輻射輸送の復活

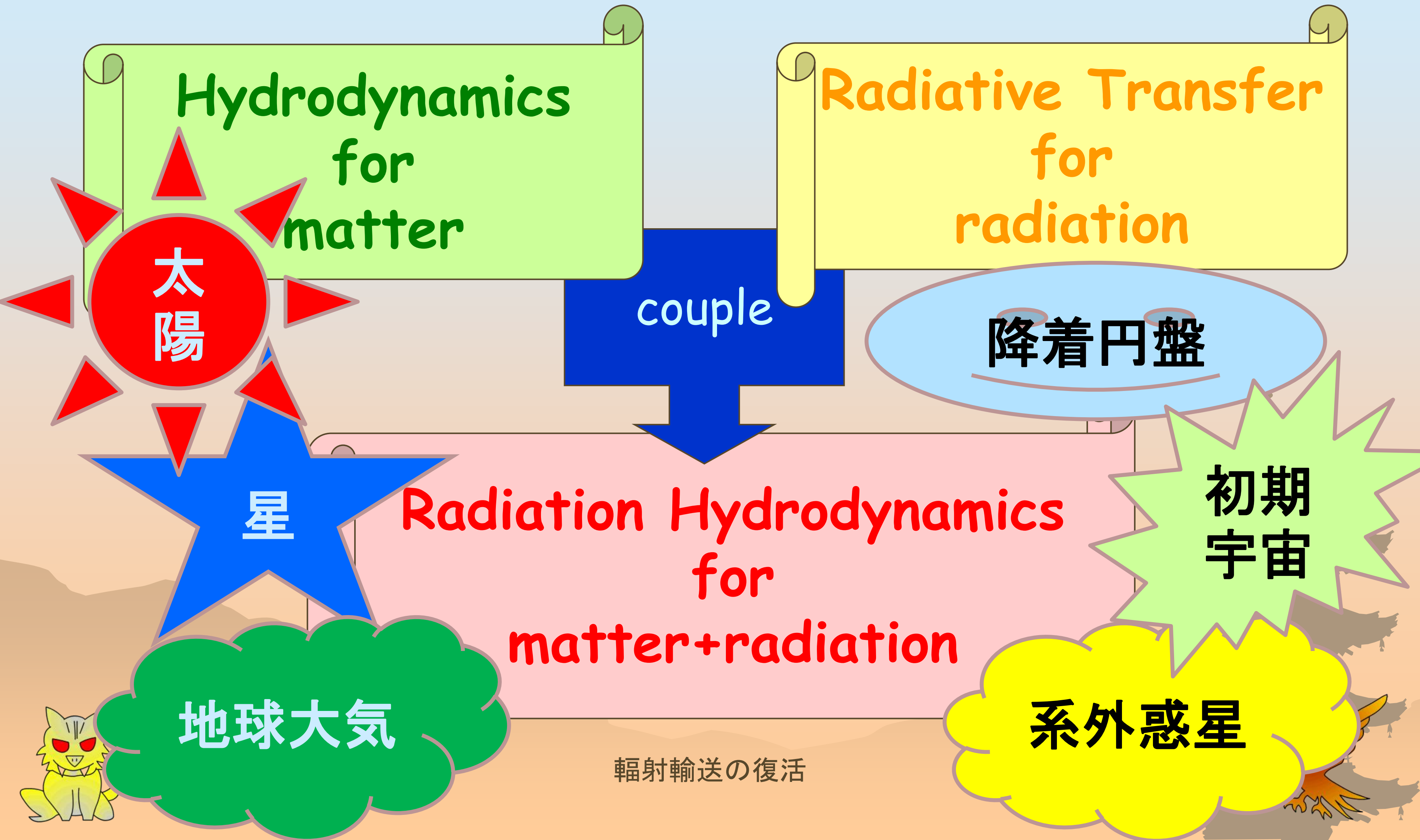
第16回　天体スペクトル研究会
@京都産業大学（2011/02/26）

福江　純@大阪教育大学

話しの流れ

- 輻射輸送と輻射流体力学の重要性
- 輻射輸送の系譜
  - 日本における輻射輸送研究教育の現状
- **Rutten Lecture**
- **Q&A**
- 輻射輸送研究教育の復活
  - 今後の計画

輻射輸送と輻射流体力学の重要性



輻射輸送の系譜

旧世代

海野和三郎
→加藤正二、|
　正木　功、近藤正明
上野季夫
→上杉　明→定金晃三 |
→平田龍幸 |
宮本正太郎→小暮智一 |
竹田洋一？

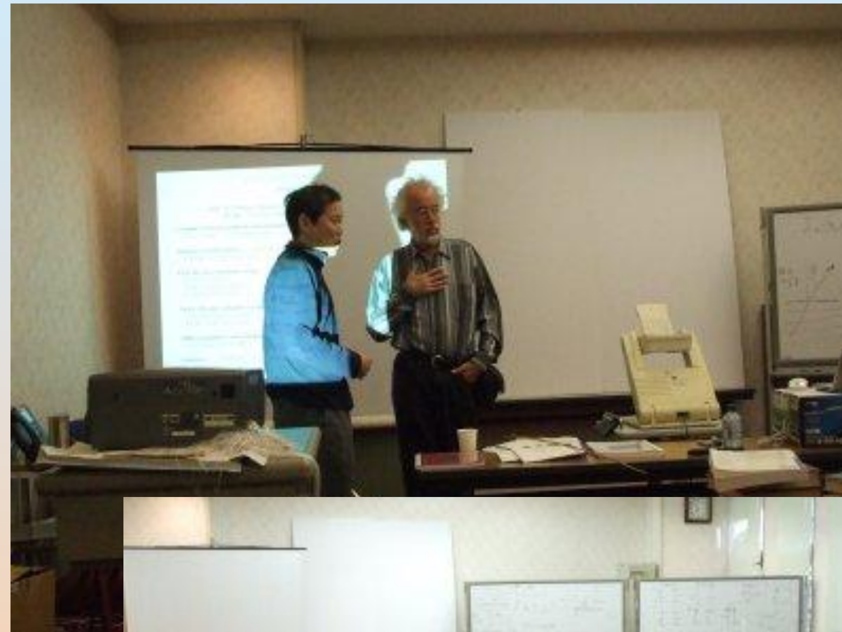
新世代

（初期宇宙）
梅村雅之→中本泰史、、
（ブラックホール活動）
福江　純

- 相対論的輻射輸送　△
- 数値解（Λ）　×
- 振動数依存性（κν）　×
- 線輪郭（Sobolev）　×

R.J. Rutten Lecture @NAO（2010 11/15-19）

- Monday: basic stellar spectrum formation
  - morning: lecture
  - **afternoon: numerical excercises SSA1, SSA2**
- Tuesday: LTE stellar spectrum formation
  - morning: lecture
  - **afternoon: numerical exercises SSA3, SSB1**
- Wednesday: resonance scattering in stellar spectrum formation
  - morning: lecture
  - afternoon: numerical exercises SSB2, SSB3
- Thursday: numerical solution schemes
  - morning: lecture
  - afternoon: numerical exercises SSC1, SSC2
- Friday: chromospheric line formation
  - morning: lecture
  - afternoon: numerical exercises SSC3



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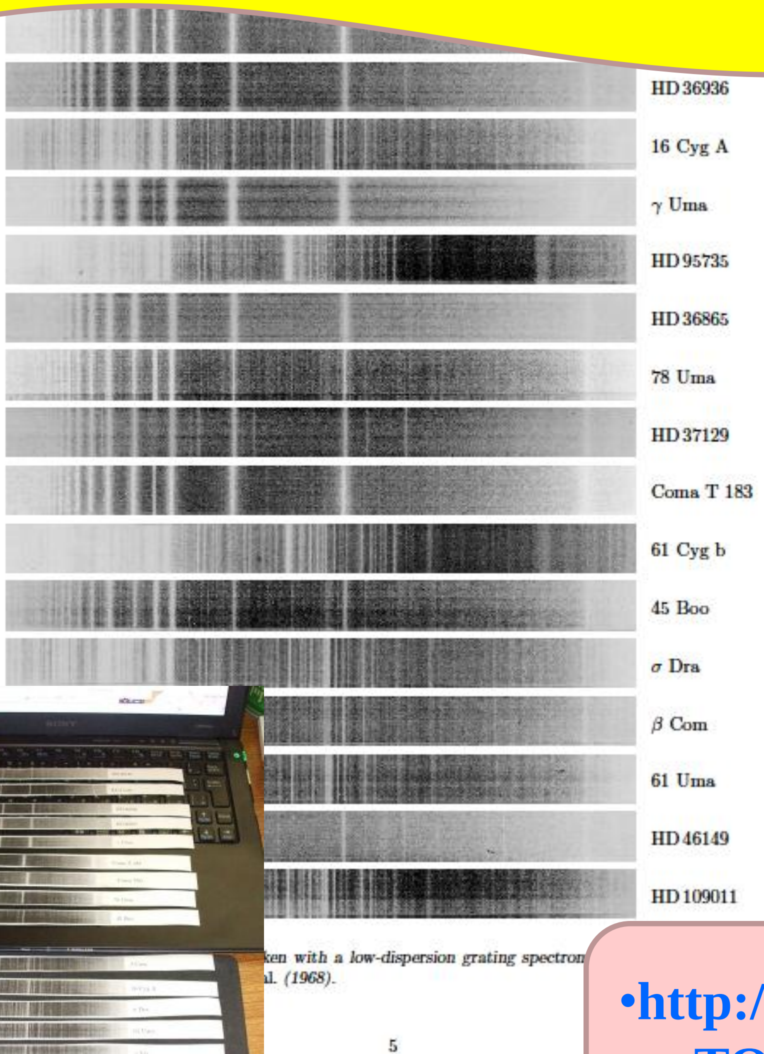
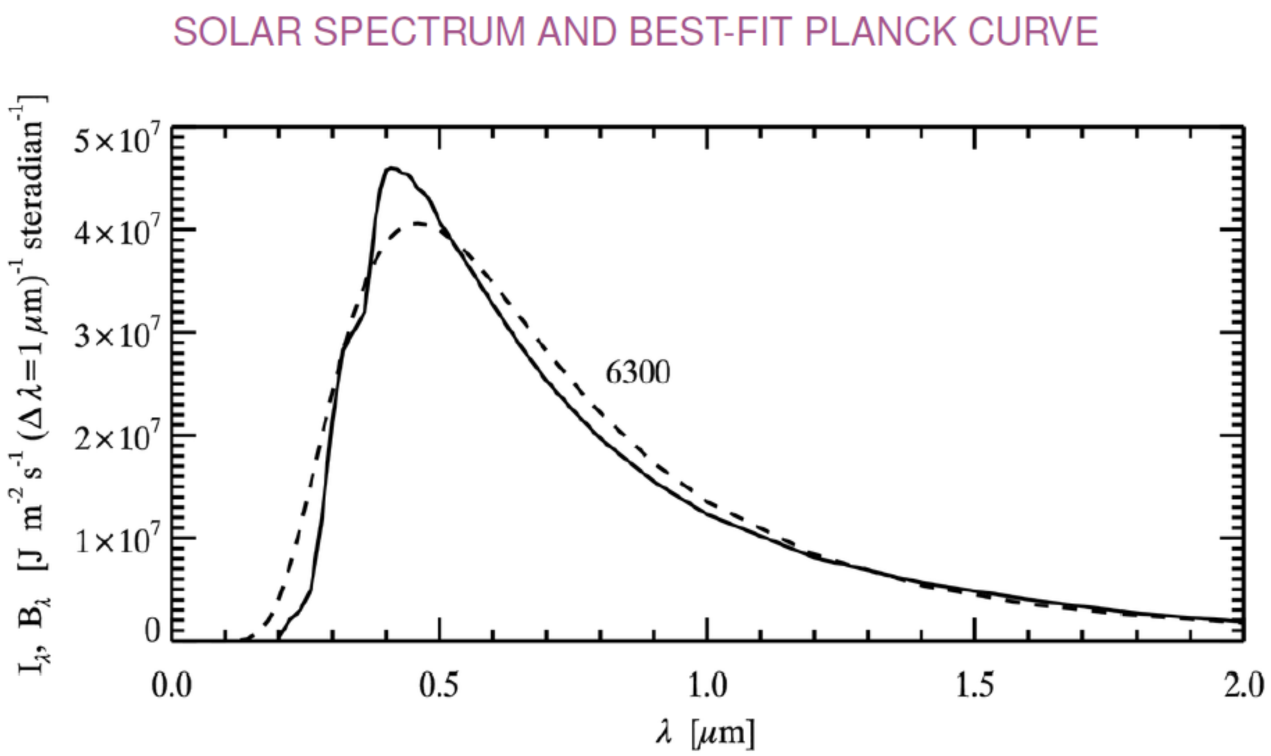


View graph
Lecture note (240p)
Program (IDL)

- http://quasar.cc.osaka-kyoiku.ac.jp/~fukue/ TOPIC/ 2010/101115.htm
- 福江　純、2011、『天文教育』、1月号、34

Q1　太陽スペクトルで一番温度が高い波長とその理由

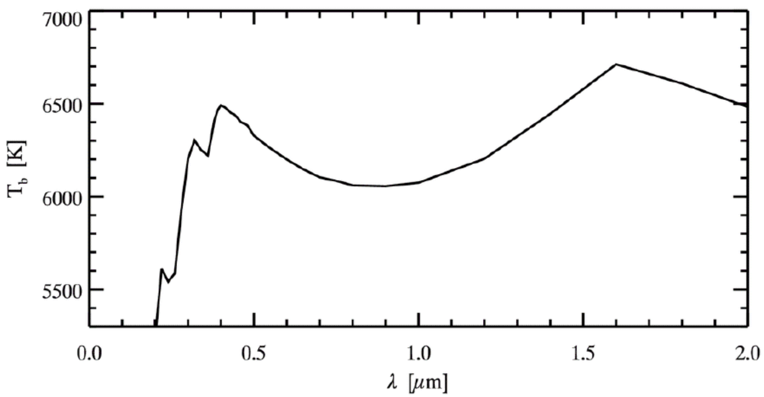


Solid: solar disk-center continuum (high points between lines).
Dashed: Planck function $B_\lambda(T)$ for $T = 6300$ K.

At which wavelength is solar radiation hottest?

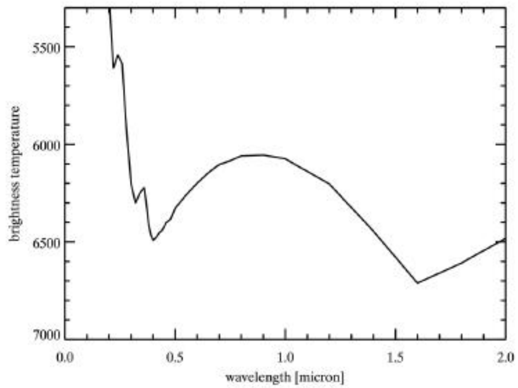
A1 太陽スペクトルで
い波長とその理由

PLANCK INVERSE OF THE SOLAR SPECTRUM

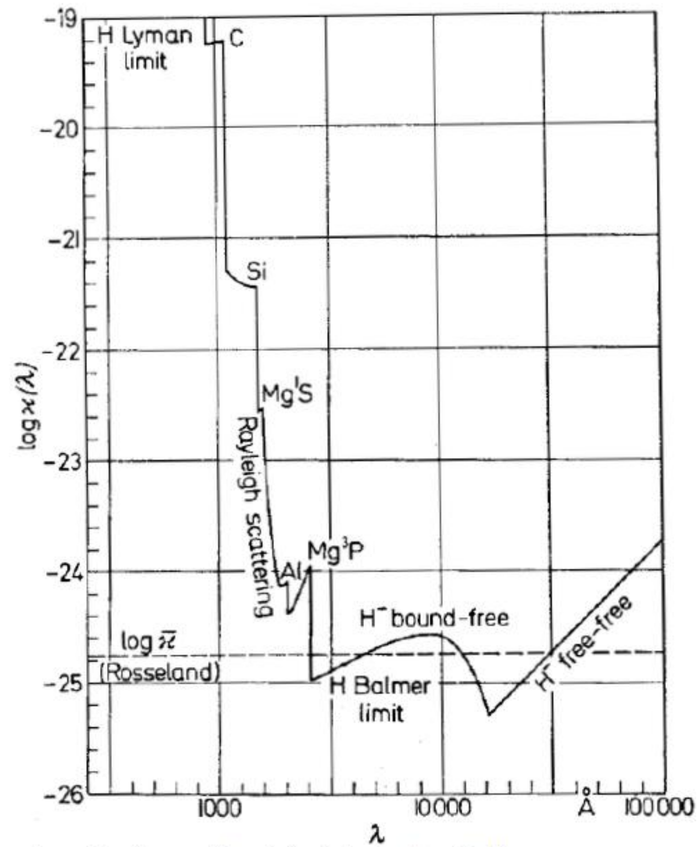


Solar radiation brightness temperature T_b with $B_\lambda(T_b) \equiv I_{\rm sun}$, or $T_b = [B_\lambda]^{-1}(I_{\rm sun})$. This is a formal temperature. It equals the gas temperature where the radiation escapes when that radiation is given by the Planck function for that temperature. This is the case for $\lambda > 0.5$ μm.

Solar radiation is hottest at wavelength $\lambda = 1.6$ μm in the near infrared.



TOSPHERE OPACITY

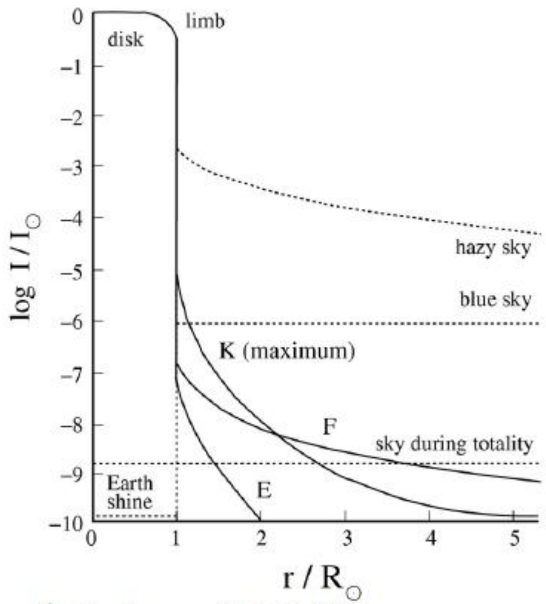


Right: photospheric gas opacity against wavelength (logarithmic), labeled with the processes causing it. Ultraviolet: ionization of C, Si, Mg, Al. Visible (λ = 0.4 – 0.8 μm = 4000 – 8000 Å) and near infrared: H^- bound-free (H^- "ionization"). Far infrared: H^- free-free (acceleration of free electrons in the Coulomb field of neutral hydrogen atoms). From E. Böhm-Vitense.

Q2　太陽コロナの本来の色と乳白色の理由

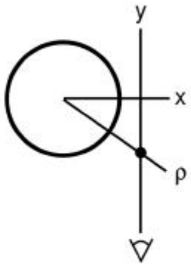
WHITE LIGHT CORONA

Stix section 9.1.3



Grotrian (1931): Thomson scattering 8000 km s^{-1} electrons (S 9.2–9.3)

$$\rho^2 = x^2 + y^2 \qquad I(x) = 2\int_0^\infty j(\rho)\,\mathrm{d}y = 2\int_x^\infty \frac{\rho\, j(\rho)}{\sqrt{\rho^2 - x^2}}\,\mathrm{d}\rho$$

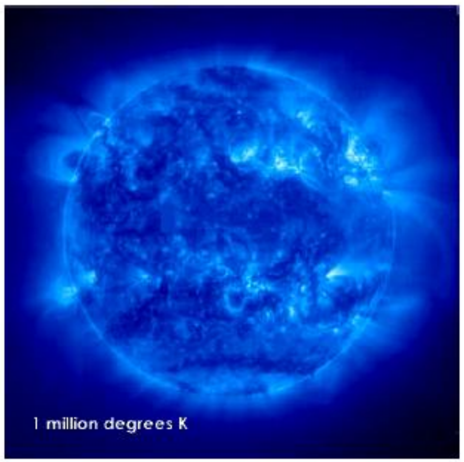


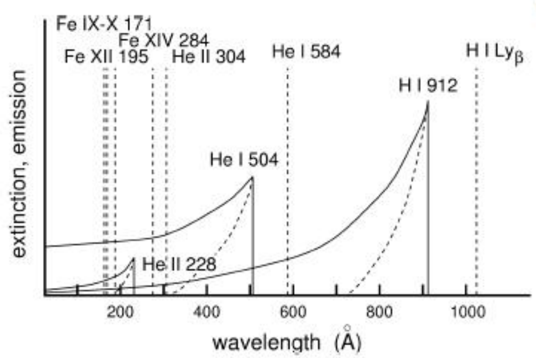
N_e from inverse Abel transform = isotropically scattered irradiation (S 9.4–9.5)

$$j(\rho) = -\frac{1}{\pi}\int_\rho^\infty \frac{\mathrm{d}I/\mathrm{d}x}{\sqrt{x^2-\rho^2}}\,\mathrm{d}x = \sigma_T N_e \frac{1}{4\pi}\int I_\odot(\theta)\,\mathrm{d}\Omega$$

A2　太陽コロナの本来の色と乳白色の理由

BRIGHT AND DARK IN EUV IMAGES





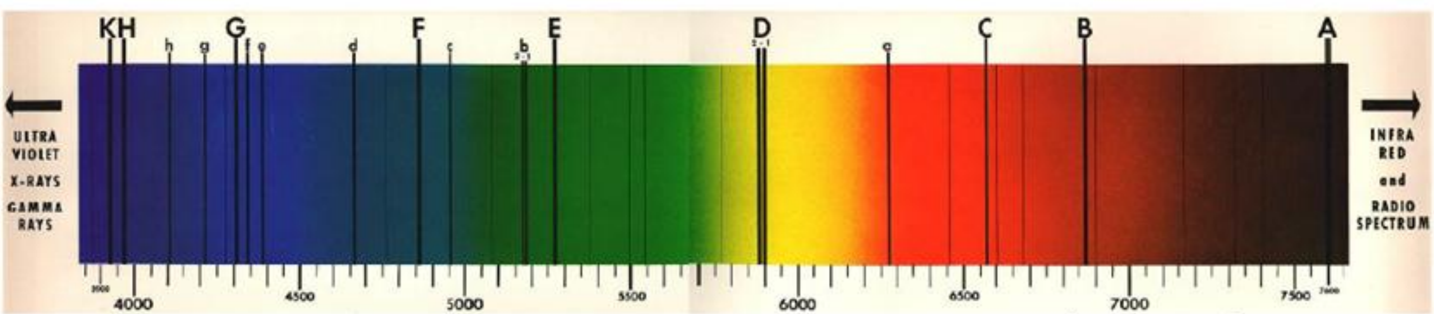
- *iron lines*
  - Fe IX/X 171 Å: about 1.0 MK
  - Fe XII 195 Å: about 1.5 MK
  - Fe XIV 284 Å: about 2 MK
- *bright*
  - collision up, radiation down
  - thermal photon creation, NLTE equilibrium
  - 171 Å: selected loops = special trees in forest
- *dark*
  - radiation up, re-radiation at bound-free edge
  - matter containing He^+, He, H: 10^4 – 10^5 K
  - large opacity

Q3　太陽スペクトルで Ca H, K線が強い理由

FRAUNHOFER'S DISCOVERY

http://en.wikipedia.org/wiki/Joseph_von_Fraunhofer

In 1814, Fraunhofer invented the spectroscope, and discovered 574 dark lines appearing in the solar spectrum. They are still called Fraunhofer lines. Kirchhoff and Bunsen showed in 1859 that they are atomic absorption features providing diagnostics-at-a-distance of the local conditions in the atmospheres of the Sun and other stars.



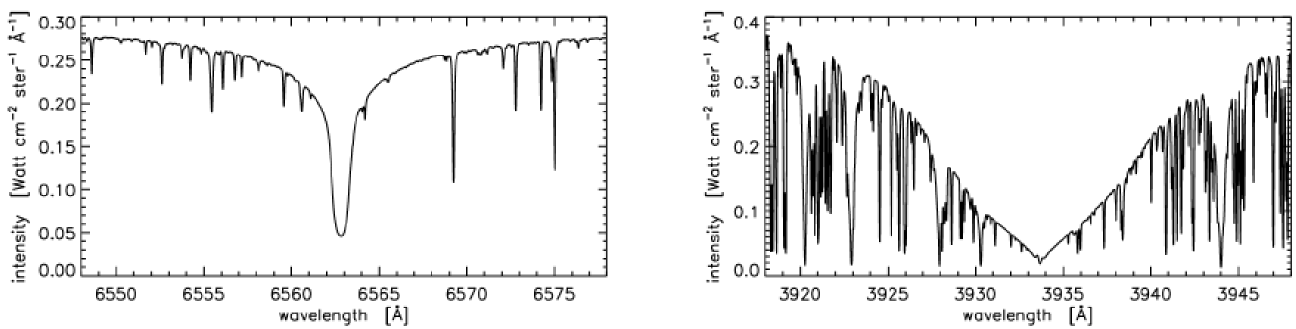
scale in Ångstrom; 1 Å = 0.1 nm

K & H: resonance lines of calcium ions
G: rotation-vibration band of CH molecules
F: Balmer-β line of hydrogen atoms
b: three lines of magnesium atoms
E: a group of lines of iron atoms
D: two resonance lines of sodium atoms (the same as in street lights)
C: Balmer-α line of hydrogen atoms
B & A: rotation-vibration band of oxygen molecules in the Earth atmosphere

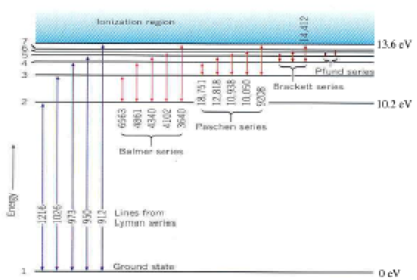
196.4 x 147.3 mm

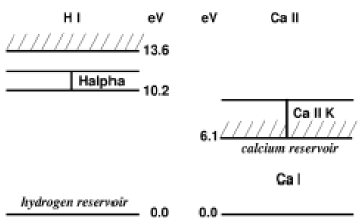
A3　太陽スペクトルで Ca H, K線が強い理由

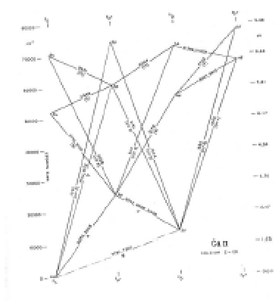
H-α AND Ca II K IN THE SOLAR SPECTRUM



solar abundance ratio: Ca/H = 2×10^{-6}







Assuming LTE at $T = 5000$ K, $P_e = 10^2$ dyne cm^{-2}:

Boltzmann H I: $\frac{n_2}{n_1} = 4.2 \times 10^{-10}$　　Saha Ca II: $\frac{N_{\mathrm{Ca\,II}}}{N_{\mathrm{Ca}}} \approx 1$　　$\frac{\text{Ca II}\,(n=1)}{\text{H I}\,(n=2)} = 8 \times 10^3$

Q4～

- 地球大気で輻射輸送が可能･必要な理由
- Hーイオンの不透明度の近似式
- 散乱等温大気でのBν/Sν/Jνの振る舞い
- Λ-iterationの計算

今日の講演で言えば…

- 新星風の光球面のν依存やスペクトル計算
- 矮新星の増光中における吸収線→輝線変化
- 超新星スペクトル（P Cyg輪郭など）の再現
- 超新星の光球面の形状と進化（含むν依存）
- 活動銀河BLRの輝線プロファイル
- 食連星の共通大気（風）からの輝線
- Be星のV/R変動と降着円盤の一本腕振動
- 基本レベルの輻射輸送で計算できることだし（ぼくはまだできないが）、観測家といえども、やらなければダメ！！！

輻射輸送研究教育の復活

- 太陽･星
  - 末松芳法@国立天文台
  - 柴田一成@京大
- 初期宇宙
  - 梅村雅之@筑波大
  - 中本泰史@東工大
- 降着円盤
  - 福江　純@大阪教育大
- 系外惑星

- **Rutten Lecture の消化**
  - **Lecture note & Exercise**
  - **Programの移植**
    IDL→Fortran, C, Basic
- **カリキュラムの策定**
- **系統的で実践的な講義**
- **サマースクール2011**
  2011 夏 @ 筑波？
- **若手の積極的な参加**
- **シニアからノウハウ提供**


Fin
輻射輸送の復活