The Real Time Flare Monitor System in HSOS

怀柔太阳观测基地实时耀斑爆发监测系统

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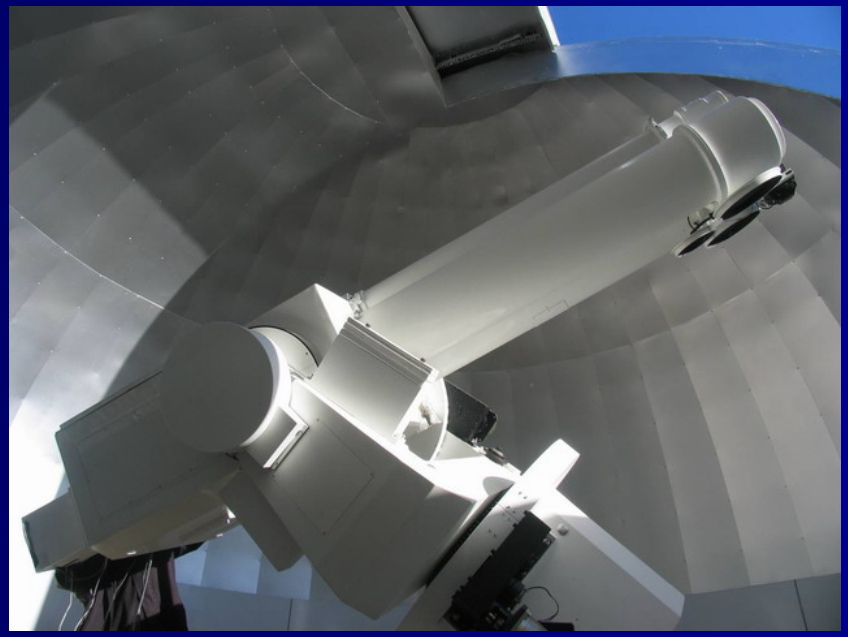
Outline of the talk

- Introduction
- Researches about the Algorithm
- Test results of the system
- What’s Next?

Origin of the system —— 缘起

Solar Magnetism and Activity Telescope (SMAT)

太阳磁场与活动监测望远镜



SMAT comprises two telescopes, one is for the measurements of full disk video vector magnetic field and the other is for full disk Ha observations. SMAT began to work with the first light at the end of 2005. In order to investigate the global magnetic configuration and the relationship with solar activities synchronously, we put two telescopes on the same mounting. (双镜同轴)

Origin of the system-缘起

- Problem（现有观测模式存在的问题）

  Routine Ha data miss the key period of a flare----the rising phase （判断滞后）

  Data overflow blured the structure of kernel of a flare.（数据溢出）

  Frame rate is too slow （帧速过慢）

- How to .....?（如何解决现存的问题）

  Detect the onset of the flare automatically

  Change the parameters of the CCD and grabber intelligently

Grab fine structure of the flare kernel

捕获耀斑核块的演化特征

- Aim of the system（目标）

  1）High speed grab and store, with the function of Real Time Flare on-set detecting and Exposure time controll.so as to catch the fine structure of the flare kernel.(高速采集、存储，自动调节观测参数)

  2）No manual intervention, the observing software could be more robust and effecient.（无须人工干预，自动稳健运行）

- Meaning（意义）

  Catch more fine features of the flare kernel, this is important for solar physics and space weather forecast.（捕获耀斑核块处的演化特征，探寻触发源点）

High speed solar flare observing systems

- 1986，Hida grab a data set, 1 f/s
- 1989，Goddard Space Flight Center, 10 f/s
- 2000，Big Bear,30f/s, with 15s interval for every group of data. CCD：512×512×10
- 2003，Poland astronmer,20f/s,Hα data record system. CCD：512×512×10
- 2004，Purple mountain,25 f/s,local Hα data record system. CCD：659×494
- 2006，Huairou Solar Observatory,48 f/s full disk Hα data record system, with GPS stamp. CCD：992×1004

Our ideas——Combination

融合高速观测与智能化算法

- Higher speed hardware （高速硬件）

- Intelligent algorithm （智能化算法）

  Region-based feature recognition?

  Neutral Network Learning algorithms?

  Support Vector Machine

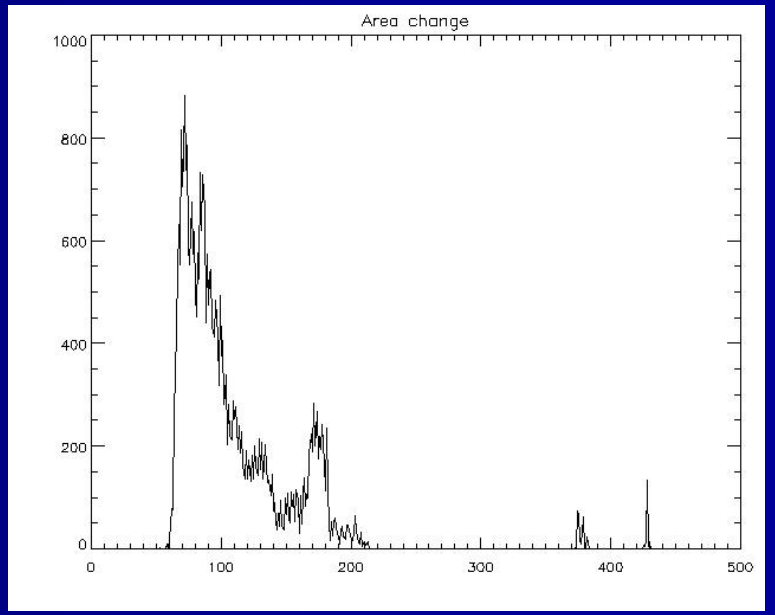
  ……

Main feature of the Ha flare

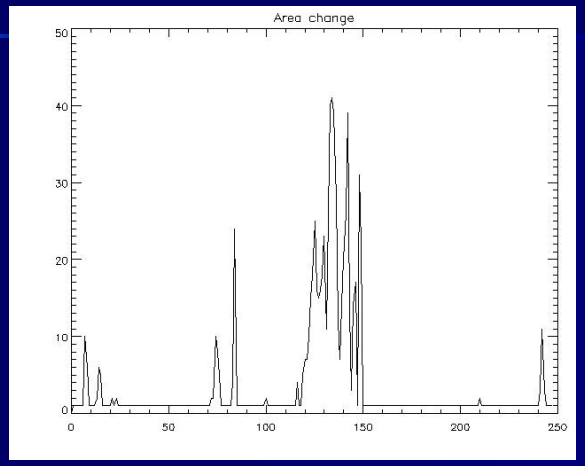
Ha耀斑的观测特征

The density of the flare rise several or dozens of times rapidly in a time from dozens to hunderds of seconds. the desecending is slowly.

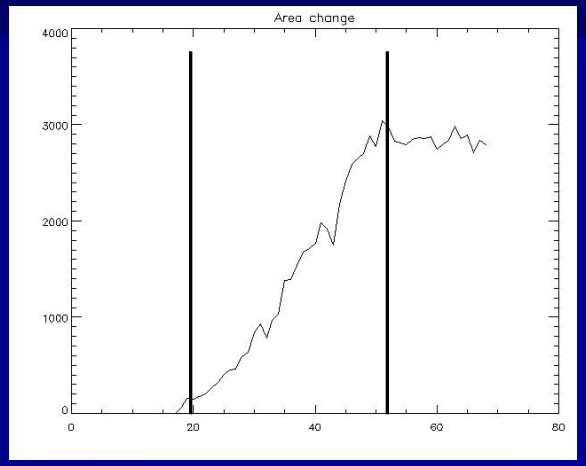
（快速增亮）



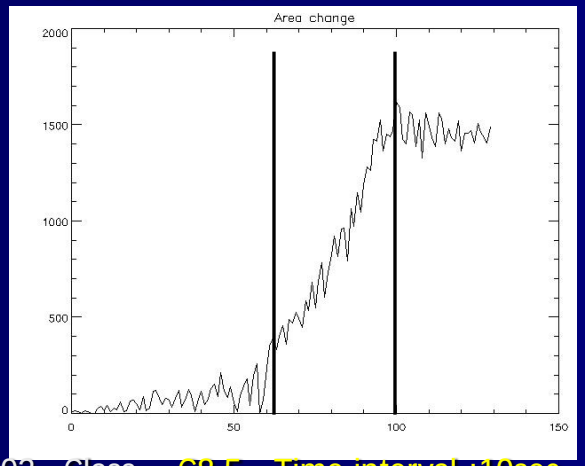
Statistical Results



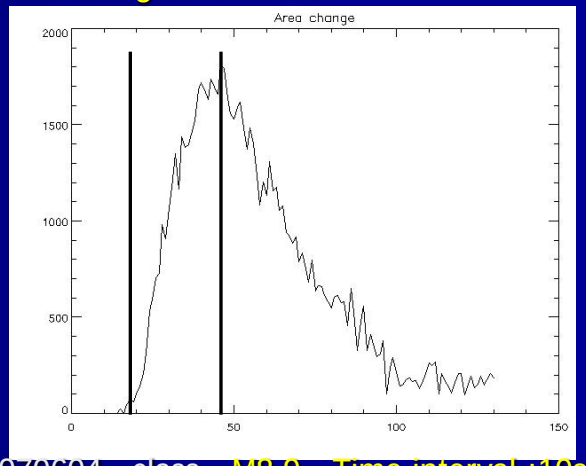
060705 Class：B 3.5~7.0 inteval :1 minute，



060706 耀斑等级：M 2.5，time interval: 10 sec，rising time:300sec



070502 Class： C8.5，Time interval :10sec，rising time :400sec

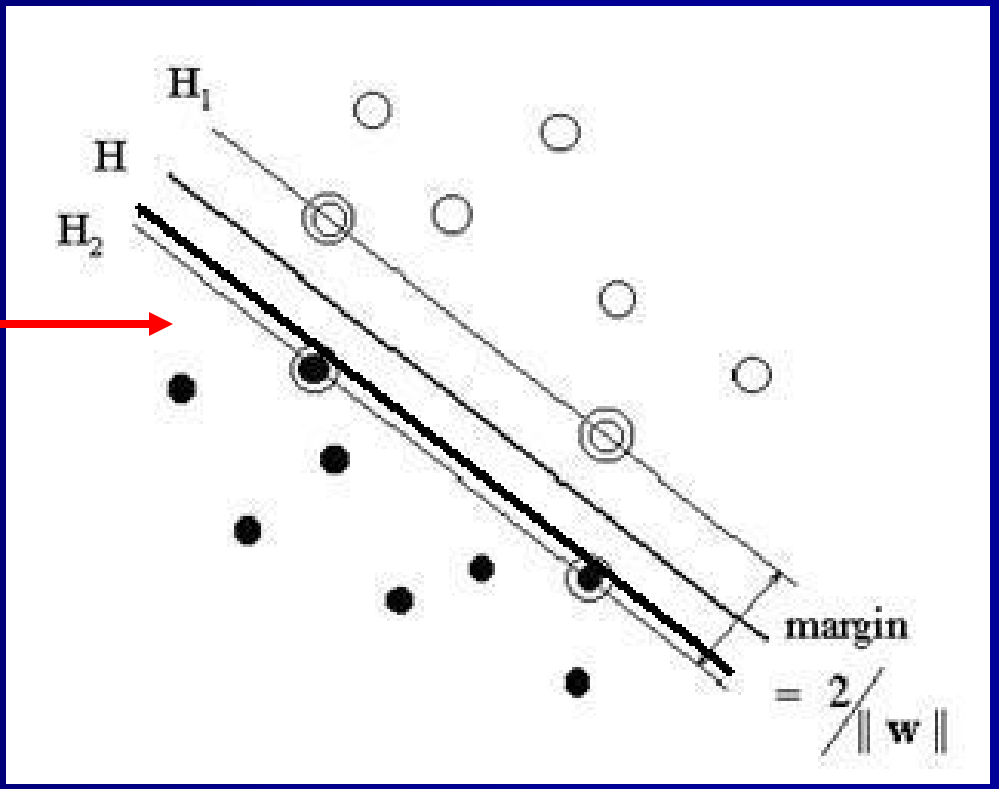


070604 class：M8.9，Time interval :10sec，rising time :300sec

Simplify the principle

实时应用-化繁为简

- few error and never miss
- best VS reliabe



Real time flare onset detecting algorithm

实时耀斑爆发监测算法

- Adaptive Threshold Segmentation Algorithm （自适应阈值分割）
- The optical flare classification
  Mean * 2.5
  15×15＝225 pixels (C 5.0 above)
- X-ray flare classification
  200 C class flare

High speed Hardwares

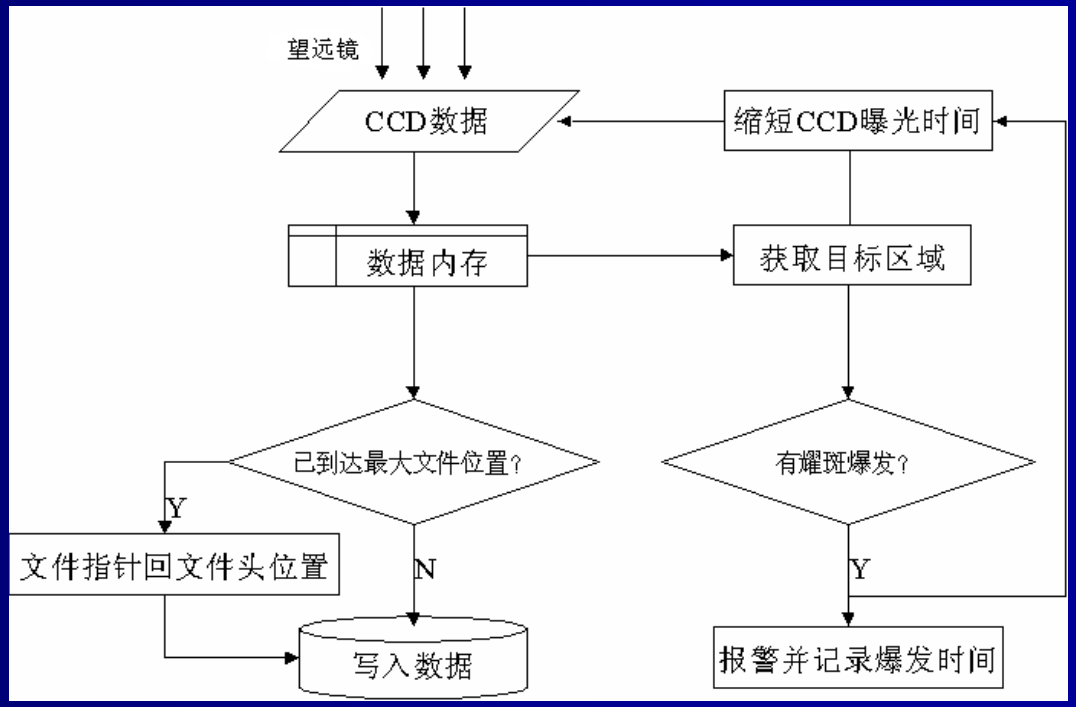
- CCD （48帧/秒）
  Imperx 1M48，1004×992×12，48 f/s
  data pipe： 1004×992×2×48≈96MB/S
- GPS time stamp
  PCI-1751 & GPS module
- Graber，（最快528 MB/s）
  XL64-Dual，PCI-64，
  Max speed：528MBytes/S
- Computer，（12核CPU，12G内存，15.7K磁盘阵列）
  T7400 （12 core CPU，12G memory）
  RAID 0 （500G×2, 15K7 high speed data disk），
  Record speed:
  .NET test program：6G Bytes/ minute, about 100MB/S

Flow chart

High speed grab and record.

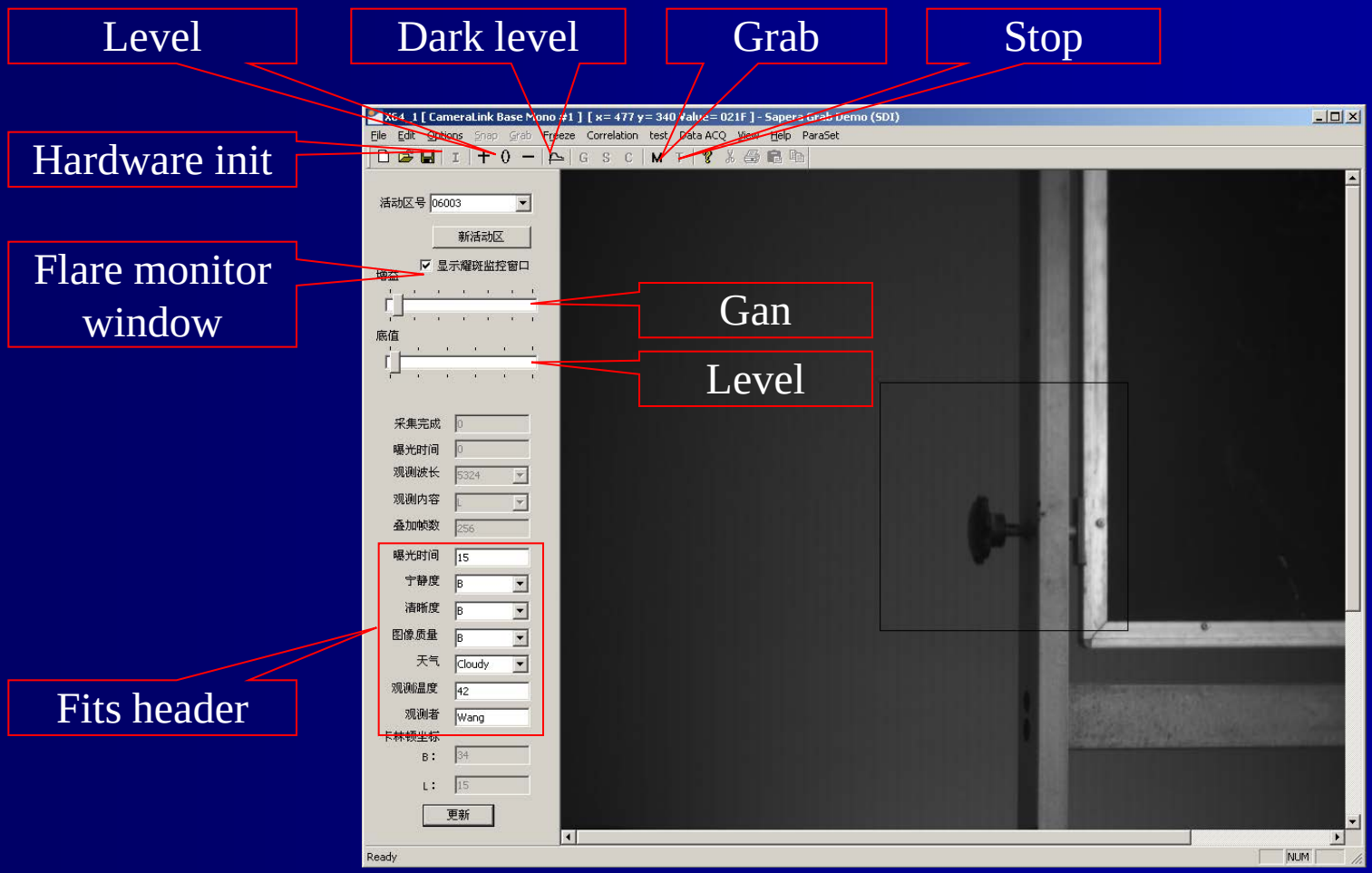
Flare on-set detecting and alarm.

Exposure time controll and Cycling record



Flow chart of the program

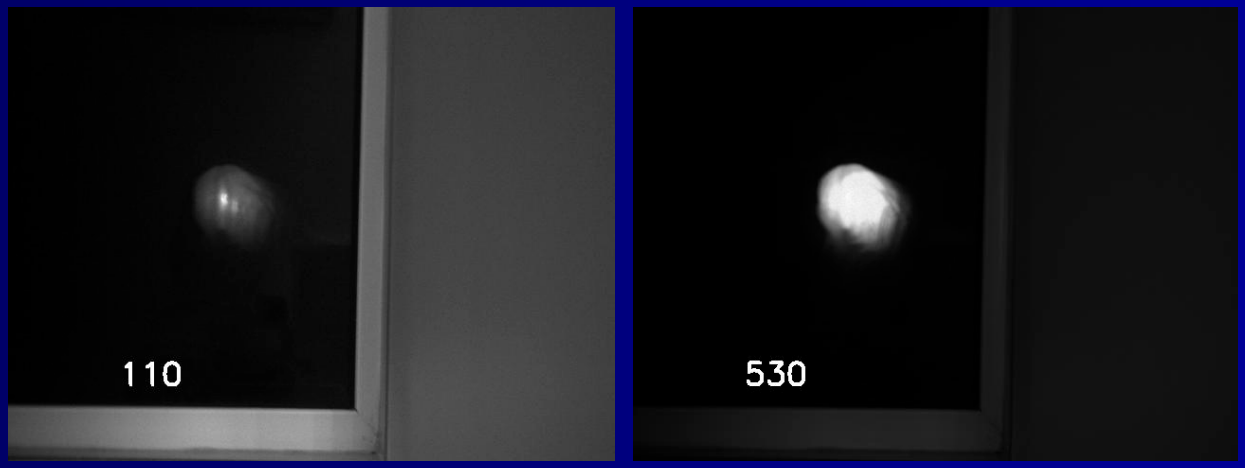
System Ⅰ User interface



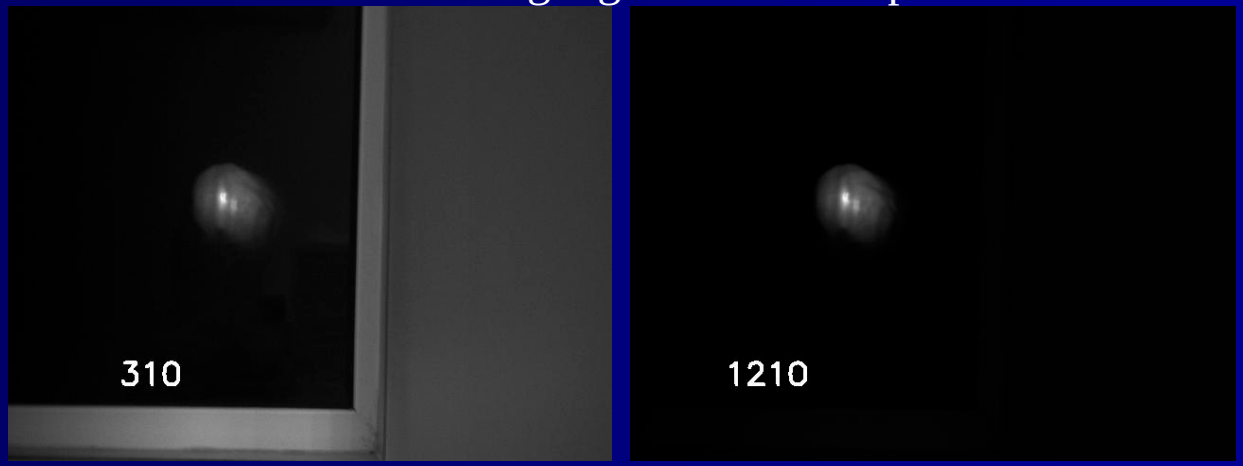
Experiment to test the Algorithm

- The lightness of the lamp is increased from dark to bright, and the process is recorded by two program, one adopted the algorithm, the other not. Their results are compared
- Process time：16sec (simulate the process of the on-set of a solar flare，用一个亮度可调的光源模拟耀斑过程)
- Frame rate of the CCD：48 F/S
- Work mode: all data recoreded

Test result



No Flare detecting algorithm and exp time control



Flare detecting algorithm and exp time contrl

How to controll the exposure time?
曝光时间控制哪种方法更好？

- Constant minus？（常数递减）
- Half？（逐次减半）
- Exponent?（指数递减）
- Any other better?

Flare and Space weather

- **How often does the flare happen?**

  Multiple ones a day around the solar maximum.

- **How do the flares affect us?----Space weather**

  The energy that's released by a flare heats up and accelerates charged particles i.e. electrons, protons and nuclei. These energetic particles produce the X-ray, gamma-ray and radio emission that we see during the flare

- Researches had revealed that big flares are closely related to the geo-storms.（研究大太阳耀斑和地磁爆密切相关，所以监测耀斑爆发很重要）

Current monitor or forecast systems
现有的监测/预报系统

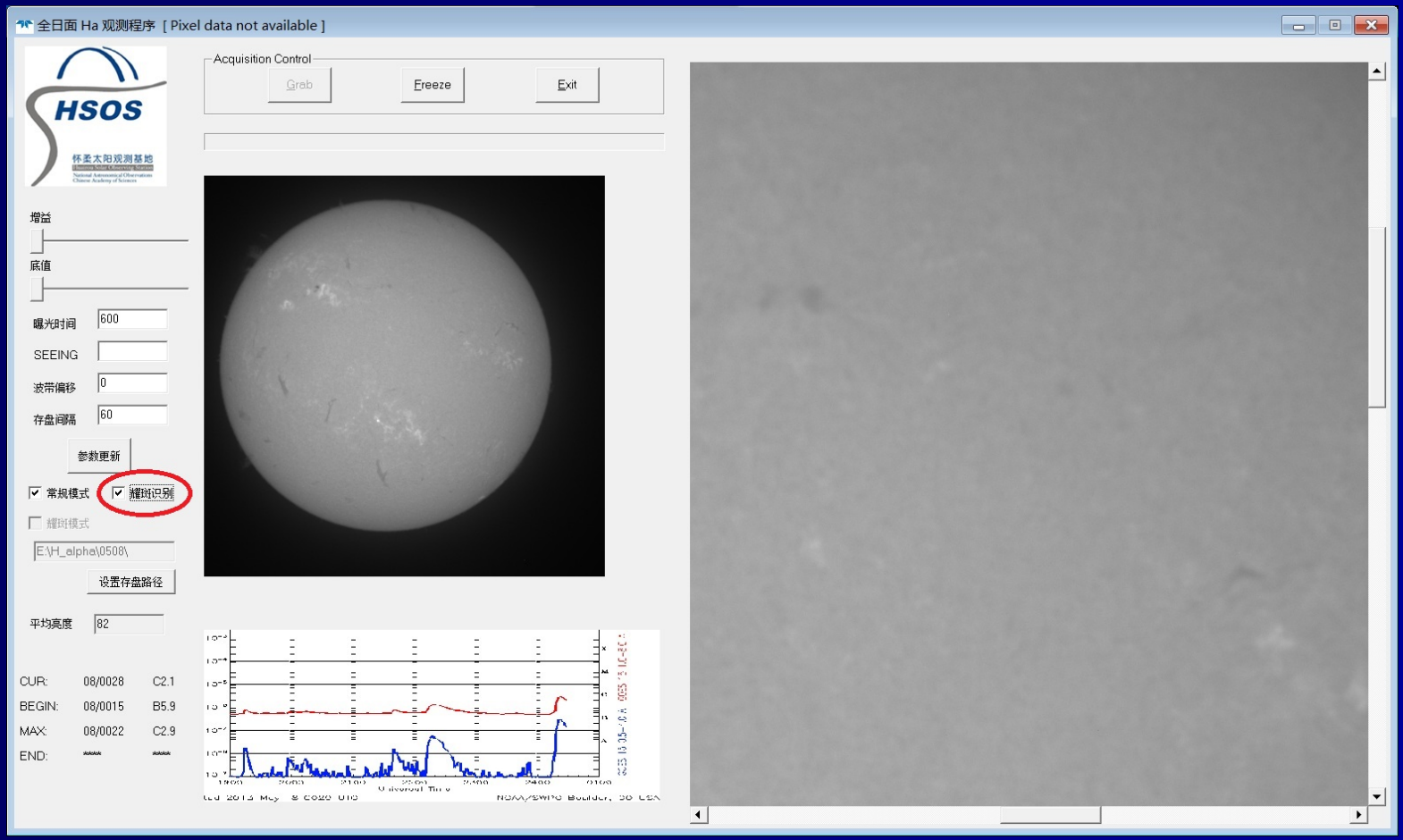
- There are many Flare/CME forecast methods and system. （预报系统、方法，无数，不详述）

- The Air Force Weather Agency (AFWA) has begun the process of upgrading the Solar Observing Optical Network (SOON) with an Improved-SOON (ISOON). The H-alpha instruments at the GONG sites have been in operation collectively since the beginning of 2011, providing one to three H-alpha images per minute Cross-site comparison and calibration of flare detection has begun using an image analysis tool called SWIFT (SWFL/ISOON Flare-cast Tool). （美国空军2011年升级了光学太阳监测网络，并特别针对Ha耀斑监测开发了智能化识别系统---多台Ha望远镜交叉验证识别结果）

The Real Time Flare Monitor System

- The recognition algorithm is ready
- The telescope is operated daily
- Embedded to the routine observation
- 算法融入常规观测软件 + Email 报警

System II
Real Time Flare Monitor



Algorithm and Conditions

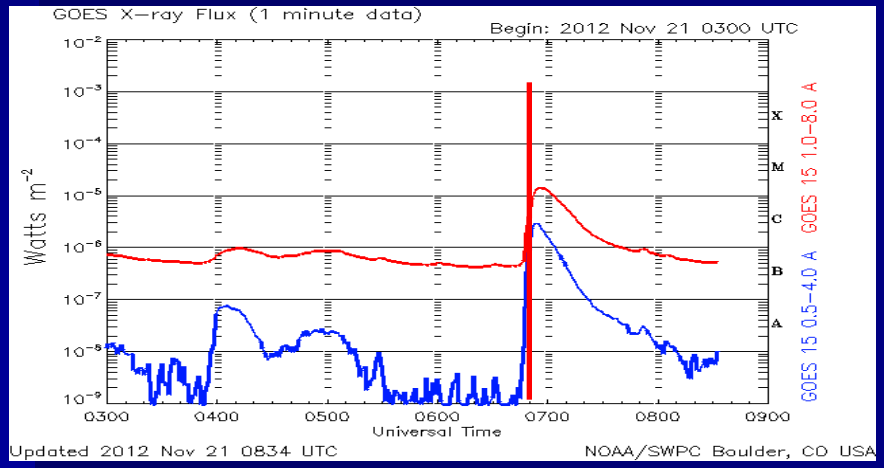
- Primary parameters set and bad weather judgments （预设亮度，坏数据剔除）
- Auto Threshold segmentation （自适应阈值分割）
- Detect the flare onset and Send alert Email （耀斑识别，发送报警）

Feature of the current system

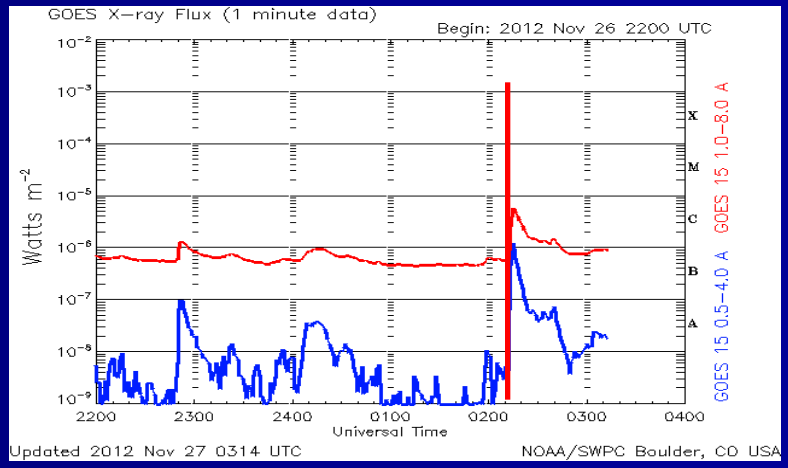
- All Functions for the routine observation
  （所有常规观测的功能都有，科学观测+应用服务）
- Real time (seconds level) Flare onset Detection（耀斑爆发实时识别，时间精确到秒）
- Email Alert combining Goes X-Ray（邮件报警功能，提供耀斑面积信息和Goes X-Ray等级信息）

Events 2012-11-21、27

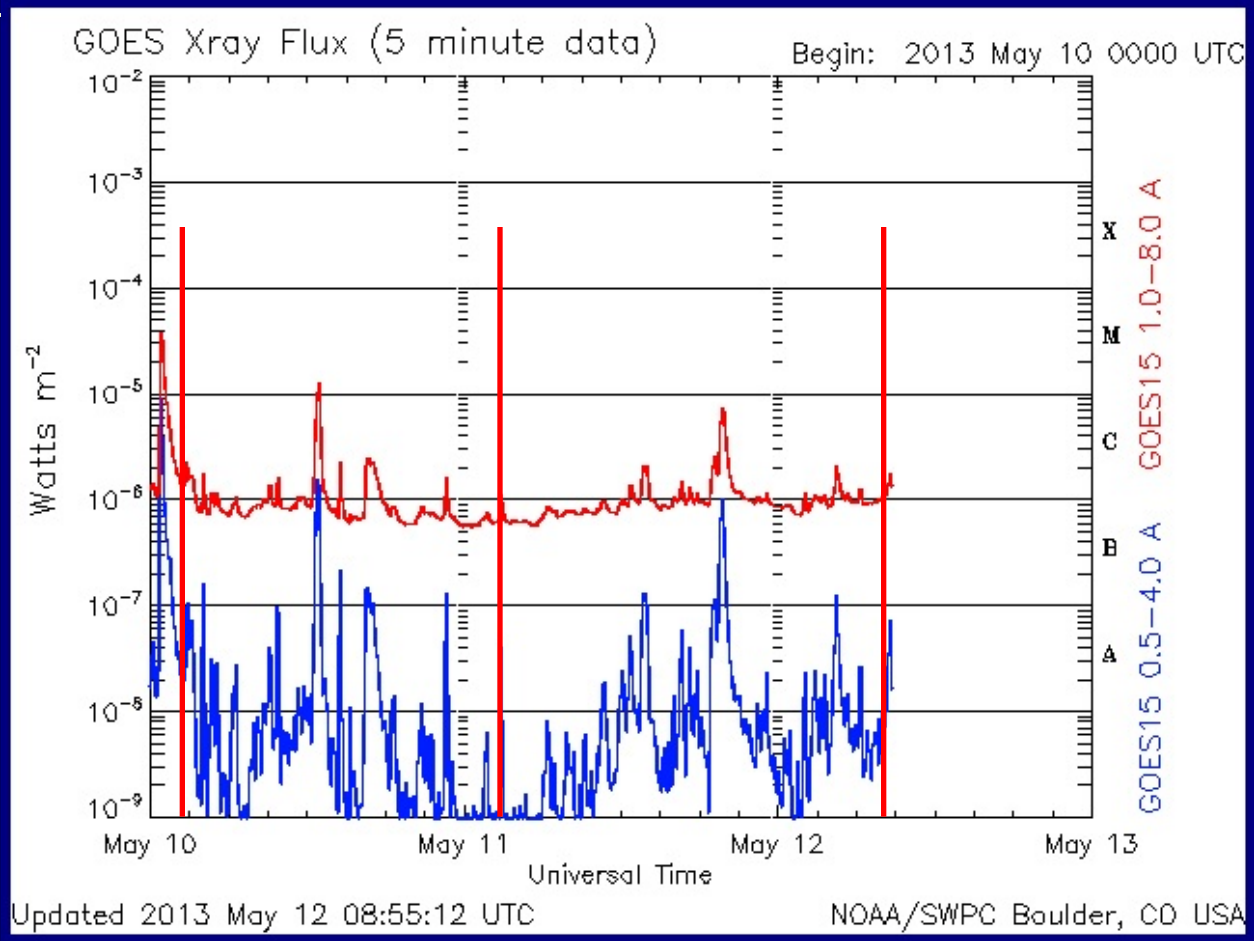
- 发件人：hsos_system@163.com
  发送日期：2012-11-21 14:53:16
  收件人：jiaben.lin@163.com
  主题：Flare Detected
  怀柔太阳基地 智能化Ha耀斑实时监测系统 识别到一个可能的耀斑爆发，增亮区域面积10*36 （日面面积约4080744），爆发时间：2012-11-21 6:53:3，目前对应的GoesX耀斑等级为C6.3，请关注。



- 发件人：hsos_system@163.com
  发送日期：2012-11-27 10:15:27
  收件人： jiaben.lin@163.com
  主题：Flare Detected
  怀柔太阳基地 智能化Ha耀斑实时监测系统 识别到一个可能的耀斑爆发，增亮区域面积10*36 （日面面积约4080744），爆发时间：2012-11-27 2:15:11，目前对应的GoesX耀斑等级为B9.3，请关注。



2013年5月10~12日

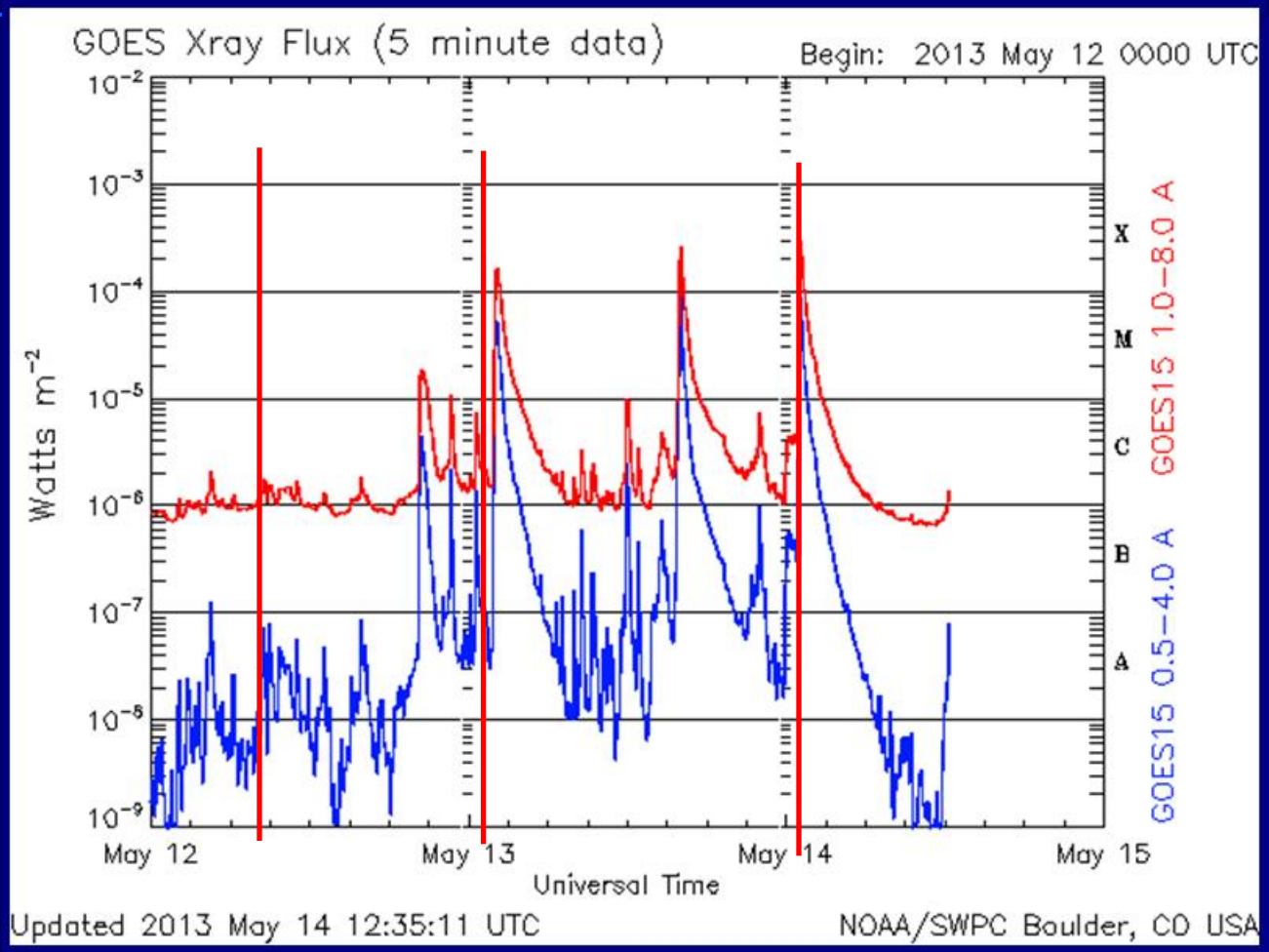


天气影响，尤其是飘云影响比较大。

改进自适应阈值方法，效果更好一些。

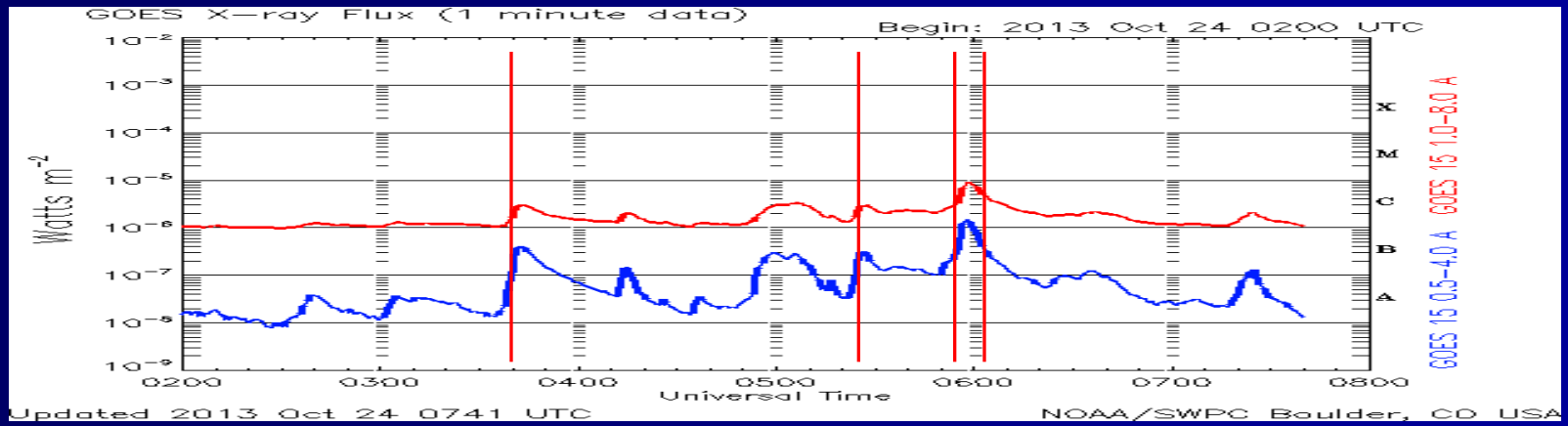
2013-05-10 01:47:07　2013-05-11 02:54:59　2013-05-12 08:33:45

2013年5月12~14日



2013-05-12 08:33:45 2013-05-13 01:21:37 2013-05-14 01:07:01

2013年10月24日



怀柔太阳基地 智能化Ha耀斑实时监测系统 识别到一个可能的耀斑爆发，增亮区域面积352 （日面面积约4080744），
爆发时间：2013-10-24 07:23:38，目前对应的GoesX耀斑等级为C1.7，请关注。

怀柔太阳基地 智能化Ha耀斑实时监测系统 识别到一个可能的耀斑爆发，增亮区域面积331 （日面面积约4080744），
爆发时间：2013-10-24 05:49:58，目前对应的GoesX耀斑等级为C2.1，请关注。

怀柔太阳基地 智能化Ha耀斑实时监测系统 识别到一个可能的耀斑爆发，增亮区域面积324 （日面面积约4080744），
爆发时间：2013-10-24 05:24:18，目前对应的GoesX耀斑等级为C1.4，请关注。

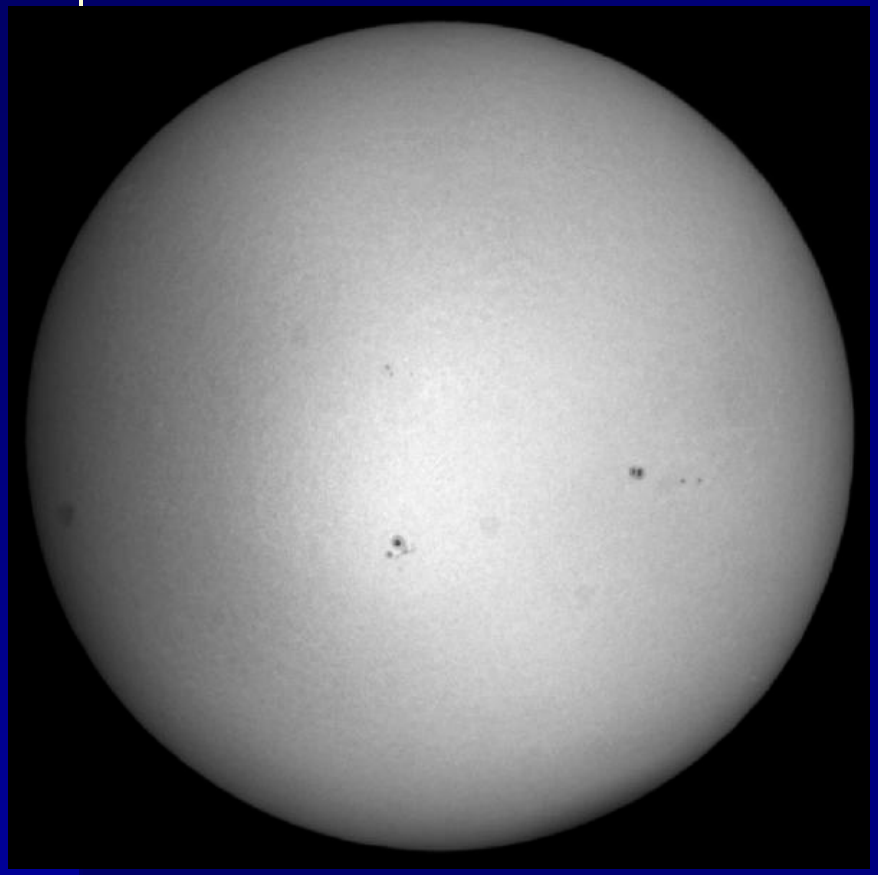
怀柔太阳基地 智能化Ha耀斑实时监测系统 识别到一个可能的耀斑爆发，增亮区域面积3843 （日面面积约4080744），
爆发时间：2013-10-24 03:40:37，目前对应的GoesX耀斑等级为C1.7，请关注。

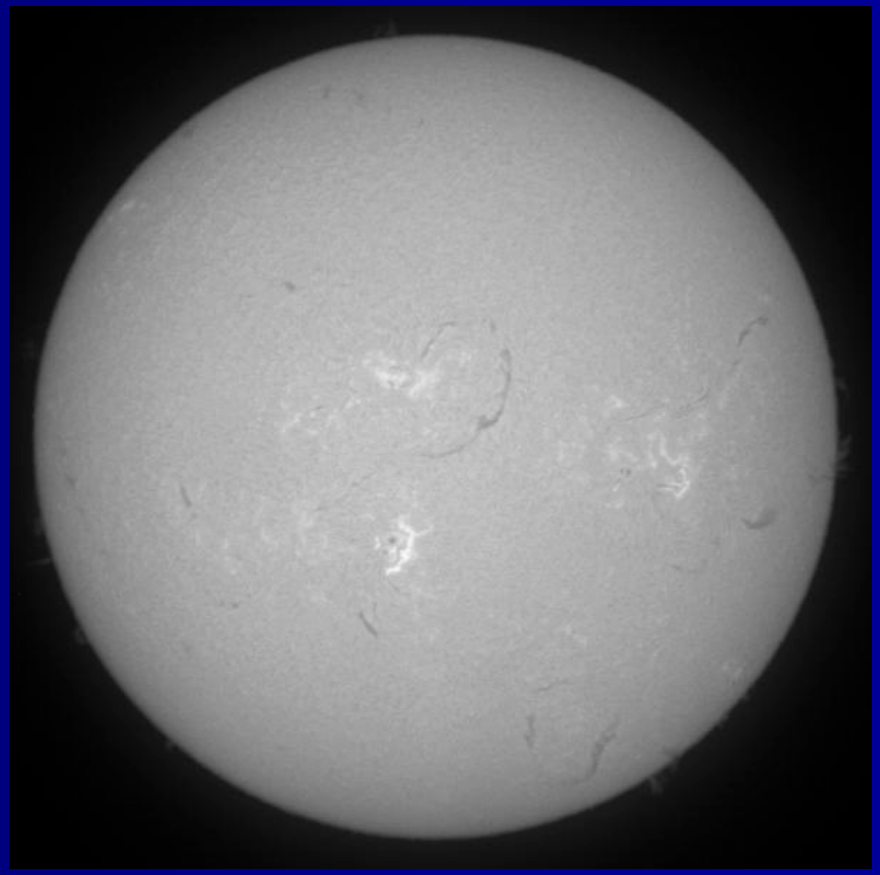
Results Summary

- 2 frames/s, Recognition Algorithm realized in real time. In the test period all the Flares above C5.0 were detected. （帧速率2帧/秒，实时判别。试观测的时间段内爆发的两次Goes X-Ray C5.0级别以上的耀斑均被捕获。）

- The robust of the Algorithm, to avoid error in cloudy weather and detect the smaller flares. （小耀斑：飘云是造成误判、漏判的主要干扰因素）

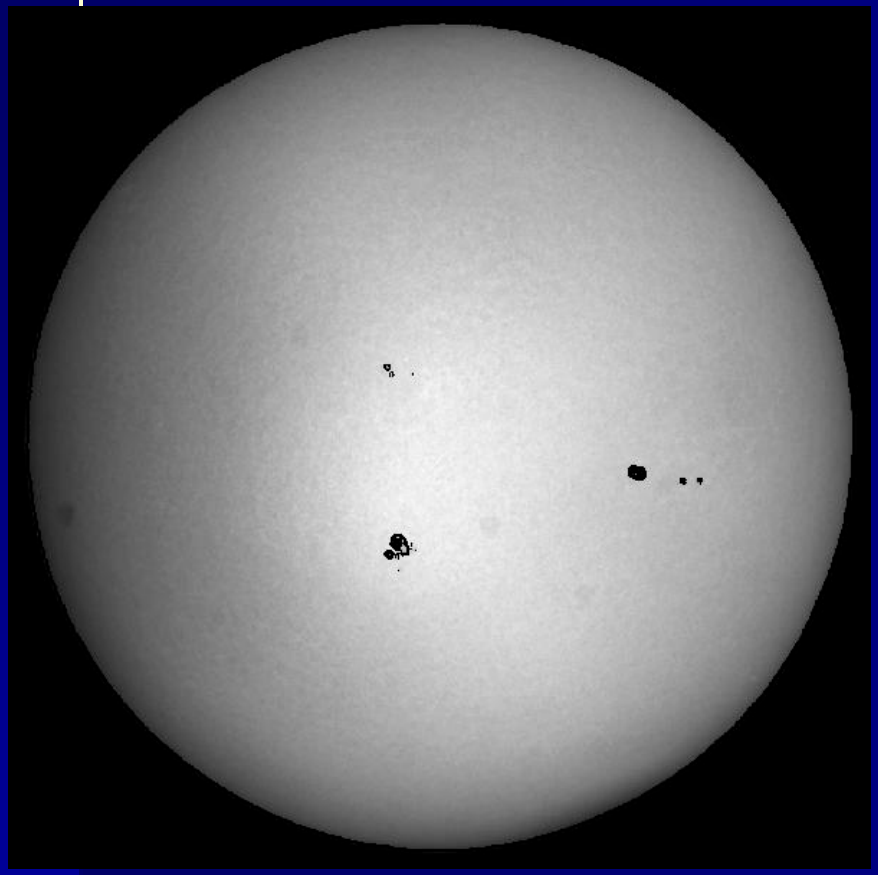
What's next? 下一步

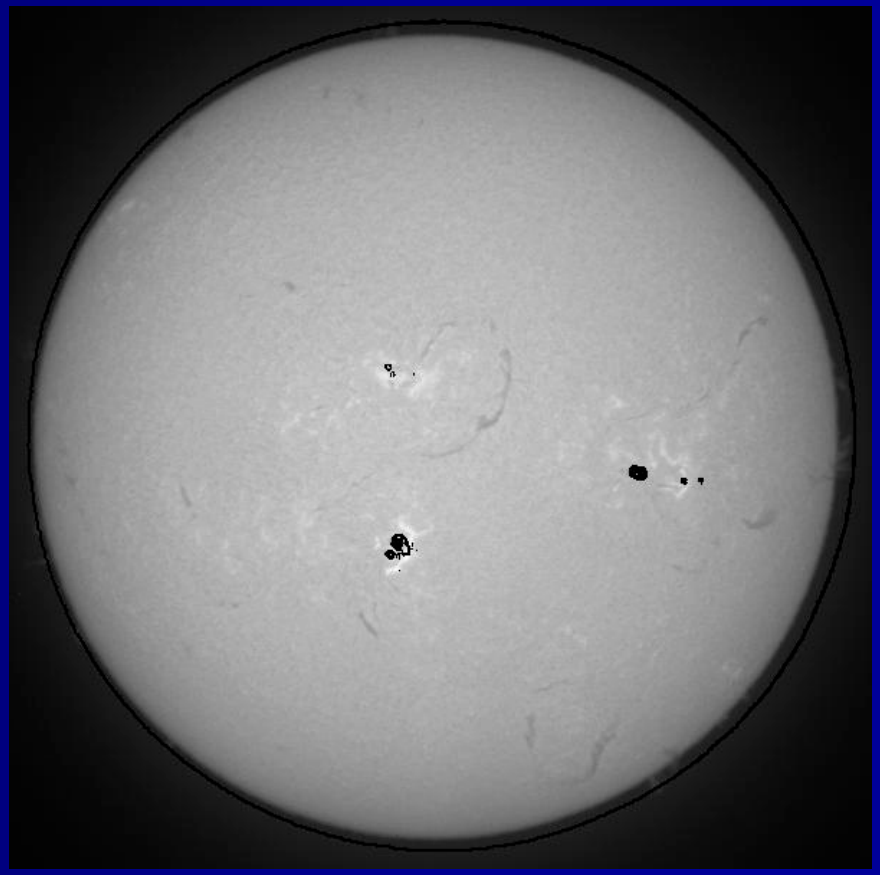




Photospheric image and chromosphere image

Sunspot monitor 黑子监测

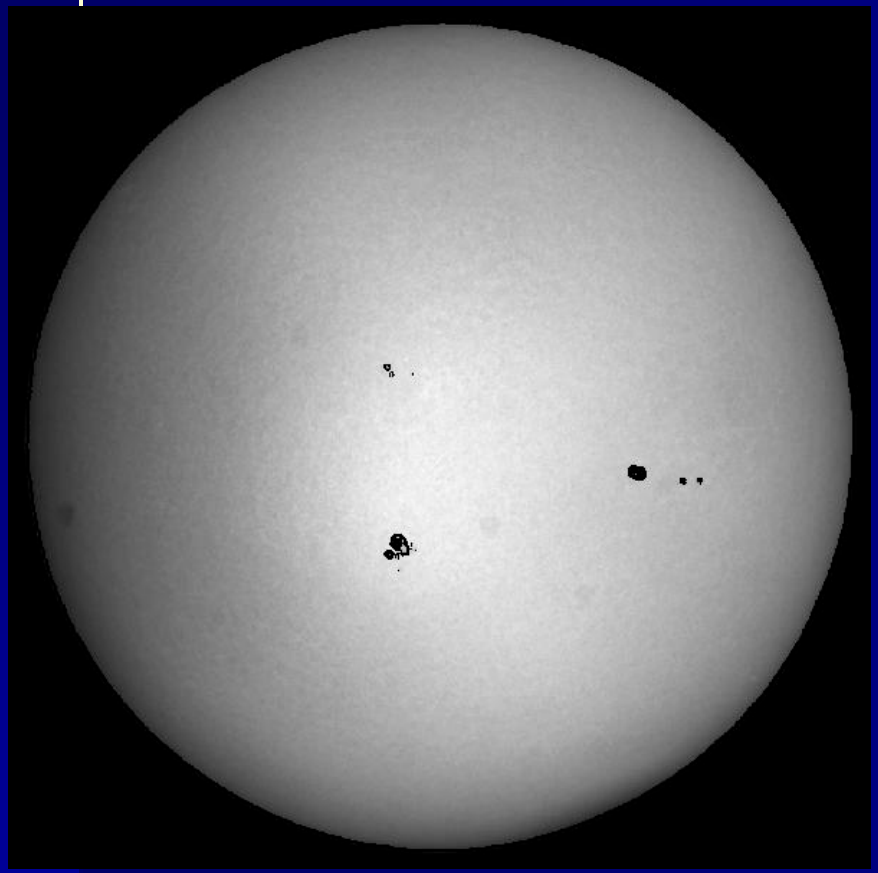


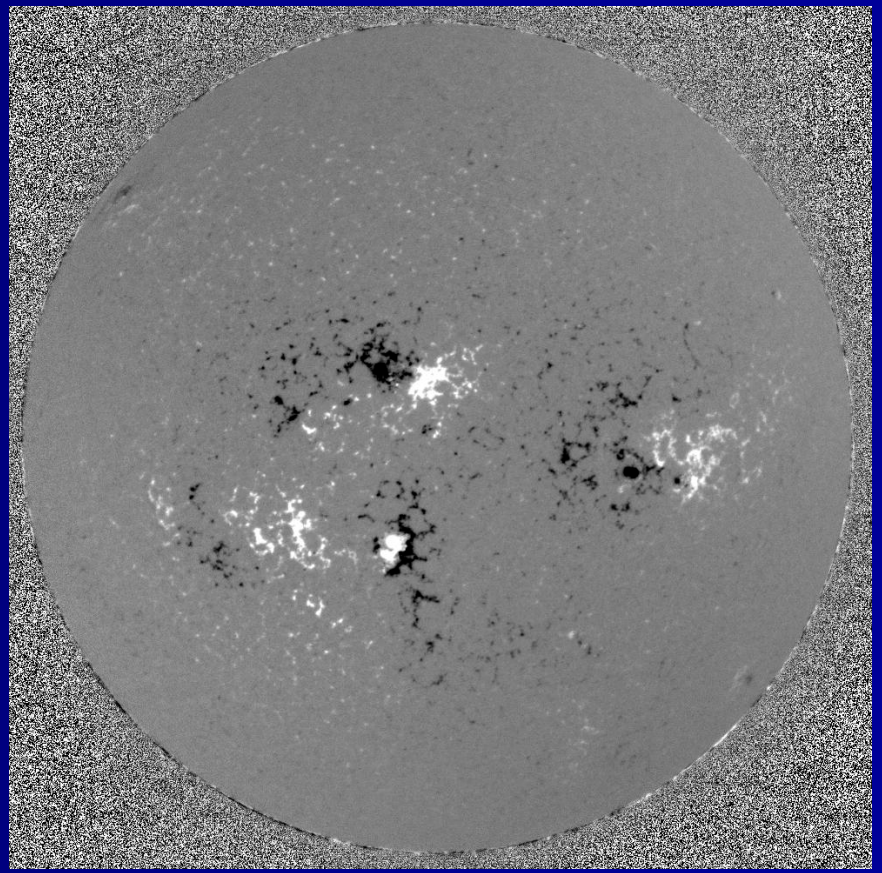


1）Sun spot area and position, 黑子面积变化可能导致耀斑，可以提供预测功能；
2）Flare area and position,大耀斑往往来自大活动区，提高耀斑识别、报警的准确性。

Magnetic Field Parameters

光球磁场参数计算





Magnetic Field Parameter

光球磁场参数计算

- The maximum area of the sunspot group indicates the size of the sunspot group. The larger a sunspot group area is, the more likely the group is to have a complex magnetic field and produce major flares and other solar activities (Sammis et al. 2000) （黑子面积）
- The sunspot dynamics, e.g., fast rotation, and strong magnetic shear in the related AR are of course important factors that determine the productivity of major flares (Yan et al. 2009)（快速旋转、强剪切、新浮磁通）
- High-gradient polarity-separation lines; the total unsigned flux. (Schrijver,2007) （强梯度、中性线、总磁通）
- Helicity？（螺度）

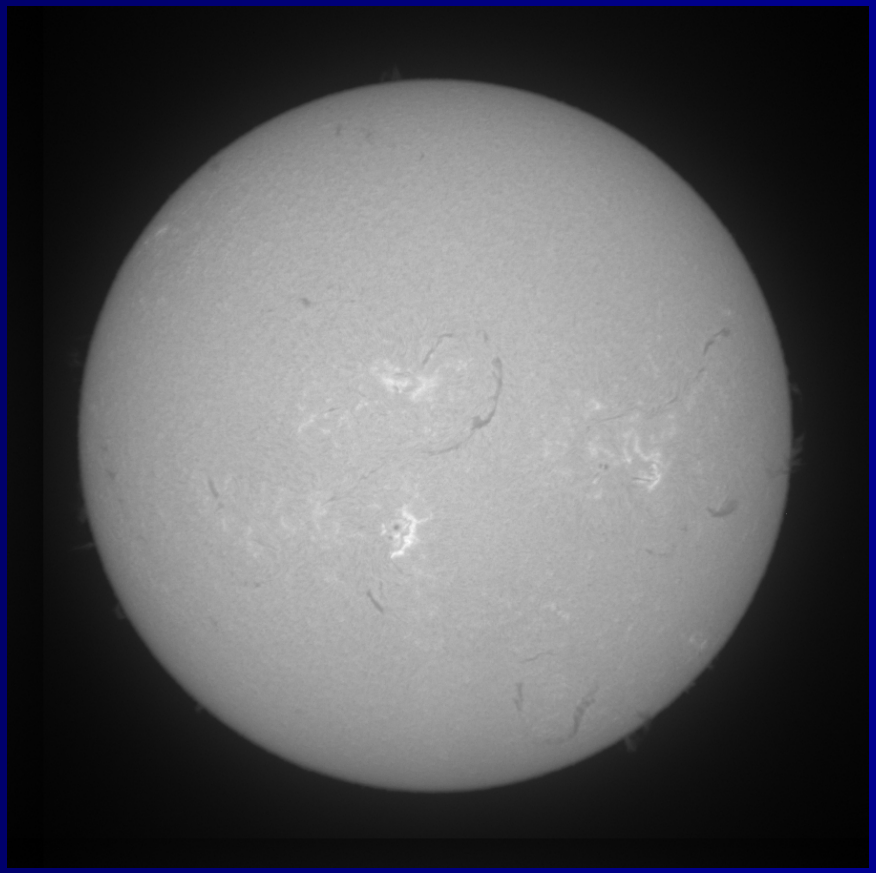
Filament Monitor

- 1. 55 (56%) of 98 events were associated with CMEs. 94% fraction reported by Gilbert et al. (2000) and the 84% fraction by Gopalswamy et al.(2003) （普通暗条爆发与CME事件存在较大概率的伴生关系）

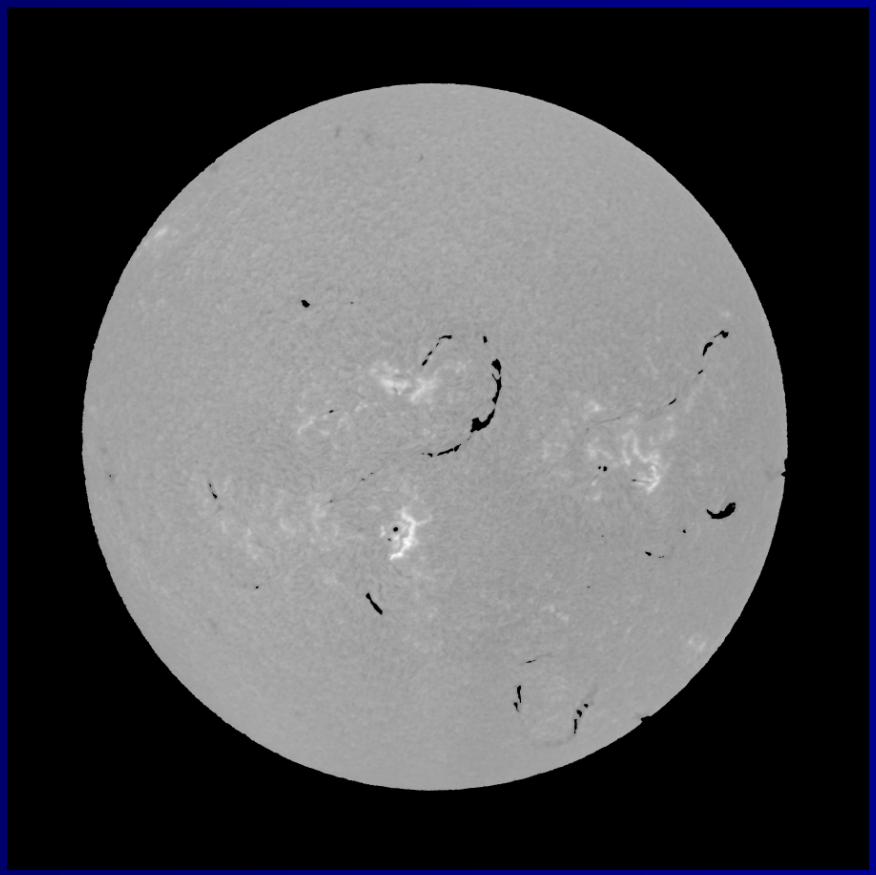
- 2. Active region filament eruptions have a considerably higher flare association (95%) than quiescent filament eruptions with only 27% association. On the other hand, quiescent filament eruptions (85 events) are more likely to be accompanied by CMEs than flares.（几乎所有的活动区暗条爆发都会有CME事件伴随）

- Monitor the big/Active region filaments is meaningful.（实时监测大暗条或者活动区暗条的变化，对空间天气预报是有重要意义的）

Original Data



Recognition Data



Filament Extraction

Summary

- With the simplified algorithm and parameters, the real time flare monitor could detect any flare above C5.0 on the front side of the sun in good weather.（天气晴朗的条件下，日面上C5.0级别以上的耀斑都可以无误的识别到）

- Sunspots and Filaments monitor function is meaningful for space weather and will be added to current system in future。（黑子和暗条监测功能将陆续加入）

THANKS!