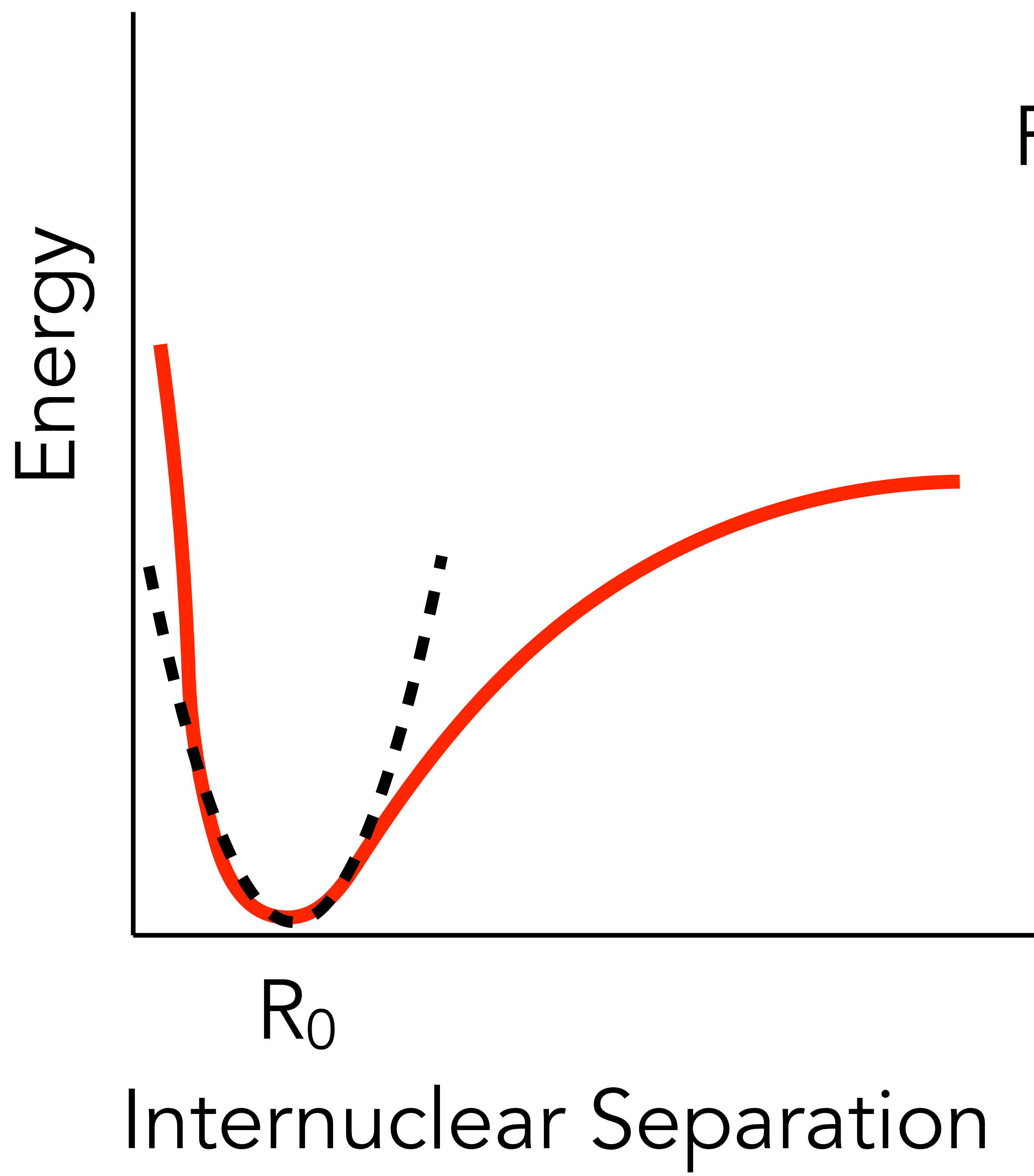


Basic structure of molecule sets this curve

R^{-6} long range attraction from van der Waal's force (fluctuations in electric dipole in one nucleus induces electric dipole in other nucleus)

http://hyperphysics.phy-astr.gsu.edu/hbase/molecule/molec.html

Can be approximated as a simple harmonic oscillator around R_0



Potential energy:

$$V(r) = V(R_0) + 1/2\ k\ (r - R_0)^2$$

k = “spring constant” related to molecular bond

Fundamental Frequency of oscillator:

$$\omega = (k/m_r)^2$$

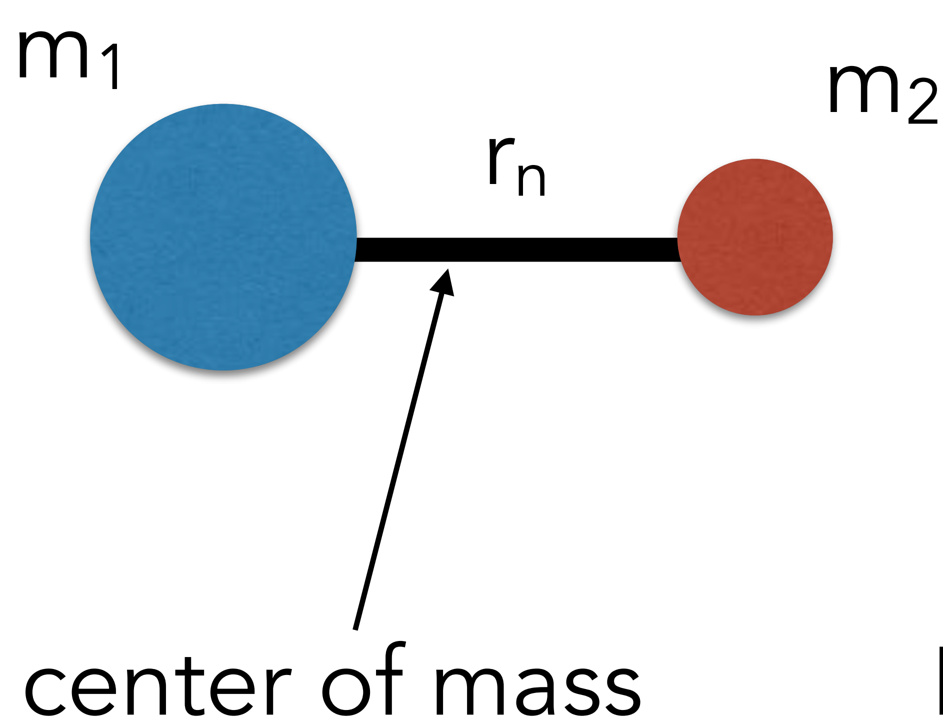
$$m_r = m_1 m_2/(m_1+m_2)$$

Vibrational Energy Levels:

$$E_{vib} = \hbar\omega(v + 1/2)$$

v = vibrational quantum number

Rotational Transitions



Moment of intertia:

$$I = m_r\, r_n^2$$

Rotational Energy Levels:

$$E_{rot} = \frac{J(J+1)\hbar^2}{2m_r\, r_n^2}$$

J = rotational quantum number

reduced mass:

$$m_r = m_1 m_2/(m_1+m_2)$$

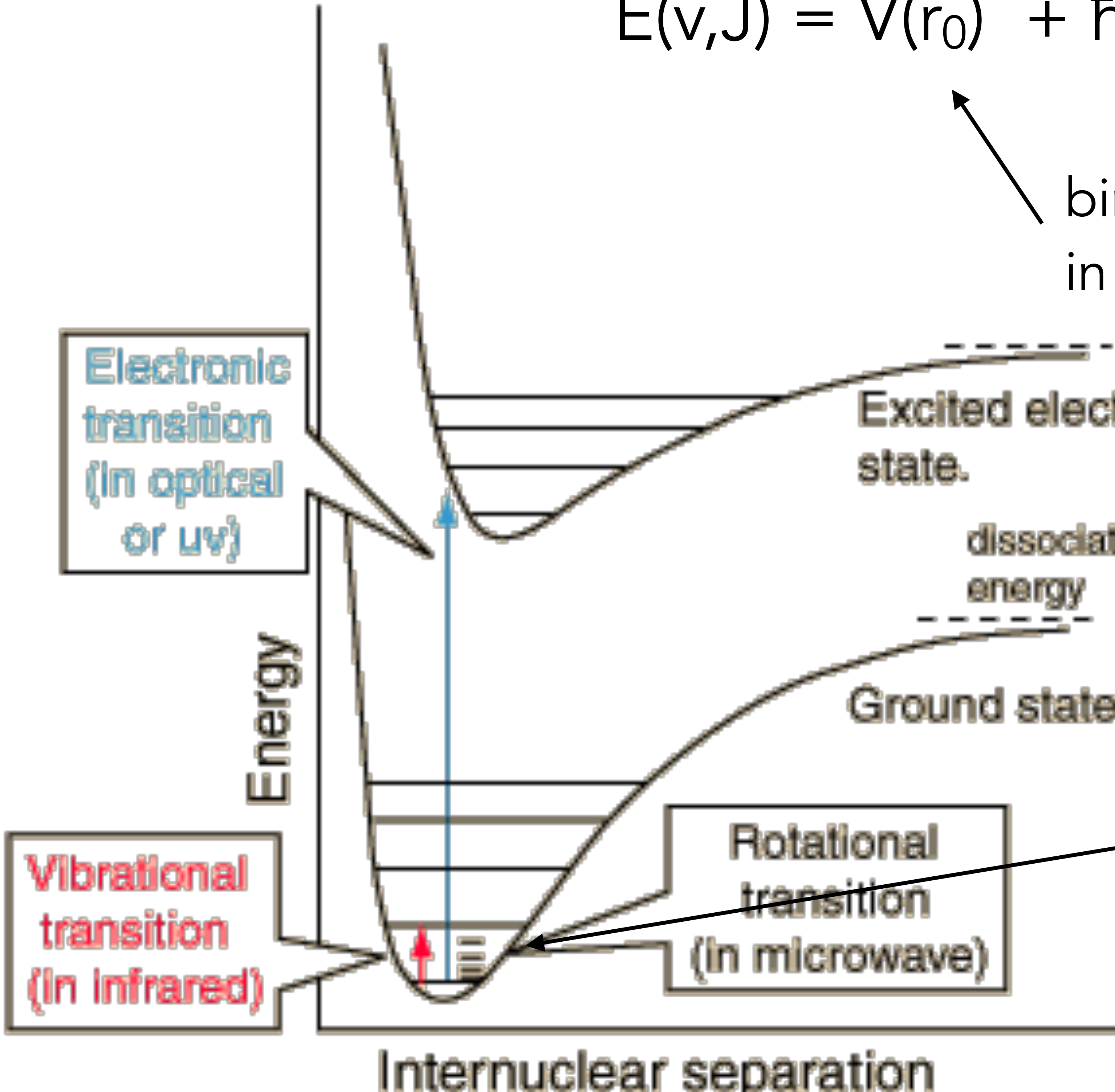
Define $B_v = \dfrac{\hbar^2}{2m_r\, r_n^2} = 2.1 \times 10^{-3}\, (m_H/m_r)\, (1\ \text{Å}/r_n)^2$ eV

"rotational constant"

Total Energy:

$$E(v,J) = V(r_0) + \hbar\omega(v + 1/2) + B_v J(J+1)$$

binding energy in ground state

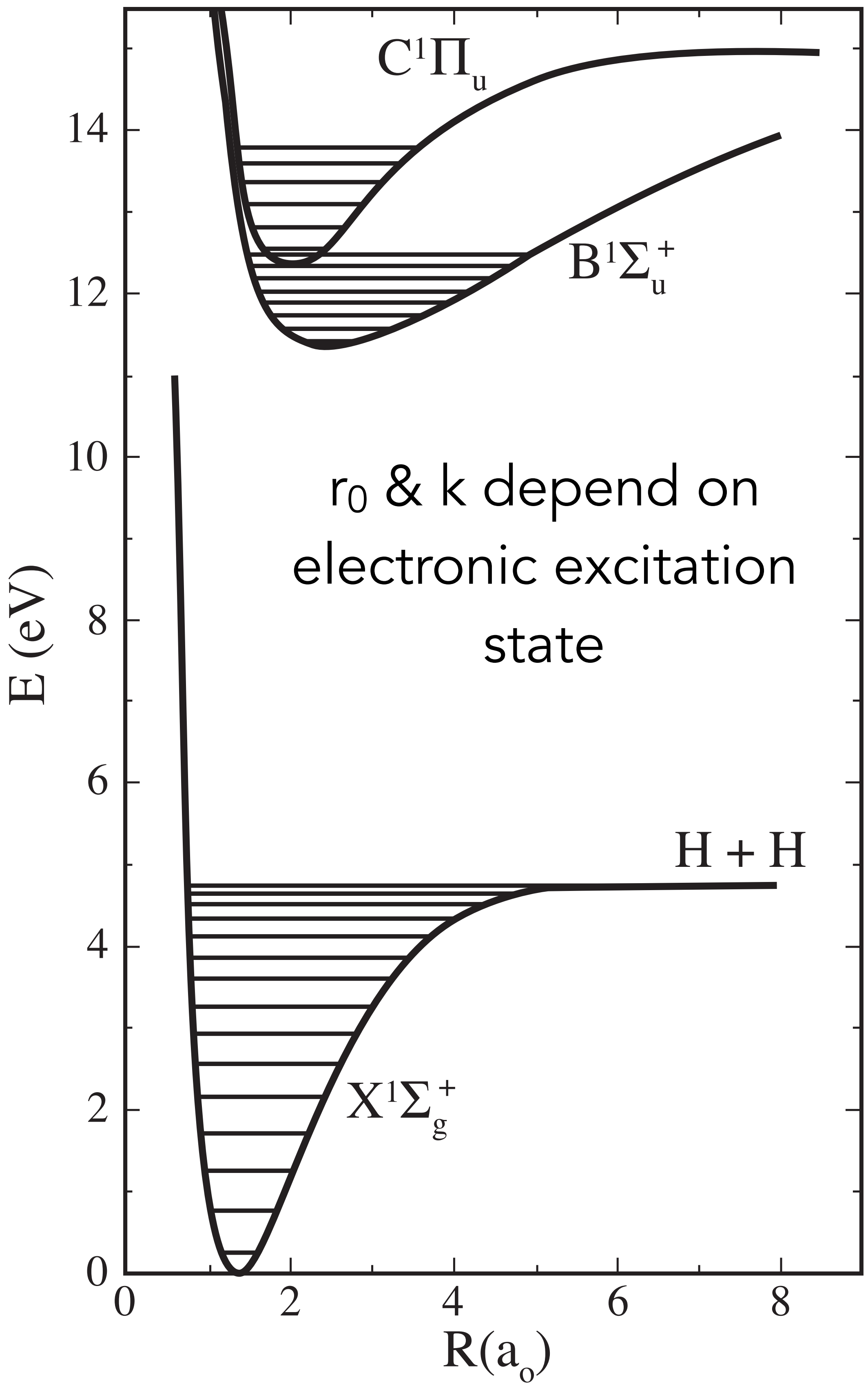


Generally:

$\hbar\omega >> B_v$

so rotational levels are more closely spaced in energy

http://hyperphysics.phy-astr.gsu.edu/hbase/molecule/molec.html



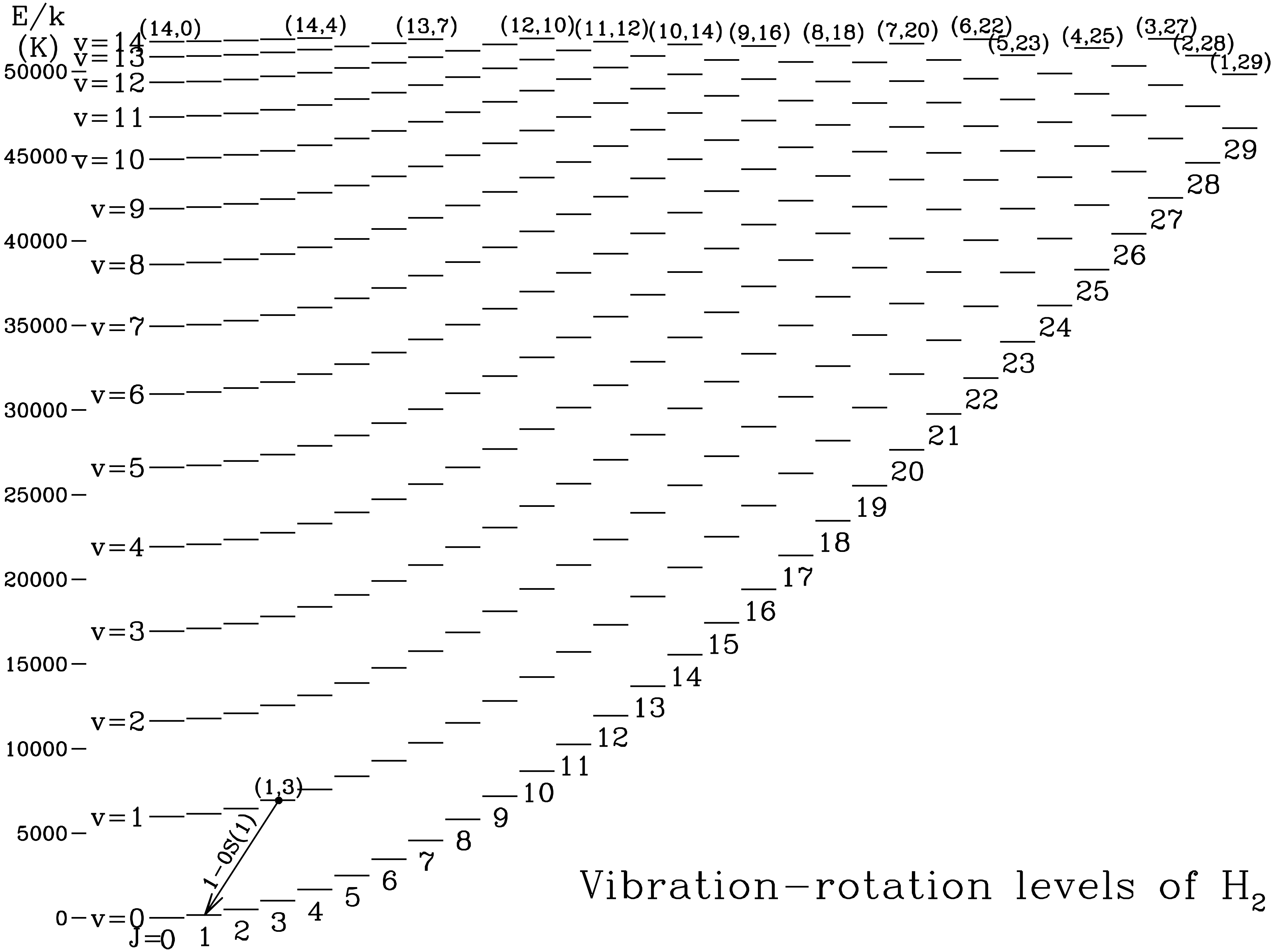
r_0 & k depend on electronic excitation state

H_2 Molecule

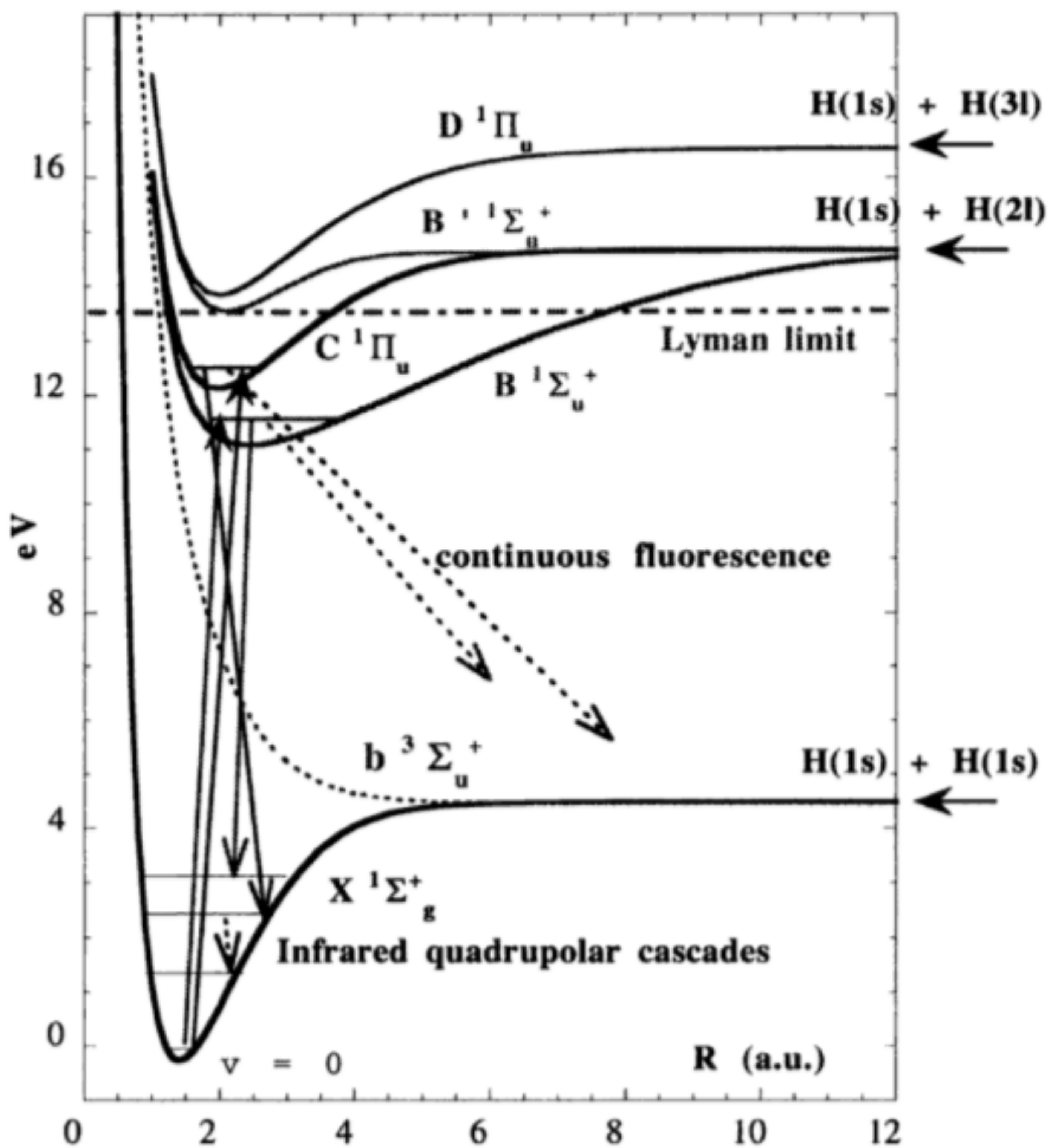
Additional wrinkle for H_2: protons, like electrons, can't share same quantum state

If total proton spin is 1, rotational number J must be even.
-> "para-H_2" J=0,2,4…

If total proton spin is 0 rotational number J must be odd.
-> "ortho-H_2" J=1,3,5…



Only ΔJ = 0, ±2 are possible to stay para-para or ortho-ortho



Combes & Pineau des-Forets 2000

Lots of interesting ways for H_2 to de-excite after getting into an electronic excited level.

Some involve dissociating some involve rotational cascades.

Will come back to H_2 when we get to molecular gas.

Proposals!

A Skill You Will Need: Writing Competitive Proposals

Type of Proposal	Approximate Acceptance Rate
Hubble Space Telescope	18% (Cycle 23)
NOAO Kitt Peak	40%
NSF Astronomy Grants	10%
Atacama Large Millimeter Array	23% (Cycle 3)
NASA Astrophysics Theory	15% (2014)
NASA Astrophysics Data Analysis	17% (2013+2014)

A Proposal is Persuasive Writing

In a proposal you need to *argue* for why you get the resources instead of all the other people who want them.

We often don't think of science writing as "persuasive" - why is that?

Proposals are different types of writing than scientific papers.

Paper: "Here is what we have learned."
Proposal: "Here is what we *want* to learn & why it is important."

A Proposal is Persuasive Writing

There are limited resources -
how do we decide who gets them?

Solicit proposals
Peer review of proposals
Allocation of resources

There is far more interesting science to be done then there are resources.

Good proposals are rejected often.

What is a proposal?

from: http://blogs.discovermagazine.com/cosmicvariance/2012/01/24/unsolicited-advice-xiii-how-to-craft-a-well-argued-proposal/#.VwdJrccfzBs

A Proposal is a Highly Structured Rigorous Argument

In its most abstract form, a proposal is a piece of persuasive writing that lays out a convincing case that the proposed research is:

1. important
2. feasible
3. efficient

By "important", I mean that the project must rise above the level of "good to do", and instead be seen as "must be done", even by people who don't work in the field. By "feasible", I mean that there must be a clear path to a definitive scientific result. By "efficient", I mean that the particular approach you've taken is the optimal one for reaching the important goals you're targeting (i.e. aim for "Studying X provides the cleanest test of Important Science Y" and avoid building a proposal to study X when studying Z is clearly a more direct approach to Important Science Y — even if you worked on X for your thesis.)

advice from J. Dalcanton (PI of 858 orbit Hubble Treasury survey of M31)

What defines an "important" project?

There is no unit of "importance" - it is all relative.

What defines an “important” project?

There is no unit of “importance” - it is all relative.

- What is the big picture question that this proposal is working tow … f and wor …
- Is th … y of mak …
- Will this project make an impact outside of its specific field?
- Is the project going to move things forward or push the boundaries of our knowledge in its field?

The proposal needs to have in it *your* narrative of what is important and why the proposal fits that definition!

What defines an “important” project?

For the purpose of your proposal
your peers who are reviewing it decide
what is important.

One way to decide if your idea is “important” -
go explain it to a colleague and get their feedback.
“elevator pitch” for your idea

What does it mean to be "feasible"?

You need to lay out a clear path to meeting the goal or answering the question you are addressing.

Most proposals are suggesting to do something *new*
- how do you know new things are feasible?

- use techniques that have addressed similar problems before
- demonstrate past evidence of solving similar problems
- provide a clear roadmap identifying the obstacles & ways around them

What does it mean to be "feasible"?

You have not yet done the project, so there is no definitive proof it can be done, so you have to *convince* the reader of feasibility.

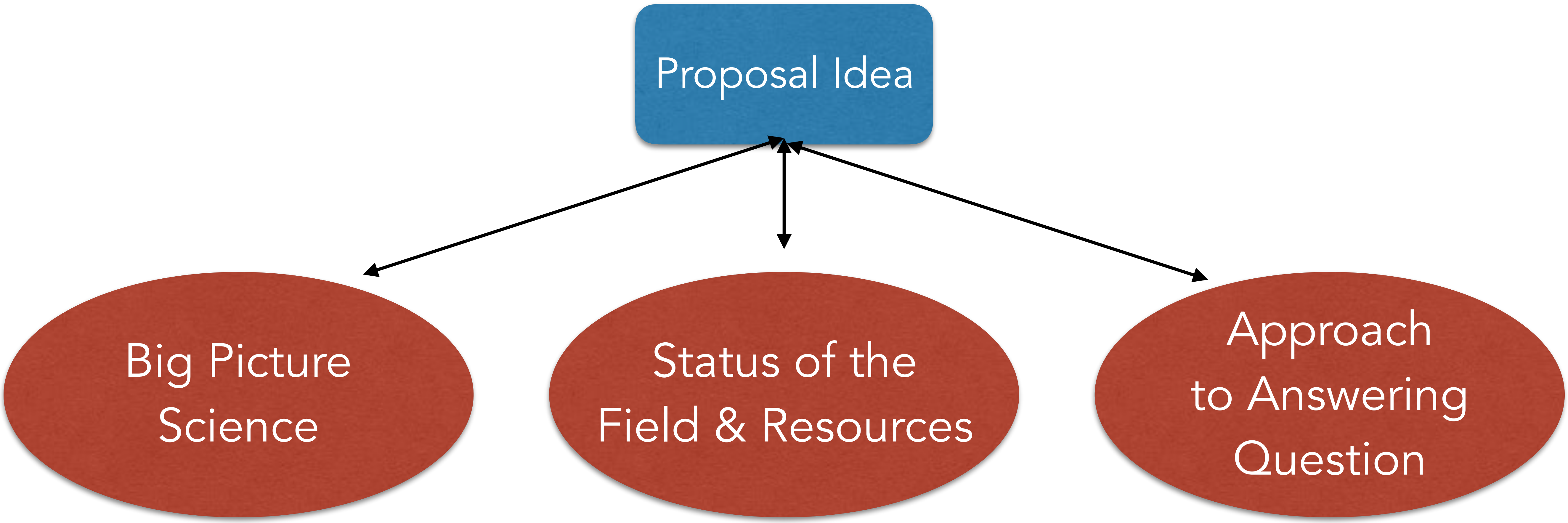
- Have a plan!!
- Be specific (explain needed measurements, calculations, resources, etc).
- If there are potential obstacles, explain how you will get around them.

What does it mean to be "efficient"?

- This is the optimal way to approach this problem.
- Now is the optimal time to do this research.

Resources are limited, many projects are both important and feasible. If the work can be done with resources that are less scarce than what you are proposing for, do that instead!

There isn't always an objective "optimal" way to do things - lead the reader to your definition of optimal.



Important

Efficient

Feasible

Before you start writing, outline each of these points.

"…proposals live or die not on the beauty of your prose, but on the structure of your argument."

from: "Unsolicited Advice XIII: How to Craft a Well-Argued Proposal"
blogs.discovermagazine.com/cosmicvariance/2012/01/24/unsolicited-advice-xiii-how-to-craft-a-well-argued-proposal/#.VwdJrccfzBs

Make things as easy as possible for the reviewer.

This is not their homework!! Don’t make them struggle.

You want your narrative to be easy for them to follow and easy for them to agree with.

Make things as easy as possible for the reviewer.

Aesthetics

- make things nice to look at
- don’t remove all the whitespace between sections
- make easy to read figures with clear captions, annotate them, remove unnecessary lines or points (powerpoint trickery),
- repeat structural elements (i.e. bold headings for sections),
- don’t overuse bold/italic fonts.

Make things as easy as possible for the reviewer.

Language

- avoid jargon as much as possible
- define your acronyms & don't use too many of them
- proofread thoroughly
- use simple, clear sentences

Make things as easy as possible for the reviewer.

Organization

- invest some time thinking about the logical structure of your proposal, make sure it is sound
- lead with the important stuff, this applies to the whole proposal, to sections, to paragraphs and to sentences (organize like: “this is important, here is evidence why” instead of “here is evidence, therefore this is important”)
- give only as much detail as you need to make the case (too much is confusing and also opens you up to unnecessary critiques if reviewer disagrees with some particular piece of evidence)

Where does persuasive become unscientific?

This is a question worth thinking about!

What goes into a proposal?

- Title
- Abstract
- Scientific Justification
- Technical Justification (varies depending on type of proposal)
- Figures
- Bibliography

An Abstract Recipe

- Start with one or two facts
- Explain why these facts are important
- State your goal
- Introduce the problem
- Explain why what you are proposing will solve it (strategy/instrument)
- Explain the broader implications of your results

Advice based on Gurtina Besla's Astro 520 class at Arizona

Example GO Program: Proper Motion Field Along the Magellanic Bridge

Abstract

Facts	Our HST proper motion (PM) measurements of the LMC and SMC have revolutionized our understanding of the Magellanic System, and have spurred new research on its use as a cosmological probe of galaxy formation. The PMs imply that the Magellanic Clouds are likely on their first infall towards the Milky Way (MW).
Importance	The disturbed nature of the Magellanic System is therefore likely due to the LMC-SMC interaction, and not to the MW influence. This has emphasized the importance of dwarf galaxy interactions for galaxy evolution.
Goal	The Clouds are connected by a complex of gas and stars called the Magellanic Bridge. We propose to map the stellar PM field of the Bridge, similar to our prior HST mapping of the LMC PM rotation field.
Problem	Our state-of-the-art N-body simulations show that the PM field will tightly constrain the impact parameter of LMC-SMC orbit at its last pericenter 100-300 Myr ago, which is the main uncertainty in our understanding of the LMC/SMC interaction history. This will test whether the tidal debris between the galaxies is due to a recent direct-hit collision. It will also test models in which the tidal debris is responsible for the observed microlensing events.
HST Strategy	We will observe once 3 fields for which first-epoch archival data already exists, and observe twice 5 other fields over a 2-cycle time baseline. With the established data reduction techniques of our successful HSTPROMO collaboration, this will yield PM accuracies of 10-25 km/s per field, well below the 130 km/s velocity difference between the Clouds.
Broader Impacts	This will yield the best constraints to date on the LMC/SMC interaction, and will further test the importance of dwarf-dwarf interactions for galaxy evolution.

Your Proposal To-do's

- Start a list of interesting topics you might want to write about.
- Think about what sort of proposal you are most interested in learning about: observing, archival research, theory, supercomputing, funding, instrumentation, etc.
- Settle on a topic/proposal type combination by late April/early May.
- Start reading some literature on the topic - review articles are a good place to start.
- Put together a bibliography of relevant literature.
- May 7: abstract & bibliography deadline (so I can give you feedback)

Presentations!

Your Goals & Your Audience

- Who are you speaking to?
- What do you want your audience to learn?
- What is the storyline of your talk?
- What visuals do you need to convey your message?

Plan all of this before you start making slides!

Similar to proposal: make following your path
easy for the audience.

Paper Presentation

You will be expected to read the paper and put together a ~15 minute presentation about it that highlights:

- big picture context of the paper
- technical approach
- key findings
- impact on subsequent work in the field (cite a recent paper that builds on this work)

Paper Presentation

1) who are you speaking to?

Your classmates.

Paper Presentation

2) what do you want your audience to learn?

- the important findings of the paper
- the big picture view of the field & why this paper made an impact

Paper Presentation

3) what is the storyline of your talk?
4) what visuals do you need?

This is up to you!

Paper Presentation

	Needs Work				Excellent
Presentation	**1**	**2**	**3**	**4**	**5**

(Was the verbal presentation clear and concise? Were the visuals helpful to the presentation and clear? Were questions handled well?)

Content	**1**	**2**	**3**	**4**	**5**

(Is the big picture context of the paper discussed? Did you learn something from the presentation? Were the implications of the research on the state of the field discussed?)

Knowledge	**1**	**2**	**3**	**4**	**5**

(Did the presenter have a strong understanding of the topic and material presented? (Shown primarily through the presentation and the handling of questions.))

Organization and Originality	**1**	**2**	**3**	**4**	**5**

(Did the presentation flow smoothly and was the timing about right? Was the presentation particularly original (i.e., it didn't come across as a standard paper review) and well organized?