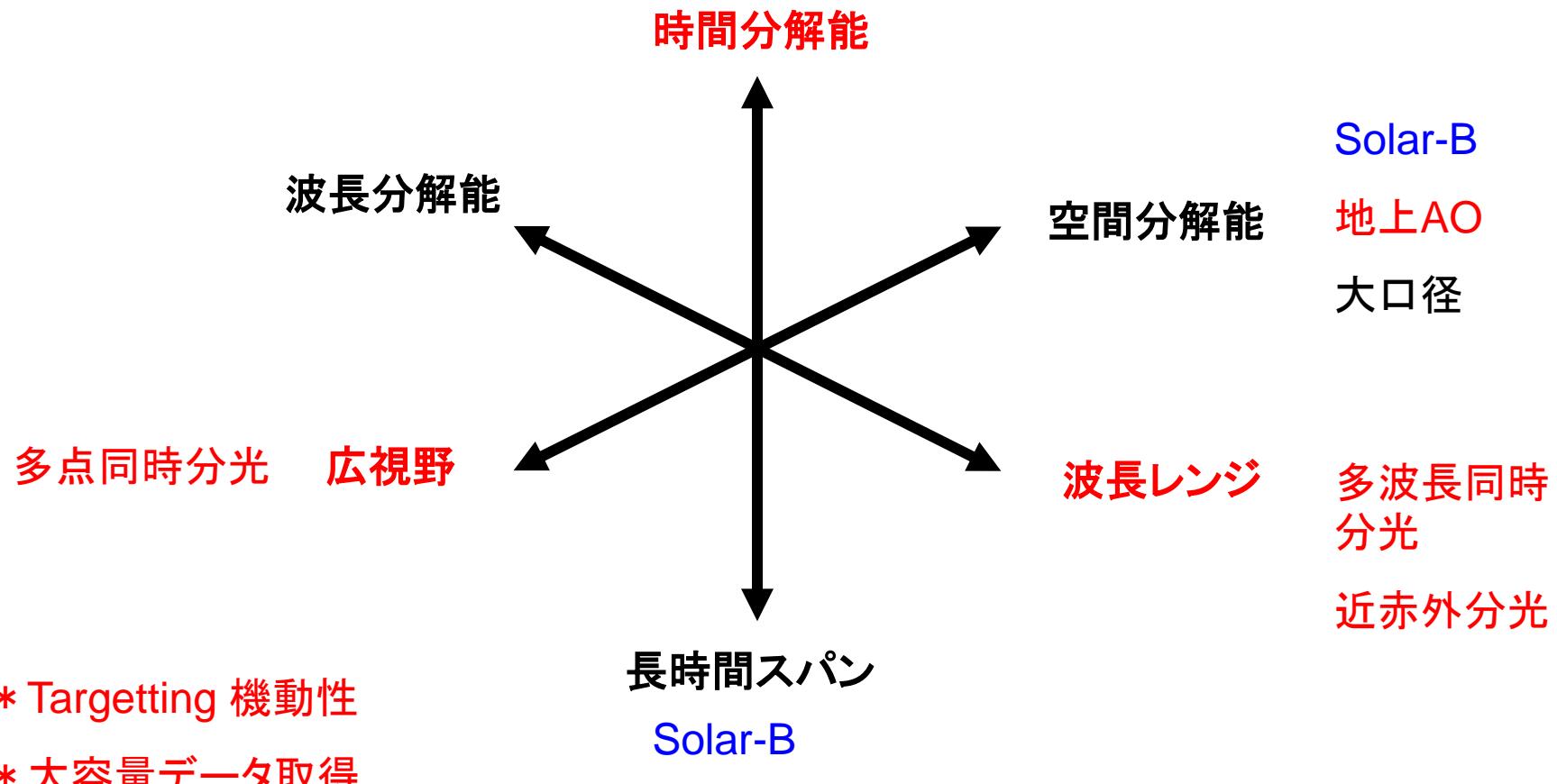


DST将来計画と 高時間分解能撮像観測

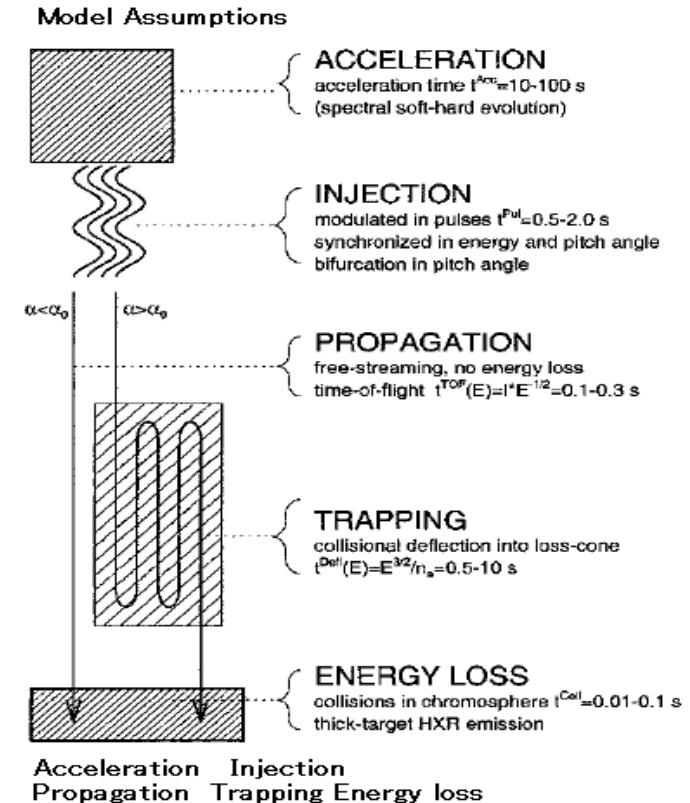
京大・理・附属天文台
北井礼三郎

太陽観測のベクトル



粒子加速の問題

- 太陽大気での粒子加速
 - * どこで加速され
 - * どのように伝播し
 - * どのように散逸されるか
- Elementary Burst (H α カーネル高時間分解観測)
 - * Duration (≤ 0.3 秒)
 - ⇒ 加速領域のサイズ導出
 - ⇒ 格段に短い？
 - * Location of acceleration
 - ⇒ HXRによるTime-of-flight 解析
 - ⇒ 彩層突入点の同定



Aschwanden (1996)

Close Relationship between H α and Hard X-Ray Emissions at the Impulsive Phase of a Solar Flare

Kurokawa, Takakura, Ohki Publ. Astron. Soc. Japan **40**, 357–367 (1988)

- Comparison of H α -1.0 Å light curve (temporal resolution 1s) with that of Hinotori HXR
 - Footpoints of a flare loop (Hakernels) **synchronously brighten**.
 - Time profiles of H α and HXR show good time correspondence in impulsive phase.
- ⇒ **Electron Beam Heating of Chromosphere**

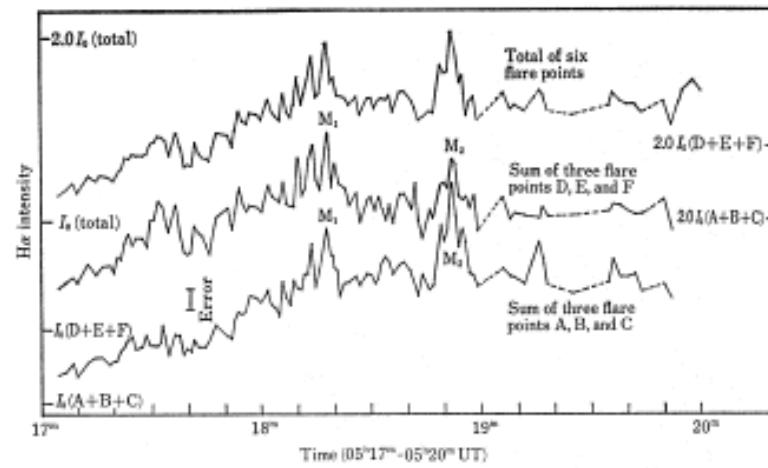


Fig. 3. Simultaneous brightenings of both footpoints of flare loops. The total intensity variation of three flare kernels A, B, and C in the preceding magnetic polarity region is compared with that of other flare kernels D, E, and F in the following magnetic polarity region. These curves simultaneously attain the first main peak at 05^h18^m18^s UT and the second main peak at 05^h18^m52^s UT within 1 s.

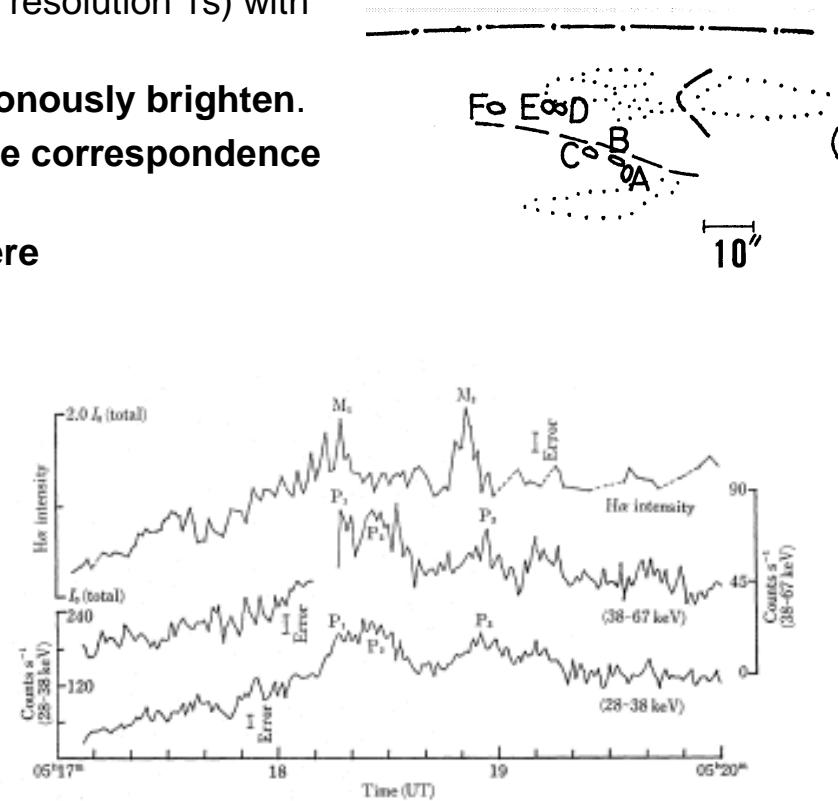


Fig. 5. Detailed comparison between H α and hard X-rays with an enlarged time axis. The main parts of the H α and hard X-ray time profiles of figure 4 are enlarged. There is good correspondence between them from the start to the first main peak of the flare. The time difference between the first main maximum M₁ of H α and P₁ of hard X-ray (38–67 keV) is only about 1 s.

High time resolution observations of the solar flare H α emission

K. Radziszewski, P. Rudawy, K.J.H. Phillips, B.R. Dennis
 Advances in Space Research 37 (2006) 1317–1322

- D:53cm Coronagraph
- 9 Channel MSDP
- EEV CCD (512 × 512, 10bit, 70f/s)
- Cadence 0.04-0.05s (Limiter by light level)
- Comparison with HXR(RHESSI) and SXR(Goes)

• Simultaneous H α
 Brightening with HXR
 (H α Integrated Intensity)

- No Periodic Variation
- No time delay between light curves
- Some H α kernels show no corresponding HXR burst

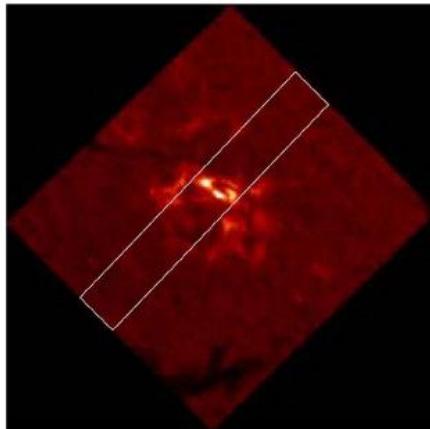


Fig. 1. H α line centre image of the C1.2 flare in active region NOAA 10410 taken at 16:07 UT on 2003 July 16. The white rectangle marks the area observed with the LC-MSDP-SECIS system.

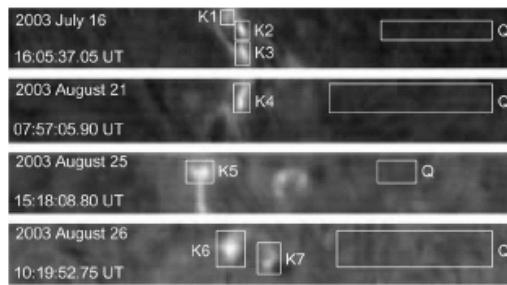


Fig. 2. Images taken in H α line centre on 2003 July 16, August 21, 25 and 26. Flare kernels K1–K7 are marked with white boxes. Reference areas of the quiet chromosphere are marked Q. The images were taken with LC-MSDP-SECIS system.

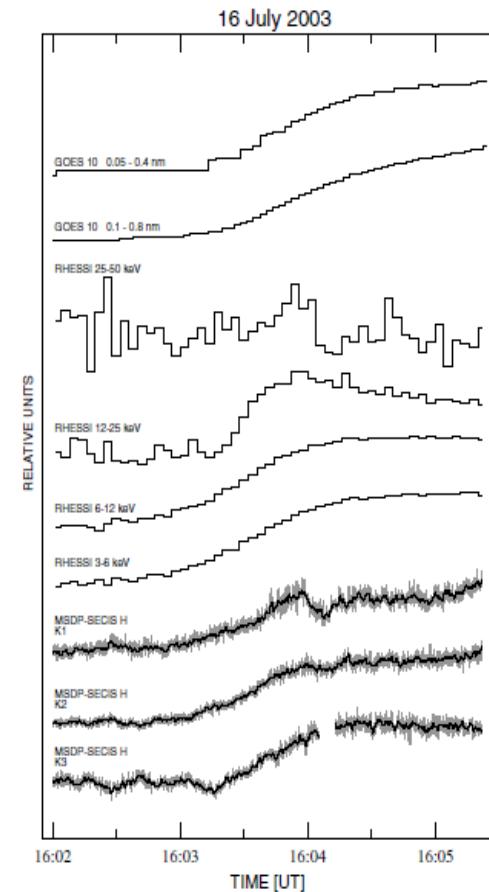
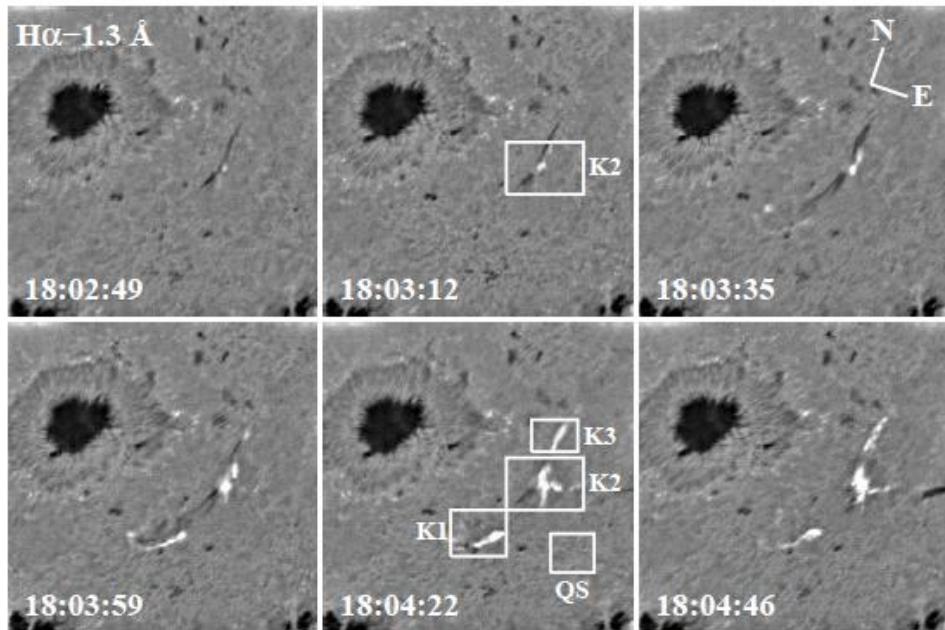


Fig. 4. Light curves of the 2003 July 16 flare. (From top) GOES 10 fluxes measured in 0.05–0.4 and 0.1–0.8 nm band with 3 s time resolution; RHESSI X-ray fluxes measured in 25–50, 12–25, 6–12 and 3–6 keV energy bands (4 s cadence); H α light curves measured in K1, K2, K3 kernels (thin curves – data taken with 0.05 s time resolution, bold curves – the data smoothed using 20-points (1 s) boxcar).

HIGH-CADENCE OBSERVATIONS OF AN IMPULSIVE FLARE

HAIMIN WANG, JIONG QIU, CARSTEN DENKER, TOM SPIROCK, HANGJUN CHEN,
AND PHILIP R. GOODE
THE ASTROPHYSICAL JOURNAL, 542:1080, 2000

- $\text{H}\alpha$ -1.3 Å Image
 - 30f/s (7s obs.+15s transfer)
- BATSE HXR 25-50Kev(1.02sec)



**C5.7 Flare occurred at 18:09 UT
on August 23, 1999 in NOAA 8673**

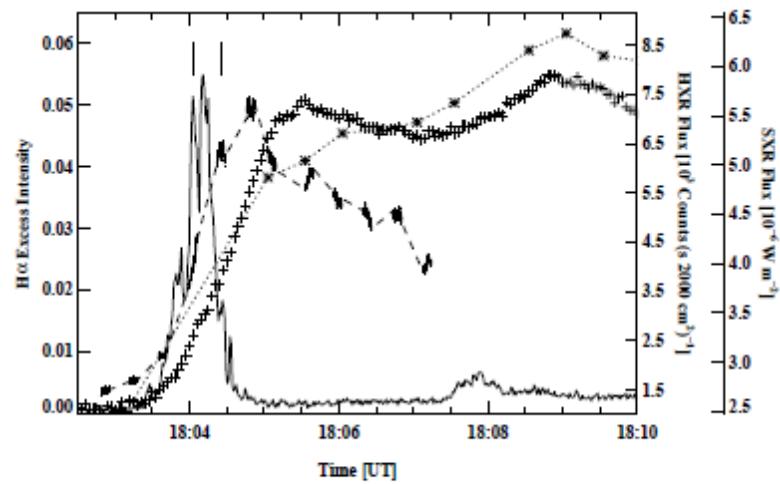


FIG. 1.—Time profiles of *GOES* soft X-ray (+), BATSE hard X-ray (solid line), $\text{H}\alpha$ line center (dotted line), and $\text{H}\alpha$ -1.3 Å (dashed line) emissions of the 1999 August 23 flare. The $\text{H}\alpha$ light curves indicate the excess emission, i.e., the flare intensity with the quiet region intensity subtracted and then normalized to the quiet region intensity. The two vertical bars in the plot indicate the two time intervals of the $\text{H}\alpha$ -1.3 Å emission analyzed in the paper and plotted in Figs. 5 and 6.

HIGH-CADENCE OBSERVATIONS OF AN IMPULSIVE FLARE

HAIMIN WANG, JIONG QIU, CARSTEN DENKER, TOM SPIROCK, HANGJUN CHEN,
AND PHILIP R. GOODE

THE ASTROPHYSICAL JOURNAL, 542:1080, 2000

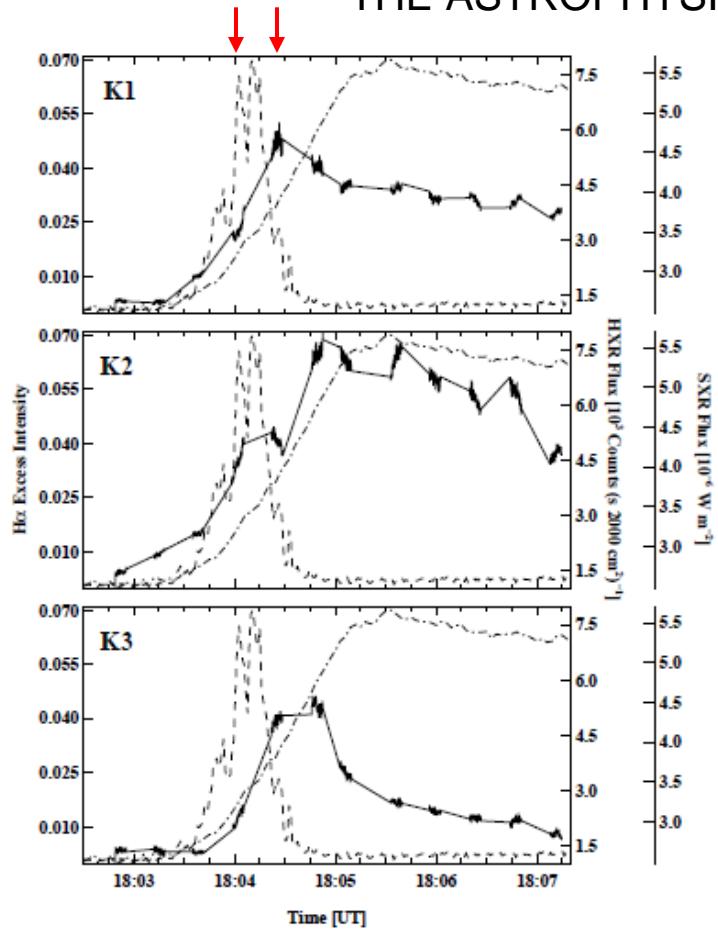


FIG. 4.—Time profiles of the flare emission in H α –1.3 Å at three flare kernels (solid line) compared with BATSE hard X-ray emission (dashed line) and GOES soft X-ray 1–8 Å emission (dot-dashed line).

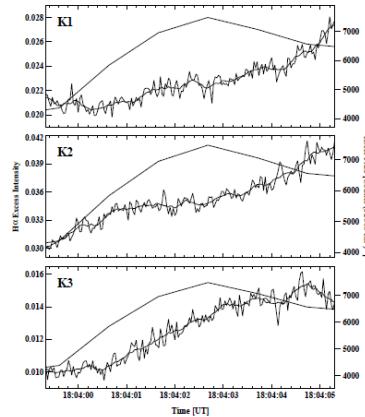


FIG. 5.—Comparison of H α –1.3 Å intensity (thin lines) and hard X-ray flux (thick lines) for three flare kernels during the time interval 18:03–59–18:04:06 UT. For the H α emission, both the raw data and a 10-point smoothed curve are plotted.

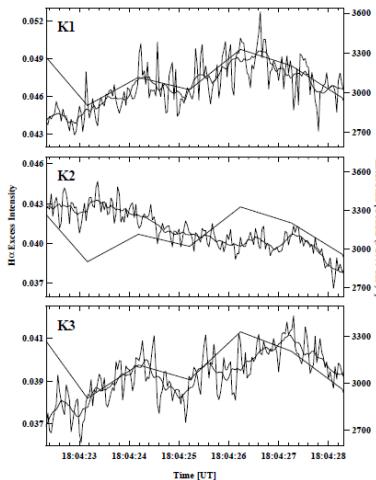


FIG. 6.—Comparison of H α –1.3 Å intensity (thin lines) and hard X-ray flux (thick lines) for three flare kernels during the time interval 18:04:22–18:04:29 UT. For the H α emission, both the raw data and a 10-point smoothed curve are plotted.

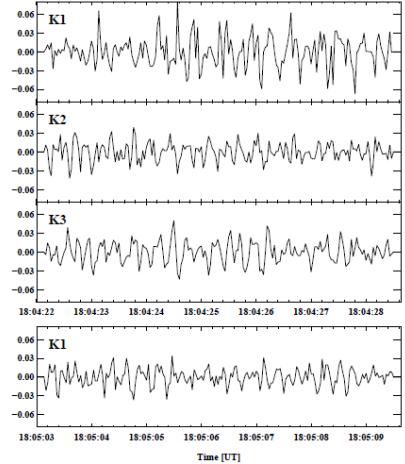


FIG. 7.—Time profiles of H α –1.3 Å flare emission. The 10-point smoothed background is subtracted from all the curves. The top three panels show fluctuations at three flare kernels in the time interval shown in Fig. 5. The bottom panel shows the variations at K1 in a time interval 40 s later.

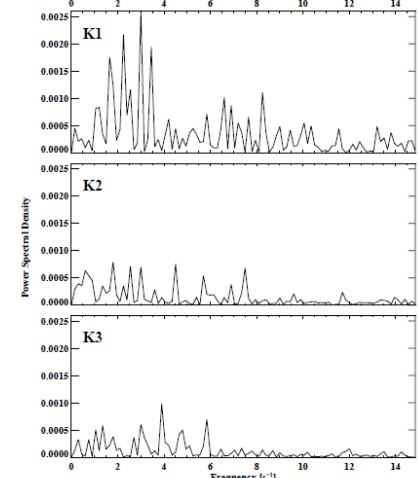


FIG. 8.—Power spectra of the fast variations of the H α –1.3 Å emission at the three flare kernels 18:04:22–18:04:29 UT.

HIGH-CADENCE OBSERVATIONS OF AN IMPULSIVE FLARE

HAIMIN WANG, JIONG QIU, CARSTEN DENKER, TOM SPIROCK, HANGJUN CHEN,
AND PHILIP R. GOODE
THE ASTROPHYSICAL JOURNAL, 542:1080, 2000

- Initial brightening at the low-lying reconnected loop (K2)
- The other kernels are footpoints of overlying loop (K1, K3)
- Temporal correlation – good/bad cases
- 0.3-0.7s fluctuations in H α wing intensity
⇒ Elementary HXR bursts
- Puzzling phenomena
 - Pre-heating in H α
 - HXR peak leads H α blue emission peak by 2-3 s at initial phase, while there are no time difference at later phase.

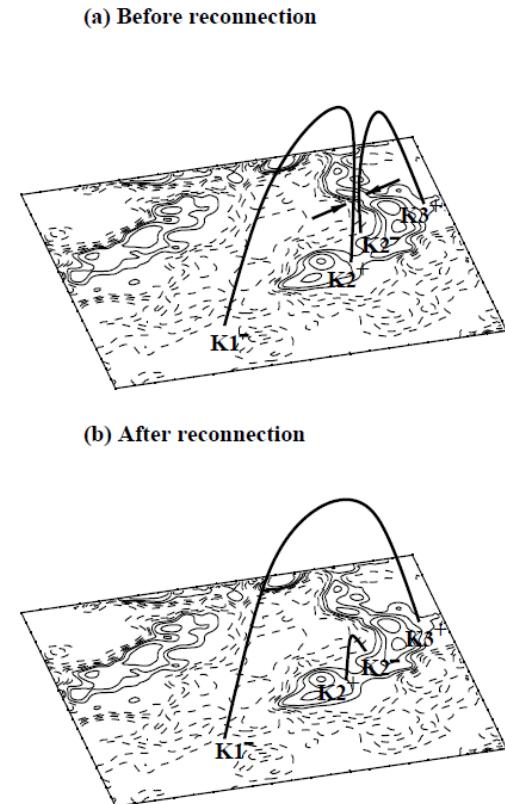


FIG. 9.—Sketch of the magnetic configuration of the flare before and after the reconnection. The background contours show the line-of-sight magnetogram taken before the flare as in Fig. 3. The solid (dashed) lines indicate the positive (negative) magnetic polarities, and the contour levels are $\pm 20, 50, 100, 200$ G.

A CHROMOSPHERIC RESPONSE TO PULSE BEAM HEATING

PETR HEINZEL

Astronomical Institute, 251 65 Ondřejov, Czechoslovakia

Solar Physics **135**: 65–88, 1991.

- Beam-heated chromosphere model
 - Fischer, Canfield, and McClymont (1985)
 - Stationary or quasi-stationary heating (several to tens of seconds)
 - NLTE radiative hydrodynamical simulation
 - Hydrogen atom : 2 bound levels+continuum
- H α simulation (NLTE Transfer)
 - Heated chromosphere model by sub-second beam injection (Karlicky 1990)
 - Hydrogen atom : 3 bound levels+continuum
 - Simulation of excitation and ionization of hydrogen by solving time-dependent population equation
 - Temperature variation given by Karlicky model
 - Collisional processes of non-thermal electrons included

A CHROMOSPHERIC RESPONSE TO PULSE BEAM HEATING

PETR HEINZEL

Astronomical Institute, 251 65 Ondřejov, Czechoslovakia

Solar Physics 135: 65–88, 1991.

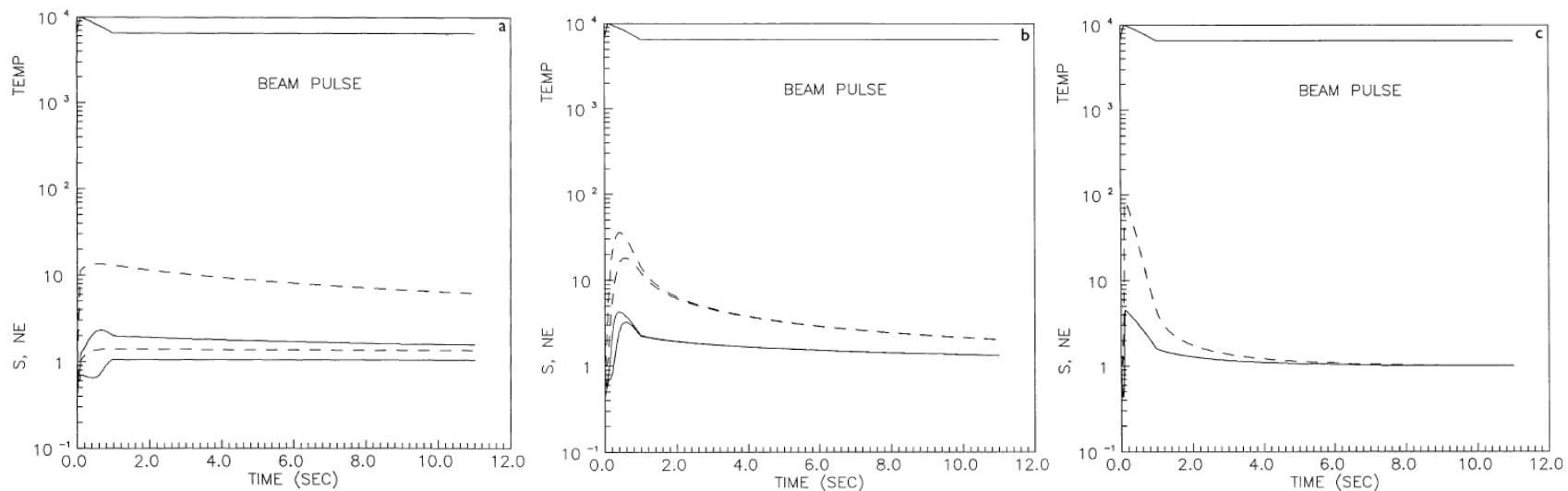


Fig. 1. Temporal variations of the kinetic temperature (TEMP), the electron density (NE – dashed lines), and an H α source function (S – solid lines) for one beam pulse with $\Delta t_h = 0.1$ s, $\Delta t_c = 0.9$ s, $T_0 = 6500$ K, and $T_m = 10^4$ K. For NE and S, the lower curves correspond to the case when non-thermal collisional rates are ignored. Higher curves were obtained with $dF/dt = 10^4 \text{ erg cm}^{-3} \text{ s}^{-1}$. Both NE and S are normalized to their initial values at $t = 0$. (a) $n_H = 10^{13} \text{ cm}^{-3}$, (b) $n_H = 10^{14} \text{ cm}^{-3}$, (c) $n_H = 10^{15} \text{ cm}^{-3}$.

⇒ (1) Slow relaxation of S, Ne (2) Initial dip of S

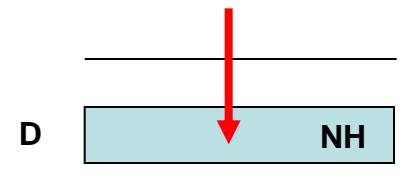
A CHROMOSPHERIC RESPONSE TO PULSE BEAM HEATING

PETR HEINZEL

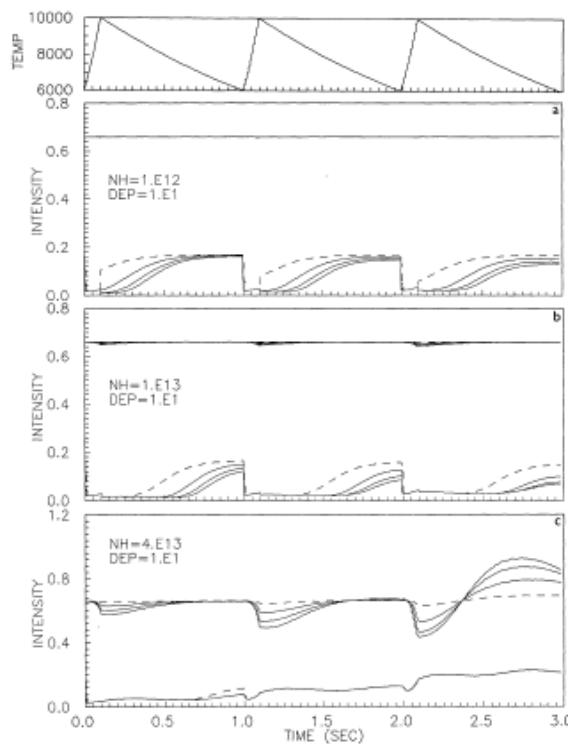
Astronomical Institute, 251 65 Ondřejov, Czechoslovakia

Solar Physics 135: 65–88, 1991.

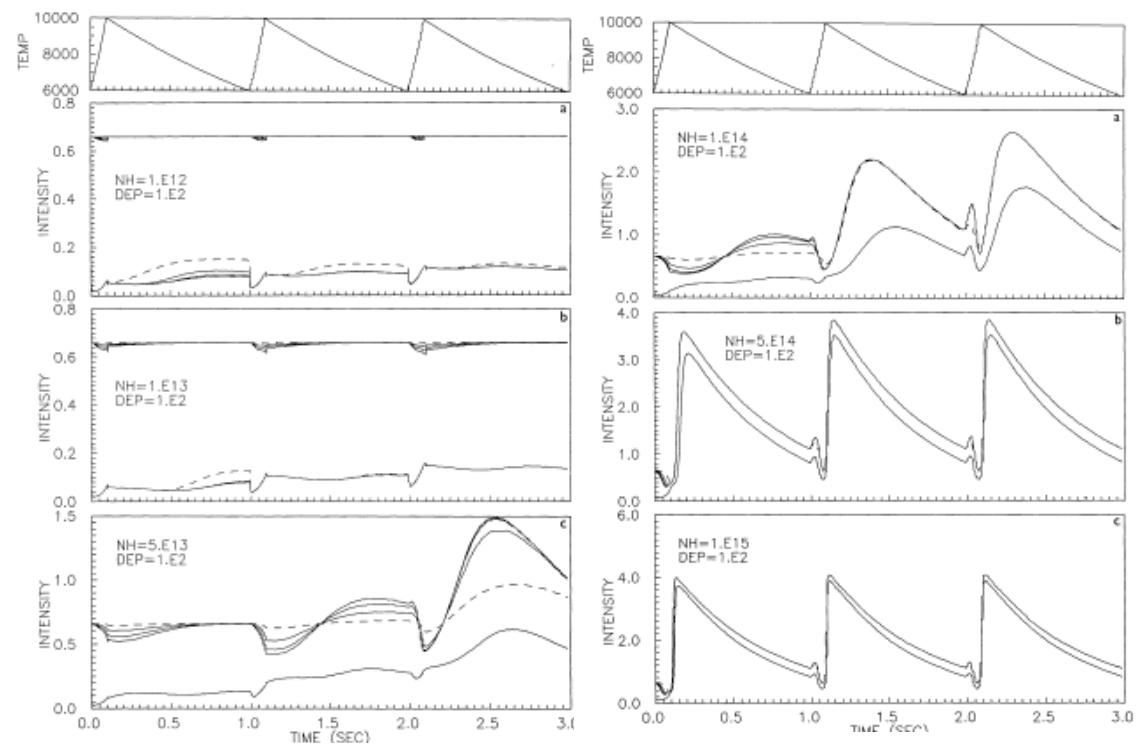
H α Intensity Time Profile (Multiple Beam Injection)



Weak Beam



Strong Beam



A CHROMOSPHERIC RESPONSE TO PULSE BEAM HEATING

PETR HEINZEL

Astronomical Institute, 251 65 Ondřejov, Czechoslovakia

Solar Physics **135**: 65–88, 1991.

- **Upper layer Injection**

$\text{H}\alpha$ intensity peaks **lag behind** the beam injection (tens of seconds)

- **Middle layer Injection**

$\text{H}\alpha$ intensity **gradually increases** along time with darkening at injected instances

- **Lower layer injection**

$\text{H}\alpha$ intensity **simultaneously variates** with the beam injection profile

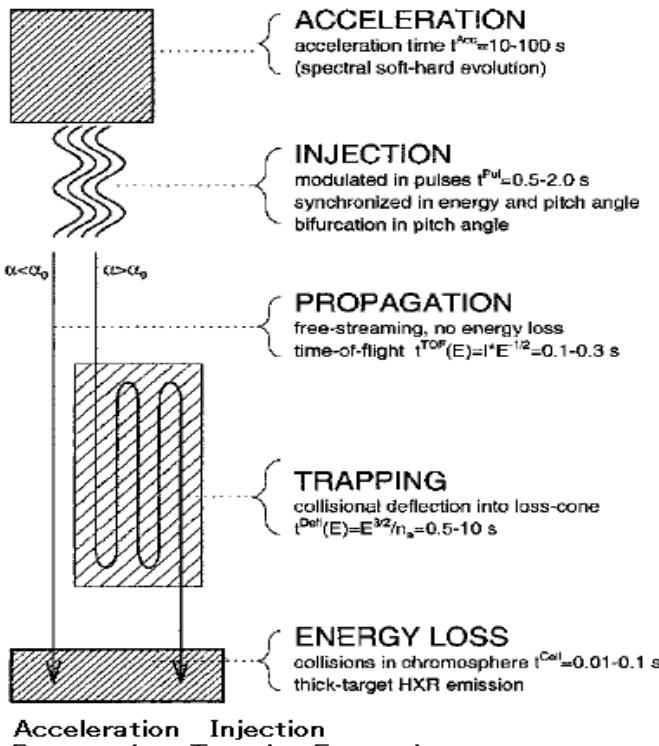
Slow relaxation of excitation and recombination

Initial dip of $\text{H}\alpha$ source function

Electron Time-of-Flight measurements during the Masuda Flare, 1992 January 13

Markus J. Aschwanden et.al. APJ, 464:985-998, 1996

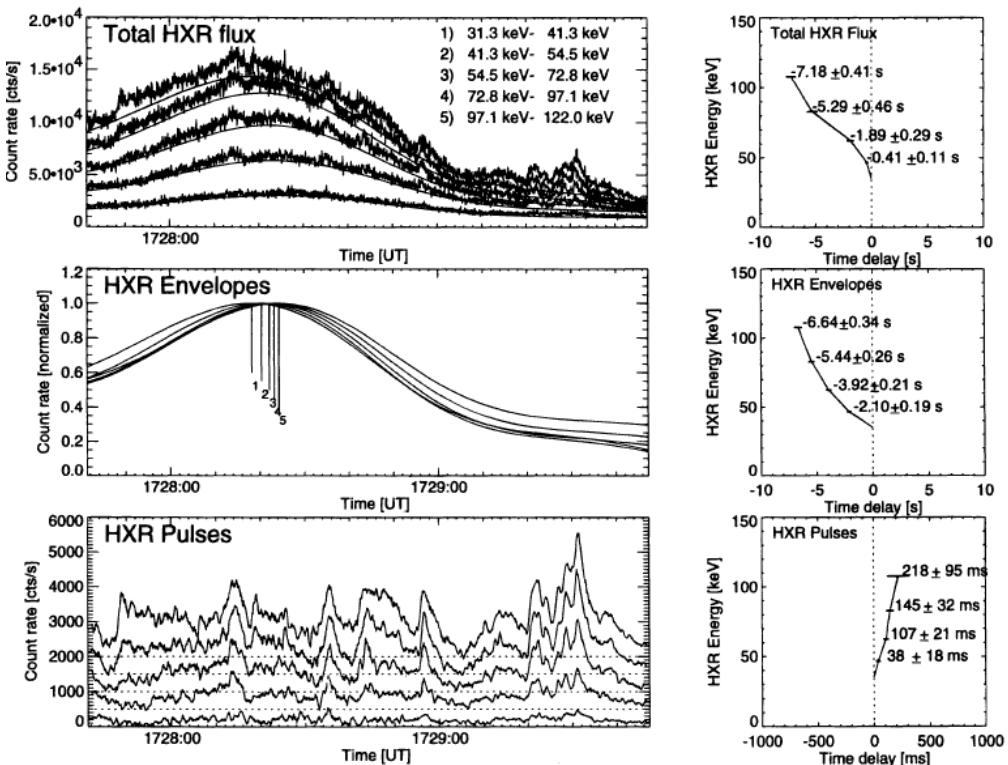
Model Assumptions



$$t_i^{\text{X}} = t_i^{\text{acc}} + t_i^{\text{prop}} + t_i^{\text{loss}}$$

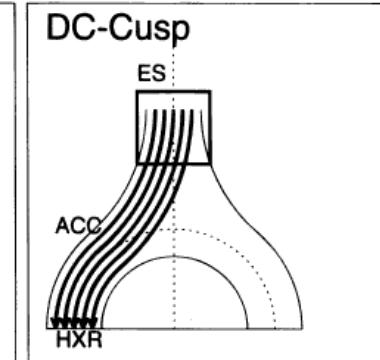
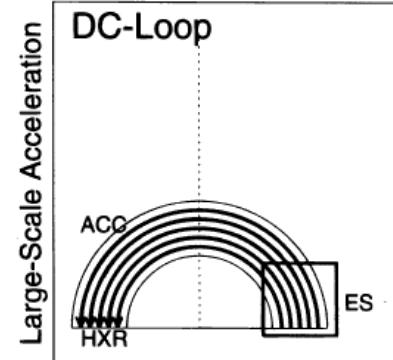
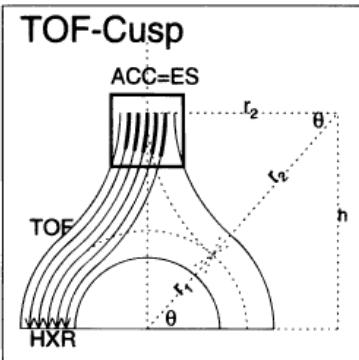
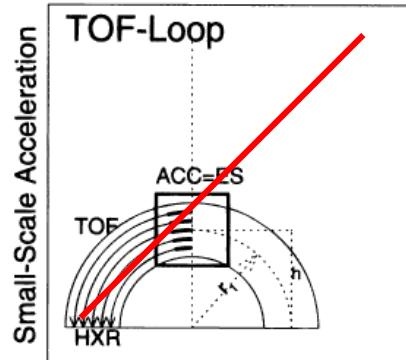
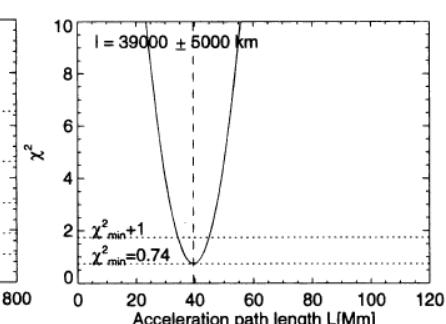
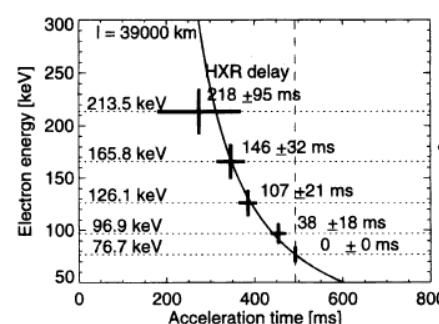
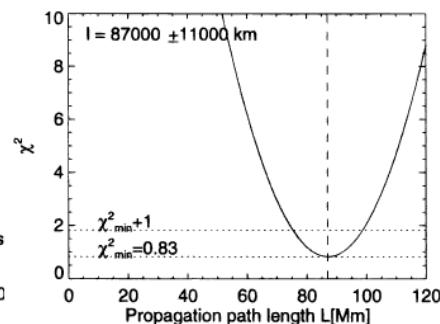
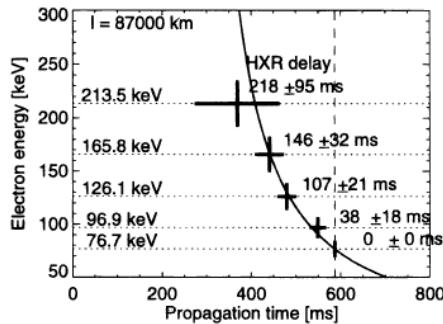
$$= \frac{c}{a} \sqrt{\gamma_i^2 - 1} + \frac{l}{c} \frac{1}{\sqrt{1 - \gamma_i^{-2}}} + t_i^{\text{loss}}(\gamma_i)$$

HXR flux with a time resolution 64ms (top) by BATSE/CGRO decomposed into lower envelopes (middle) and into pulsed components (bottom)



Electron Time-of-Flight measurements during the Masuda Flare, 1992 January 13

Markus J. Aschwanden et.al. APJ, 464:985-998, 1996



$L' = 47,000 \text{ km}$

$L' = 33,000 \text{ km}$

まとめ

- Elementary Burst (これまでの観測結果)
 - Duration ≤ 0.3 秒
 - カーネルサイズ $\sim 1''$
 - ΔI 0.2%
 - Cusp/Loop 加速
 - ? Temporal correlation
 - ? Time lag
- H α カーネル高時間分解能観測
 - 時間分解能 10 - 1 msec \Rightarrow 高速カメラ
 - 高空間分解能 0.2'' \Rightarrow Seeing AO
 - 高精度測光 0.1 - 0.01% \Rightarrow 大口径
 \Rightarrow Scintillation AO

Atmospheric Intensity Scintillation of Stars. III. Effects for Different Telescope Apertures

D. Dravins, L. Lindegren, E. Mezey and A. T. Young

Publications of the Astronomical Society of the Pacific, 110:610–633, 1998

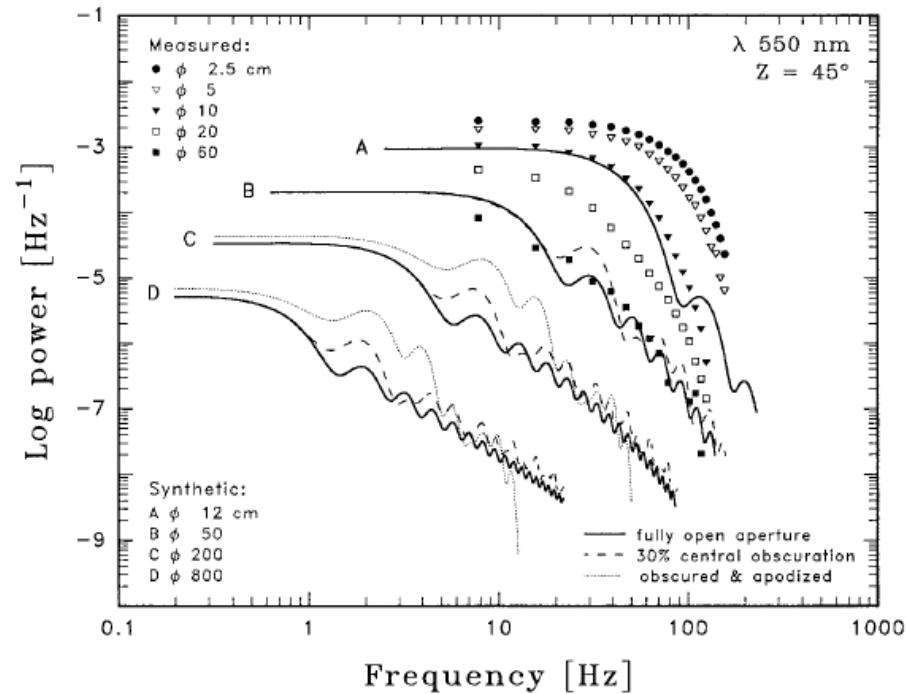
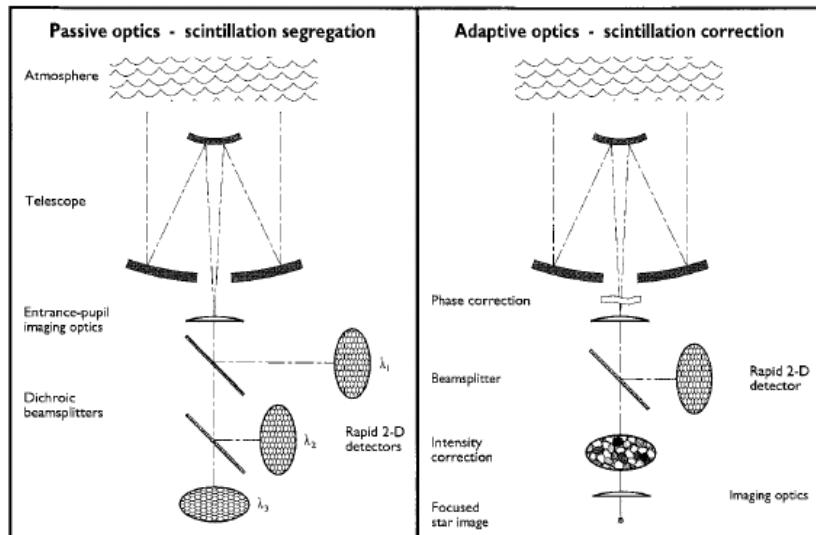
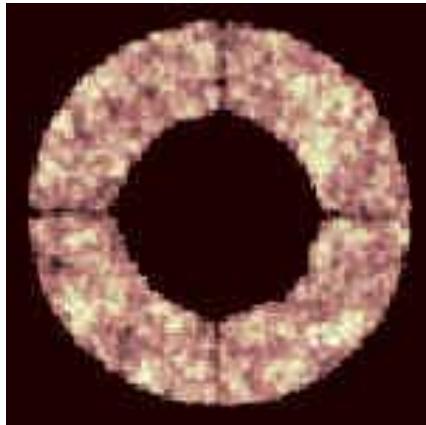


Fig. 1.—Power spectral density of scintillation in telescopes of different size. The symbols are values measured on La Palma for a sequence of small apertures.

Their fit to a sequence of synthetic spectra predicts the scintillation also in very large telescopes up to 8 m diameter. Bold curves are for fully open apertures. A central obscuration (secondary mirror) increases the scintillation power, while apodization decreases it for high temporal frequencies.

END

RHESSI

- Spatial Resolution

2 " to 100 keV

7 " to 400 keV

36" above 1 MeV

- Time Resolution

Tens of msec for a basic image

2 seconds (half a rotation of the spacecraft) for a detailed image

