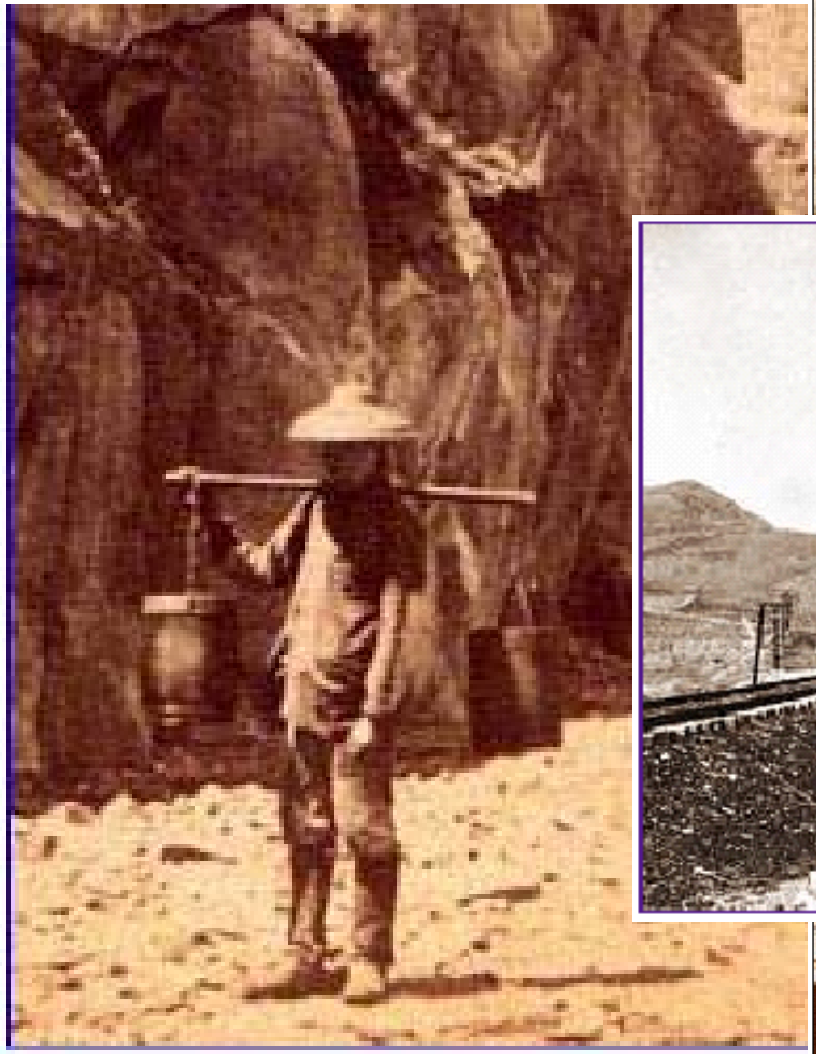
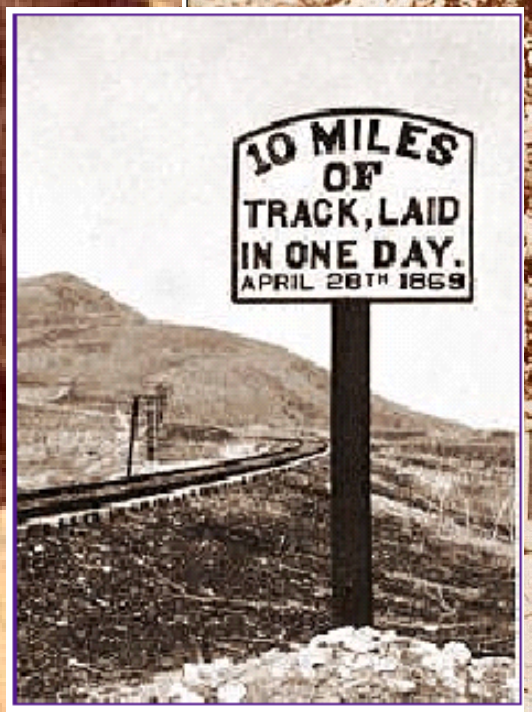
Intentionally Blank




10 MILES
OF
TRACK, LAID
IN ONE DAY.
APRIL 28TH 1869

Xue Yuyang

Yao Ming

Whither Superconductivity?

Road to Room Temperature Superconductivity, June 2007, Loen, Norway
http://www.w2agz.com/rtsc07.htm

Road to Room Temperature Superconductivity

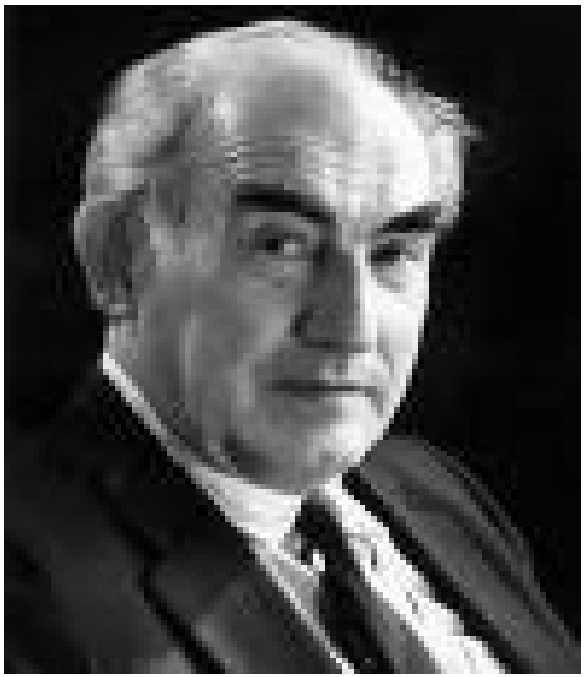
17-23 June 2007, Hotel Alexandra, Loen, Norway
AFOSR, Twente, Trondheim, HKUST

http://www.srudesigns.com/road2rts/

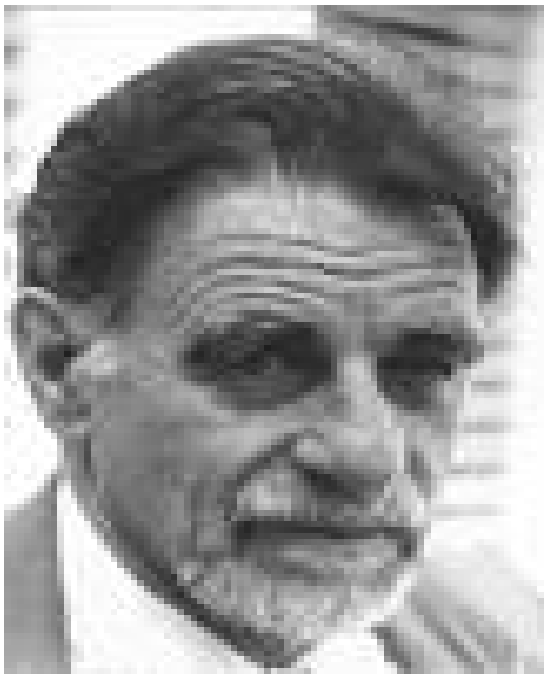
http://www.w2agz.com/rtsc07.htm

Chu	Varma	Cohen	Bosovic	Kivelson
Kresin	Mannhart	Scalapino	Beasley	Antipov
Akimitsu	Gurevich	Fischer	Pavuna	Hasuo
Ashcroft	Rice	Shimizu	Geballe	Uchida
Sudbo	Klemm	Zakhidov	Raveau	Grant

Superconductivity
The Day Before Yesterday – Yesterday – Today - Tomorrow



Vitaly Lazarevich Ginzburg



Karl Alexander Mueller

"Best wishes, and hang in there, Guys !"

Exactly What is a "Superconductor?"

- Does it have to be a "perfect conductor?"
  - i.e., zero TAFF
- Does it have to exclude flux (Meissner)?
- Or does it only need to be a "real good conductor ("ultraconductor")?"
  - 200x σ Cu @ 300 K @ 1000 Hz
    - Ballistic CNTs
    - Sliding P-F CDWs
    - Charged Solitons
    - ???

“From Rags to Riches”

The Road to Room-Temperature Superconductivity

For Fame:

- T_c = 300 K
- no layered cuprate

Thanks, Jochen !

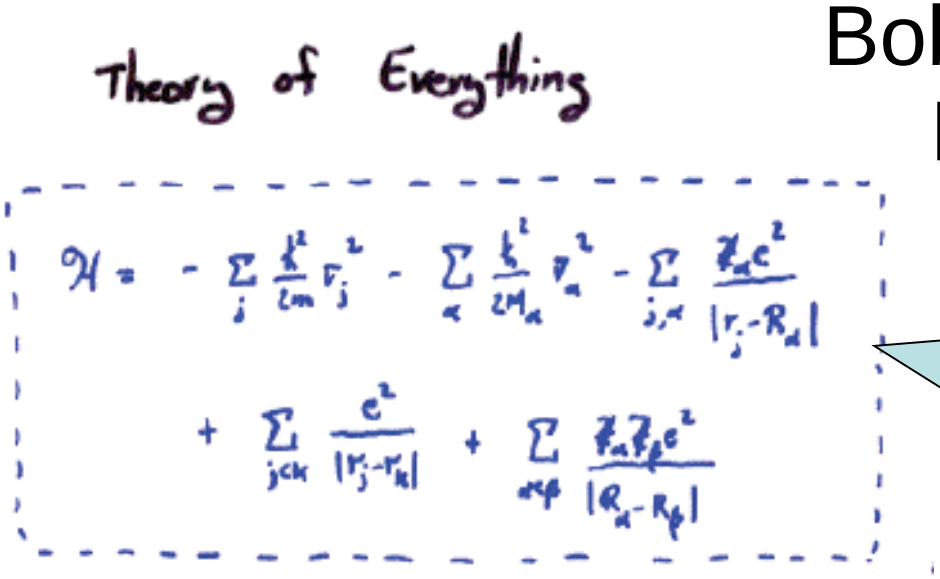
For Fortune:

- T_c > 500 K
- J_e (350 K) > 10^4 A/cm^2 in 5 T
- ductile, robust, good thermal properties
- good Josephson junctions
- environmentally friendly compound
- available in large quantities
- < 20 € kA/m

Guidance from Our Elders

- *“Don’t listen to theoreticians”* (B. Matthias, ca. 1970s).
- *“To make a long story short, searches for high-temperature superconductors, especially with the existing obscurities in the area of theory, may lead to unexpected results and discoveries”* (V. L. Ginzburg, 1984).
- *“At the extreme forefront of research in superconductivity is the empirical search for new materials”* (M. R. Beasley (1983), as communicated by K. A. Mueller and J. G. Bednorz, (1986)).
- “*If you find an old metal laying around in the literature, try cooling it down,”* (P. M. Grant, 1976).

Bob Laughlin's "Theory of Everything" (that matters)



- Hydrogen atom
- Methane molecule
- water
- Air
- Rocks
- Concrete
- Steel
- Glass
- Plastic
- Buildings
- Cities
- Continents

- Proteins
- DNA
- Viruses
- Bacteria
- Yeast
- Slime mold
- Butterflies
- Sharks
- Rats
- Lawyers
- Ebola virus
- Legislatures
- Civilizations

- Flowers
- Trees
- Cows
- Cheese
- Sauce Bernais
- Computers
- Television
- Cars
- Jets
- Lawnmowers
- Sewage
- Spotted Owls
- ...

Where's spin, Pauli and Darwin? Ya screwed up, Bob…should'a used the many body Dirac equation! Oh yeah, and maybe Maxwell, Boltzman and Gibbs, too…and Newton's Apple.

The crunch comes when Σ_i with i >= 3 -> "thermodynamic limit."

"Size Matters !"

"Naked BCS"

$$T_C = a\Theta e^{-\frac{1}{\lambda - \mu^*}}$$

$$\lambda k\Theta \ll E_F$$

Where

Tc = Critical Temperature

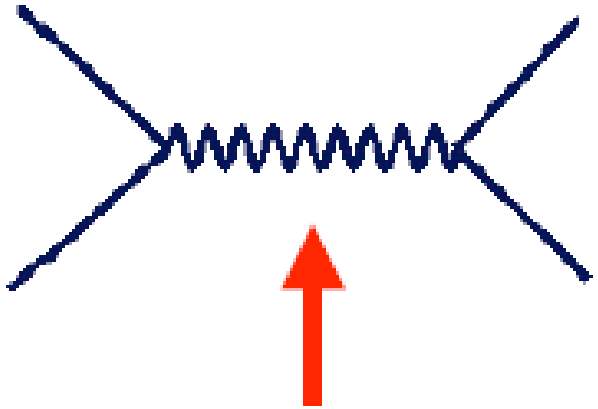
Θ = Boson Characteristic Temperature

λ = Fermion-Boson Coupling Constant

μ^* = Fermion-Fermion Repulsion

a = "Gap Parameter, ~ 1-3"

When “electron-electron” interactions are involved,
the phrase “pairing glue” can be a dirty word!



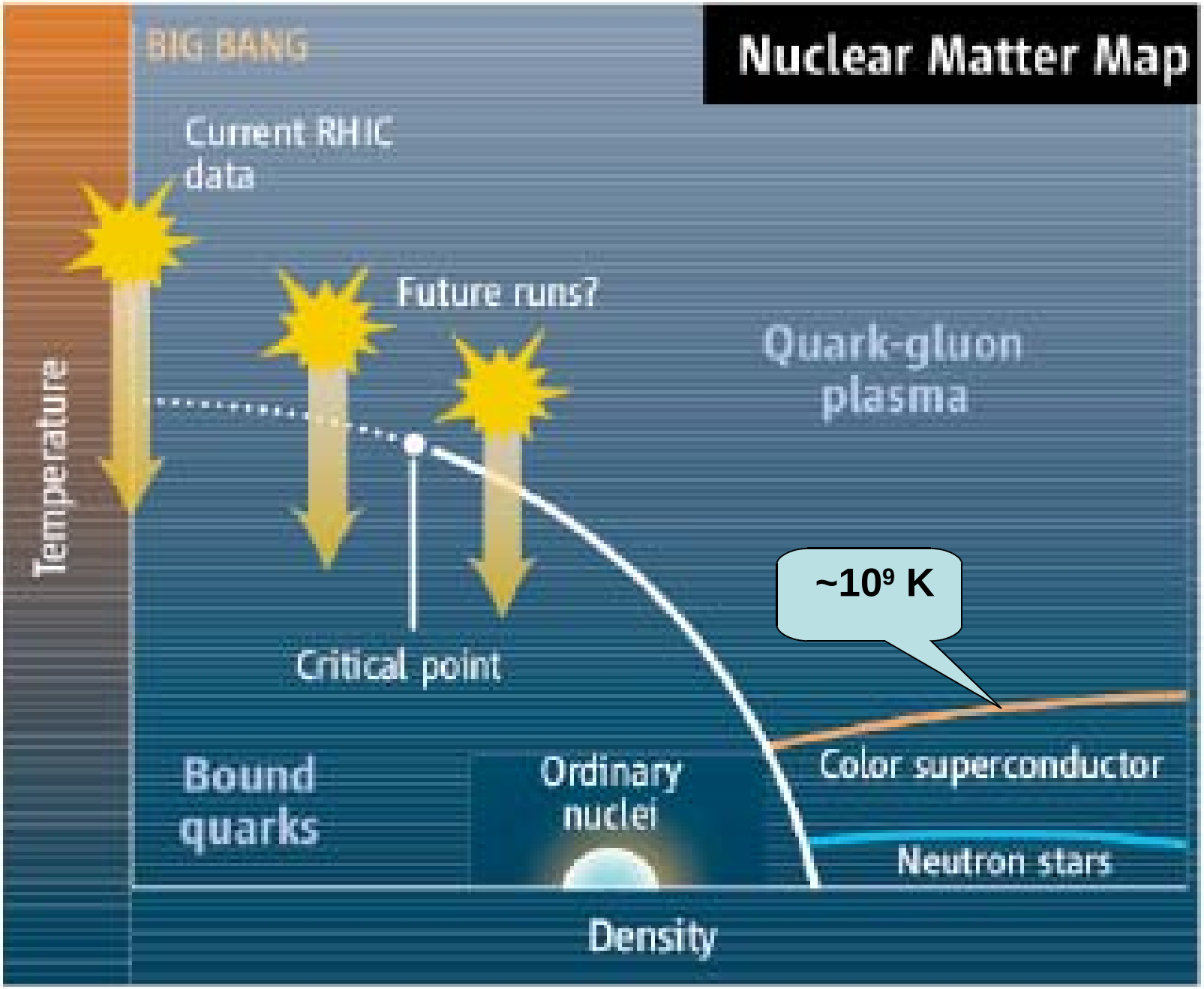
Insert your favorite “on” here

(phonon, magnon, exciton, plasmon, anyon, moron …)

“Put-on !”

Mike Norman, Alexandria, VA 2006

Really High-Tc



Electron-Phonon Coupling a la Migdal-Eliashberg-McMillan

(plus Allen & Dynes)

$$H_{el-ph} = \sum_{\mathbf{k}\mathbf{q}\nu} g^{\mathbf{q}\nu,mn}_{\mathbf{k}+\mathbf{q},\mathbf{k}}\, c^{\dagger m}_{\mathbf{k}+\mathbf{q}} c^{n}_{\mathbf{k}}\, (b^{\dagger}_{-\mathbf{q}\nu} + b_{\mathbf{q}\nu}) \qquad (1)$$

First compute this via DFT…

$$\alpha^2 F(\omega) = \frac{1}{N(\varepsilon_F)} \sum_{mn} \sum_{\mathbf{q}\nu} \delta(\omega - \omega_{\mathbf{q}\nu}) \sum_{\mathbf{k}} |g^{\mathbf{q}\nu,mn}_{\mathbf{k}+\mathbf{q},\mathbf{k}}|^2$$
$$\times \delta(\varepsilon_{\mathbf{k}+\mathbf{q},m} - \varepsilon_F)\delta(\varepsilon_{\mathbf{k},n} - \varepsilon_F), \qquad (2)$$

$$\lambda = 2\int \frac{\alpha^2 F(\omega)}{\omega} d\omega = \sum_{\mathbf{q}\nu} \lambda_{\mathbf{q}\nu}, \qquad (3)$$

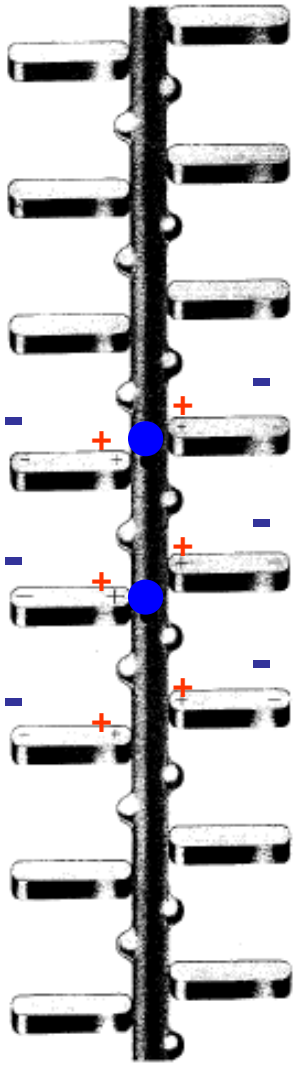
$$\lambda_{\mathbf{q}\nu} = \frac{2}{N(\varepsilon_F)\omega_{\mathbf{q}\nu}} \sum_{mn} \sum_{\mathbf{k}} |g^{\mathbf{q}\nu,mn}_{\mathbf{k}+\mathbf{q},\mathbf{k}}|^2$$
$$\times \delta(\varepsilon_{\mathbf{k}+\mathbf{q},m} - \varepsilon_F)\delta(\varepsilon_{\mathbf{k},n} - \varepsilon_F). \qquad (4)$$

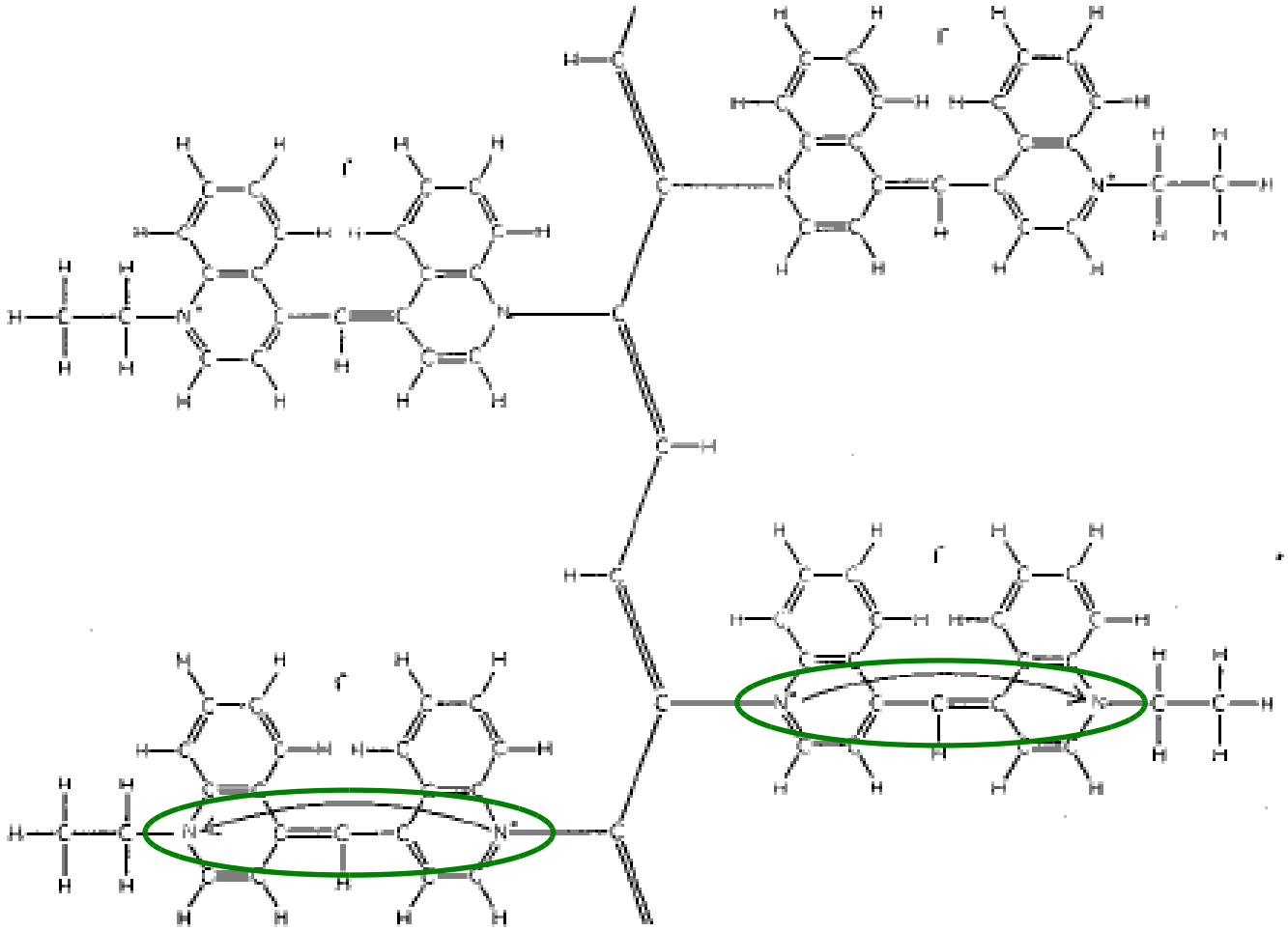
Then this…

Quantum-Espresso (Democritos-ISSA-CNR)

http://www.pwscf.org Grazie!

Little, 1963





Diethyl-cyanine iodide

Davis – Gutfreund – Little (1975)

PHYSICAL REVIEW B VOLUME 13, NUMBER 11 1 JUNE 1976

Proposed model of a high-temperature excitonic superconductor*

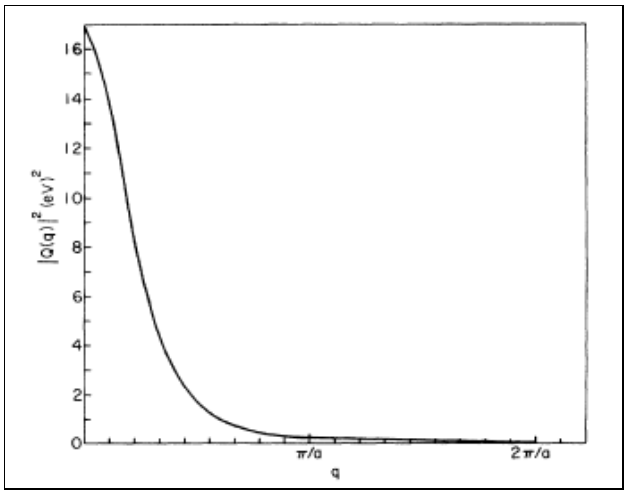
D. Davis,† H. Gutfreund,‡ and W. A. Little
Physics Department, Stanford University, Stanford, California 94305

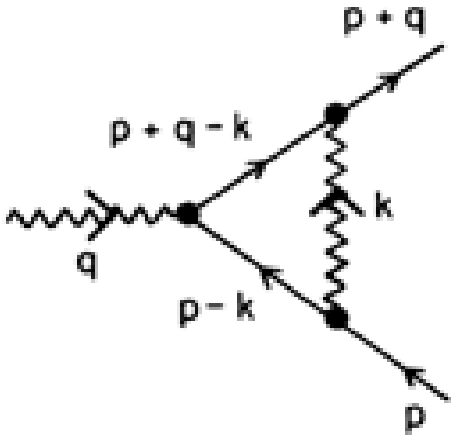
(Received 16 October 1975)

$g^{q\nu,mn}_{k+q,k}$ → Kirzhnits, Maximov, Zhomskii

$$\phi^*(r_1-R_j)\,\phi(r_1-R_h)e^{i[kR_h-(k-q)R_j]}V(r_1r_2)\sum_{m,l,\nu}\left[u^{\nu}_{\alpha l}(q)+iv^{\nu}_{\alpha l}(q)\right]e^{-iqR_l}\,\Psi^*_{\nu}(R_{ml})\Psi_{00}$$

$$Q_\alpha(q)=\frac{1}{N^{3/2}}\int\sum_{j,k}\phi^*(r_1-R_j)\,\phi(r_1-R_h)e^{i[kR_h-(k-q)R_j]}V(r_1r_2)\sum_{m,l,\nu}\left[u^{\nu}_{\alpha l}(q)+iv^{\nu}_{\alpha l}(q)\right]e^{-iqR_l}\,\Psi^*_{\nu}(R_{ml})\Psi_{00}\,d^3r_1d^3\tau$$





Migdal Issues:

- Only small exciton q's, $v_q >$ v_f, couple to the electrons.
- Thus vertex corrections are of order $\lambda^2/0$ and we're OK.
- DGL claim this is NOT the case for ABB.
- IMHO, this is an item amenable to numerical analysis.

“Bill Little’s BCS”

$$T_C = a\Theta e^{-\frac{1}{\lambda - \mu^*}}$$

~~$\lambda k\Theta < E_F$~~

Where

Θ = Exciton Characteristic Temperature (~ 22,000 K)

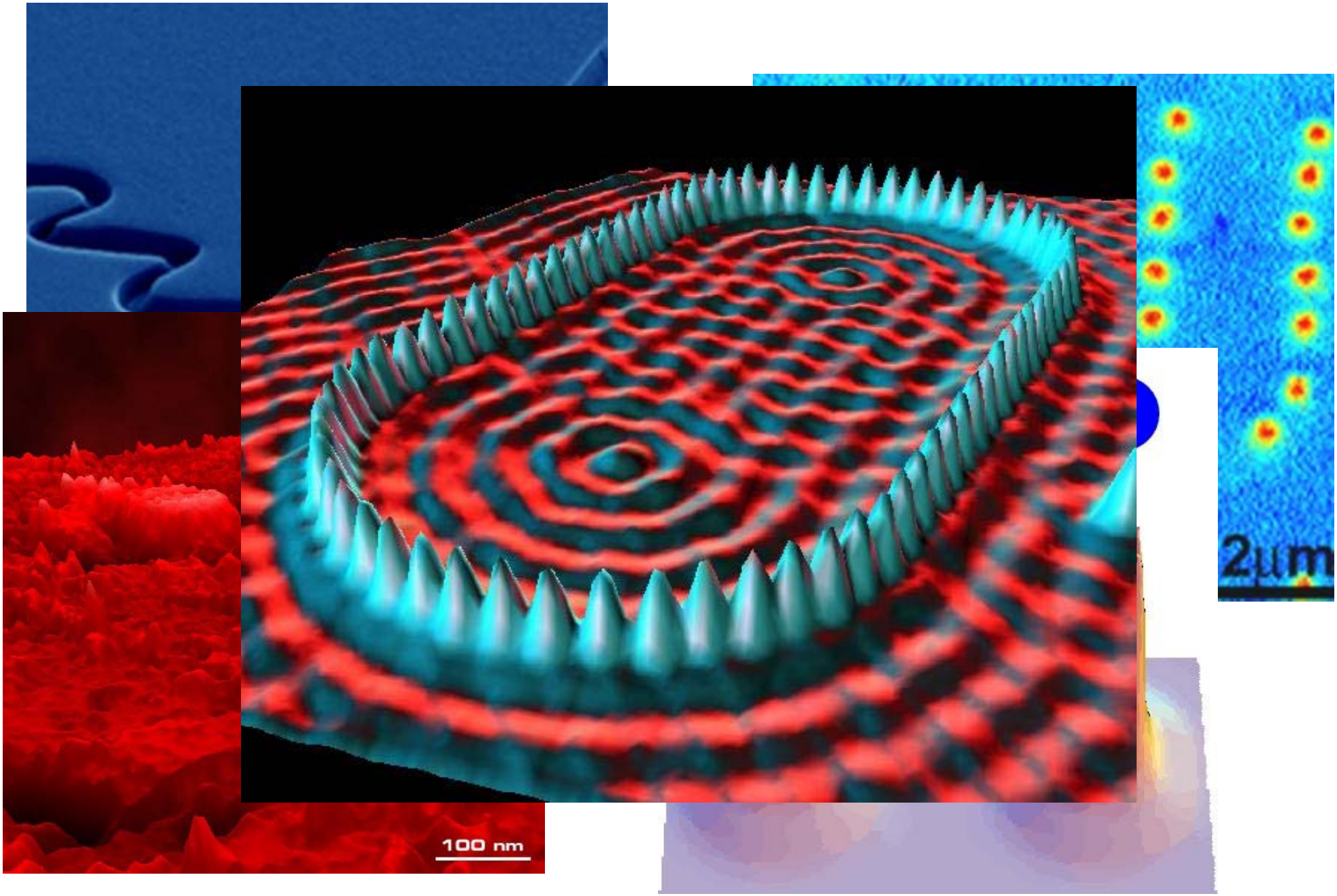
λ = Fermion-Boson Coupling Constant (~ 0.2)

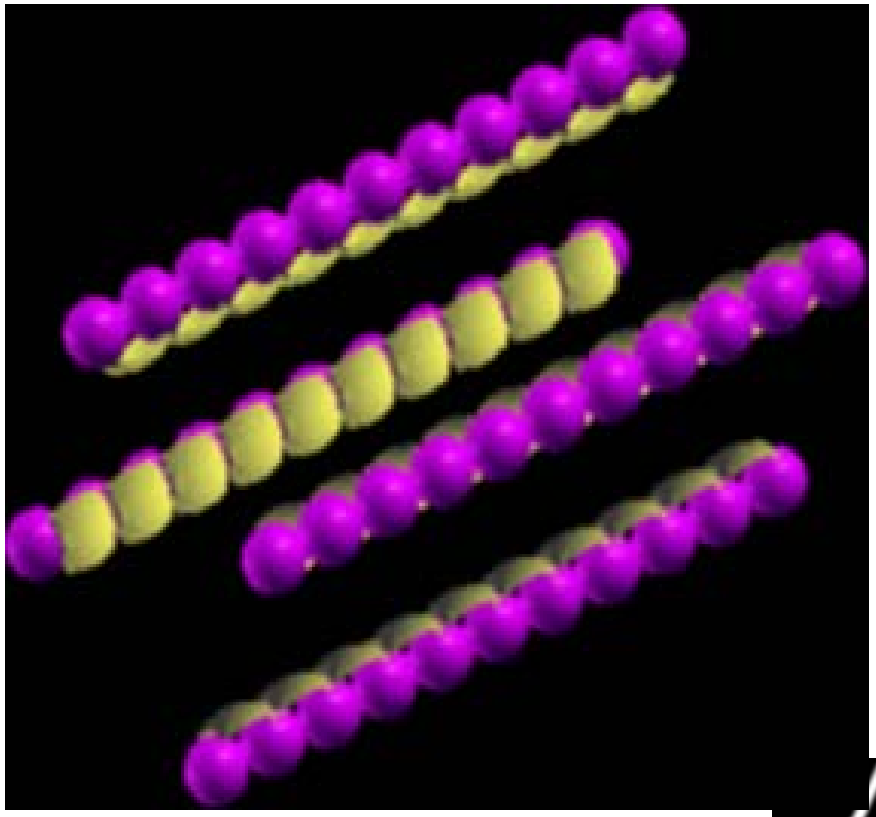
μ^* = Fermion-Fermion Repulsion (?)

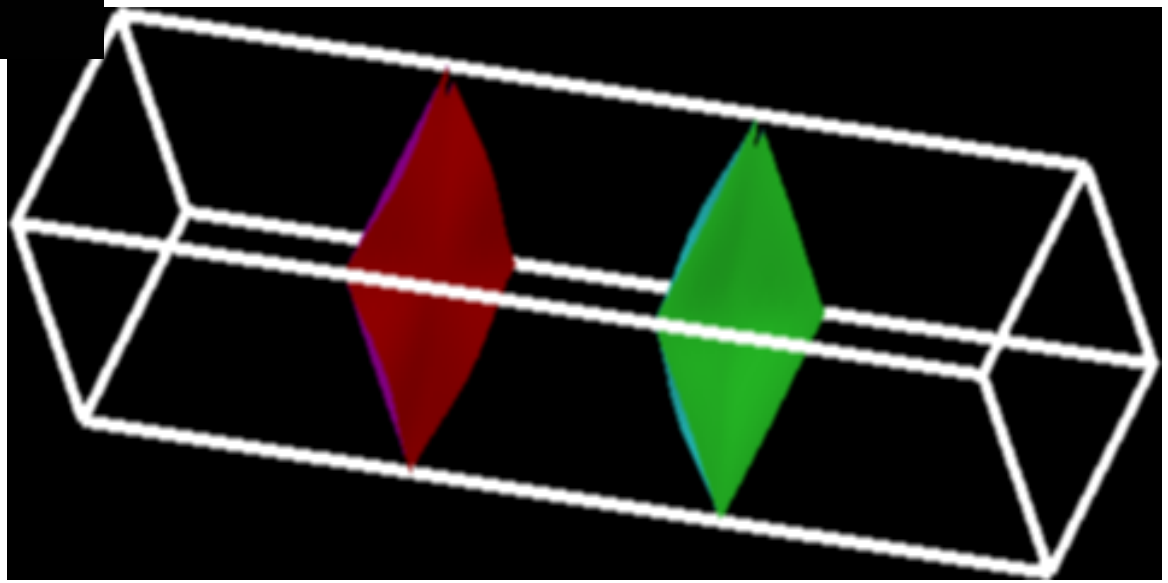
a = “Gap Parameter, ~ 1-3”

Tc = Critical Temperature, ~ 300 K

NanoMachining







"Not So Famous Danish Kid Brother"

Harald Bohr

Silver Medal, Danish Football Team, 1908 Olympic Games

Fibonacci Chains

"Monte-Carlo Simulation of Fermions on Quasiperiodic Chains,"

P. M. Grant, **BAPS March Meeting** (1992, Indianapolis)

$$G_n \equiv G_{n-1} \,|\, G_{n-2}, \quad n = 3, 4, 5, \ldots, \infty$$

Where $G_1 = a, \; G_2 = ab$

And $\lim_{n \to \infty} N_a(G_n) / N_b(G_n) \equiv \tau = (1+\sqrt{5})/2 \simeq 1.618\ldots$

Example: $G_6 = abaababaab \;\; (N = 13)$

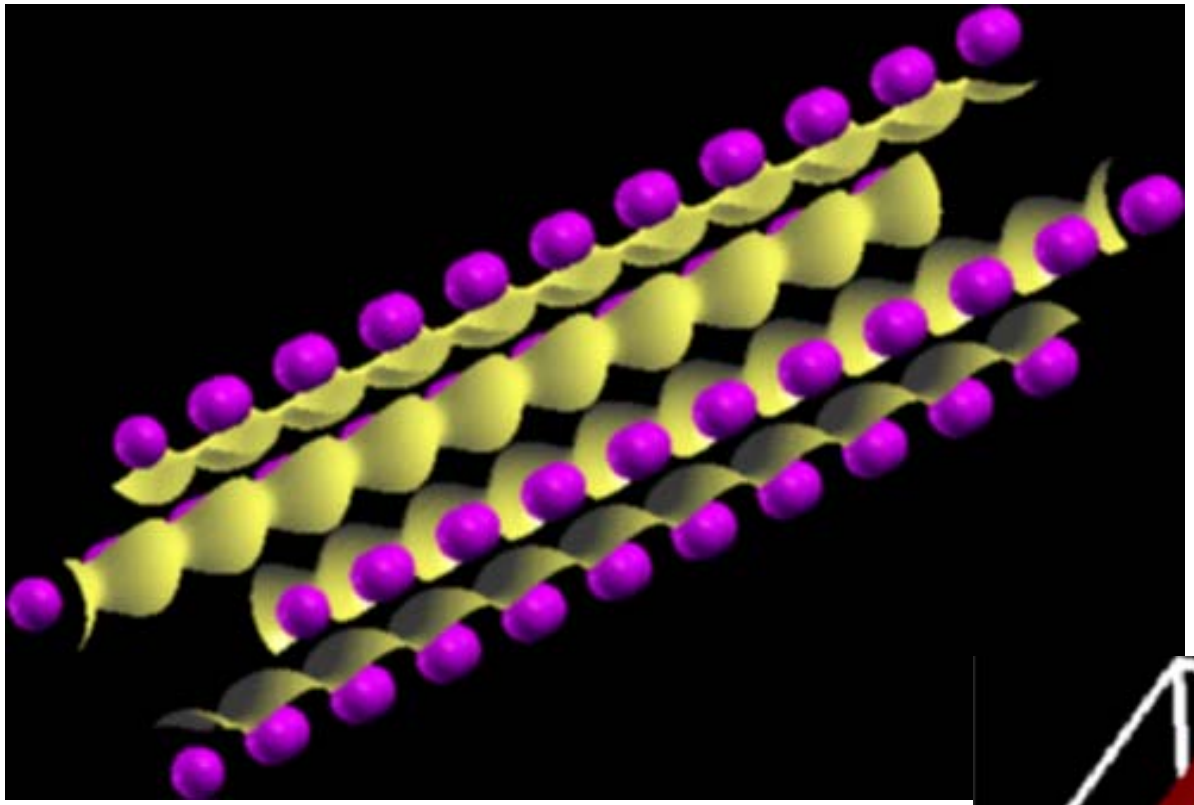
Let $a = c\tau b,$ subject to $\langle a, b \rangle$ invariant,

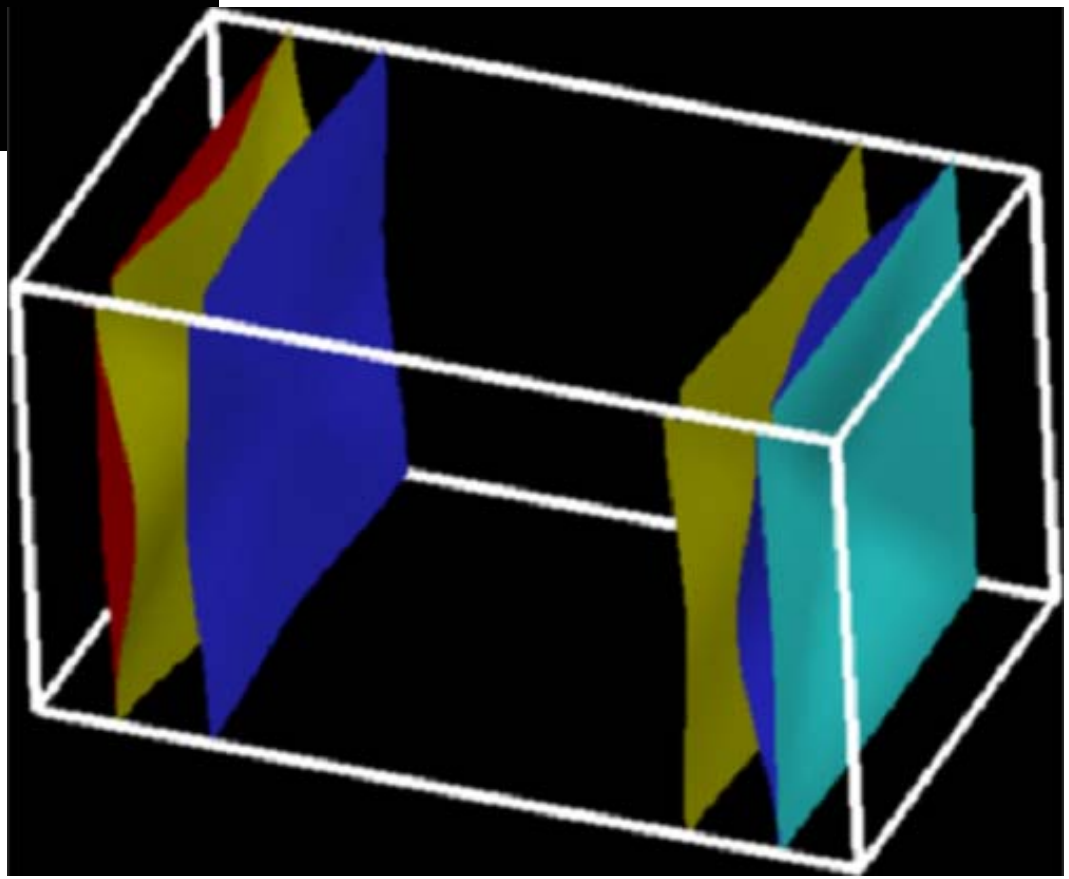
And take a and b

to be "inter-atomic n-n distances,"

Then $b = \tau \langle a, b \rangle / \left[(1+c)\tau - 1 \right].$

Where c is a "scaling" parameter.





Norwegian Dreams

- Geballe (“Negative U”)
- Kresin (“Magic Clusters”)
- Mannhart-Bosovic (“Interfaces”)
- Gurevich-Beasley (“Large Lambda”)
- Fischer (“Dig out $2\Delta = (8?)kTc$”)
- Ashcroft (“Keep it light”)
- Grant (“da Vinci Code”)

“Superconduct-ress”

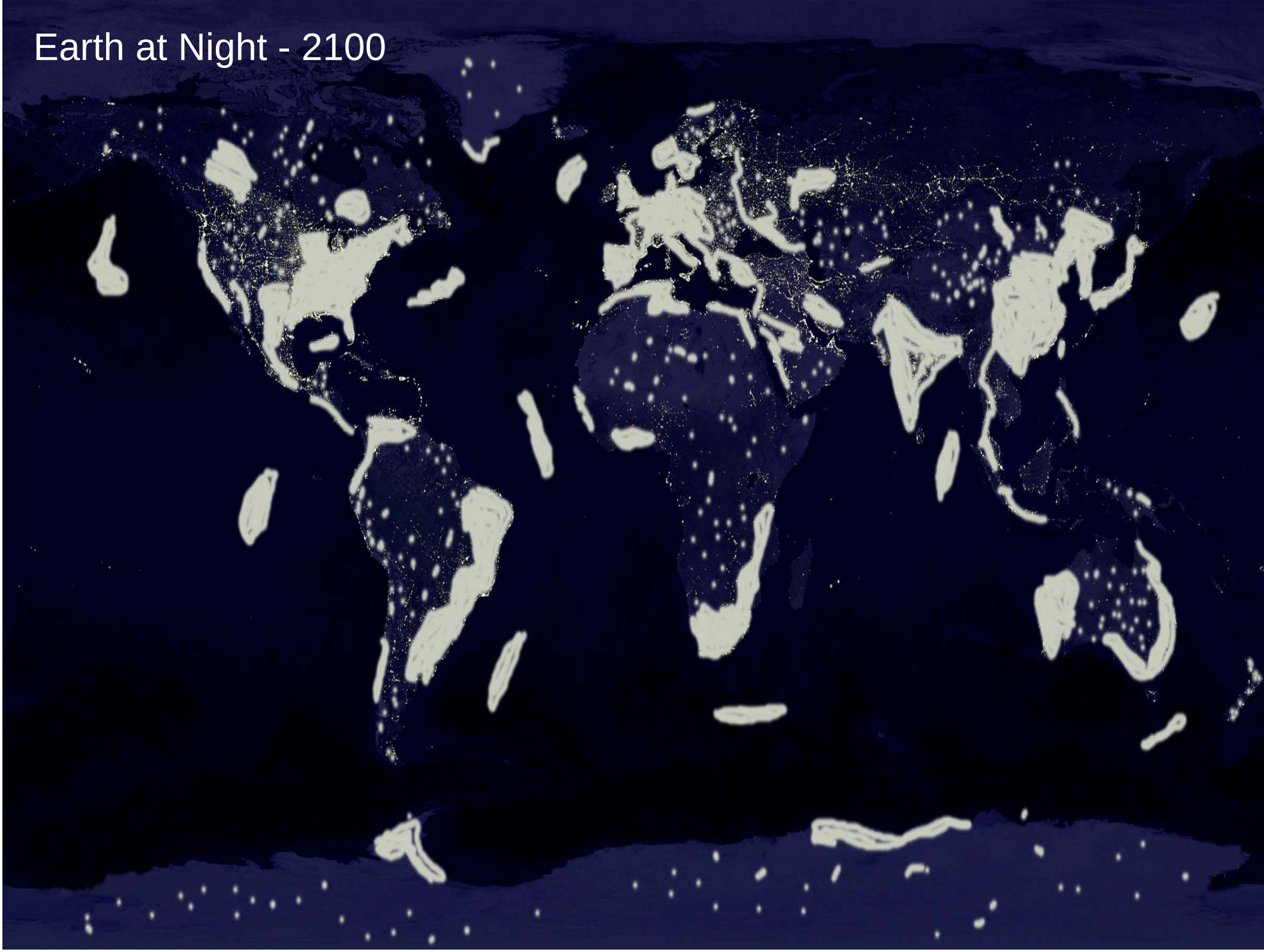
“You can’t always get what you want…”

“…you get what you need!”

Where there is no vision,
the people perish…

Proverbs 29:18

Earth at Night - 2100



Enfranchisement of Women