

# Beobachten mit modernen Großteleskopen

„Zu Besuch“ beim Very Large  
Telescope der ESO in Chile

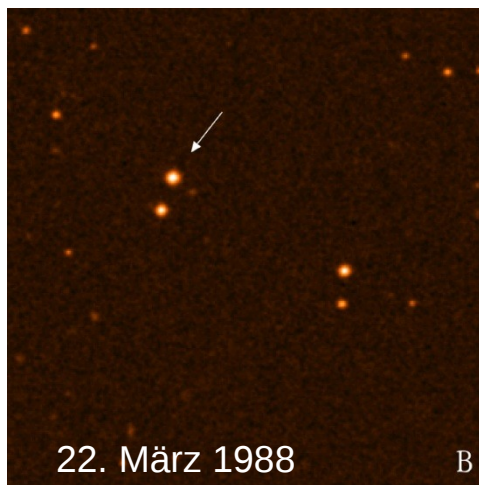
Carolin Liefke

1. Dezember 2016



# Der Stern CN Leo (Wolf 359)

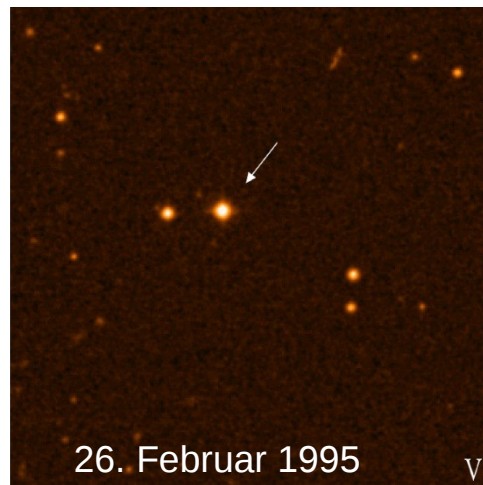
- Von der Sonne aus gesehen der fünftnächste Stern
- Etwa so „hell“ wie Pluto ( $m_V = 13.45$  mag)
- Rötliche Farbe (Spektraltyp M5.5), Oberflächentemperatur ca.  $2500^\circ\text{C}$
- Zeigt Helligkeitsausbrüche (sogenannte Flares)
- Röntgenquelle



22. März 1988

B

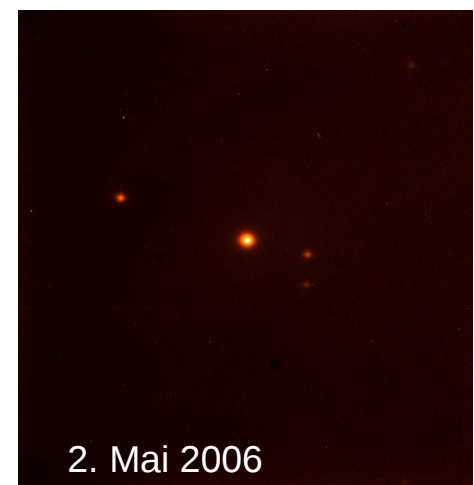
Bild: DSS2



26. Februar 1995

V

Bild: DSS2



2. Mai 2006

Eigenes Bild

# Lichtverschmutzung

- Moderne Großobservatorien befinden sich an abgelegenen Standorten fernab größerer Städte



Blick vom Heidelberger  
Königstuhl über die  
Rheinebene

Eigenes Bild

# Beobachtungsanträge

Von der Idee für ein Forschungsprojekt zu den Messdaten

- Formulierung als Antrag: Welches Himmelsobjekt, Forschungsfrage, wie lange, warum mit diesem Teleskop/Instrument?
- Gutachterkomitee wählt die besten Anträge aus
- Überbuchungsfaktor bei HST, VLT etc. liegt bei 5-7



European Organisation for Astronomical Research in the Southern Hemisphere

OBSERVING PROGRAMMES OFFICE • Karl-Schwarzschild-Straße 2 • D-85748 Garching bei München • e-mail: ope@eso.org • Tel.: +49 89 320 06473

APPLICATION FOR OBSERVING TIME

PERIOD: 98A

Important Notice:

RRM ToO

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of CoIs and the agreement to act according to the ESO policy and regulations, should observing time be granted.

1. Title		Category: D-3							
Chasing stellar giant flares with UVES or X-Shooter in Rapid Response Mode									
2. Abstract / Total Time Requested									
Total Amount of Time: 0 nights VM, 4 hours SM									
We propose to observe a giant stellar flare – so strong that it triggers the BAT detector on-board the Swift satellite – immediately after the flare outburst with UVES or X-Shooter in Rapid Response Mode. Tremendous amounts of energy are released in such an extremely rare event, and optical spectroscopy will allow us to determine how the physical conditions in the lower atmosphere react to this violent change. By monitoring flare continuum emission and the fluxes and shapes of chromospheric emission lines from the UV up into the infrared, we will investigate how the flare energy is redistributed in photosphere, chromosphere, and transition region, and which processes let the stellar atmosphere return to its quiescent state.									
3. Run	Period	Instrument	Time	Month	Moon	Seeing	Sky	Mode	Type
A	98	UVES	1h	any	n	n	THN	s	TOO
B	98	XSHOOTER	1h	any	n	n	THN	s	TOO
C	98	UVES	1h	any	n	n	THN	s	TOO
D	98	XSHOOTER	1h	any	n	n	THN	s	TOO
4. Number of nights/hours				Telescope(s)		Amount of time			
a) already awarded to this project:				UT2		2h in Periods 86-90, 93 and 95, but no observations.			
b) still required to complete this project:									
5. Special remarks:									
The RMM trigger process for the proposed observation of this very rare event will be handled automatically. A script will check alert notices from the Swift satellite for transient sources of stellar origin, check the visibility at Paranal, and send the trigger information for the observations.									
6. Principal Investigator: Carolin Liefke, liefke@hda-hd.de, D, Zentrum fuer Astronomie									

# Die chilenische Atacamawüste

- Liegt im Regenschatten der Anden, der Humboldtstrom verhindert die Bildung von Regenwolken



Luftbild des Paranal-  
Observatoriums. Foto: ESO/M.  
Tarenghi

# Der Berg Paranal

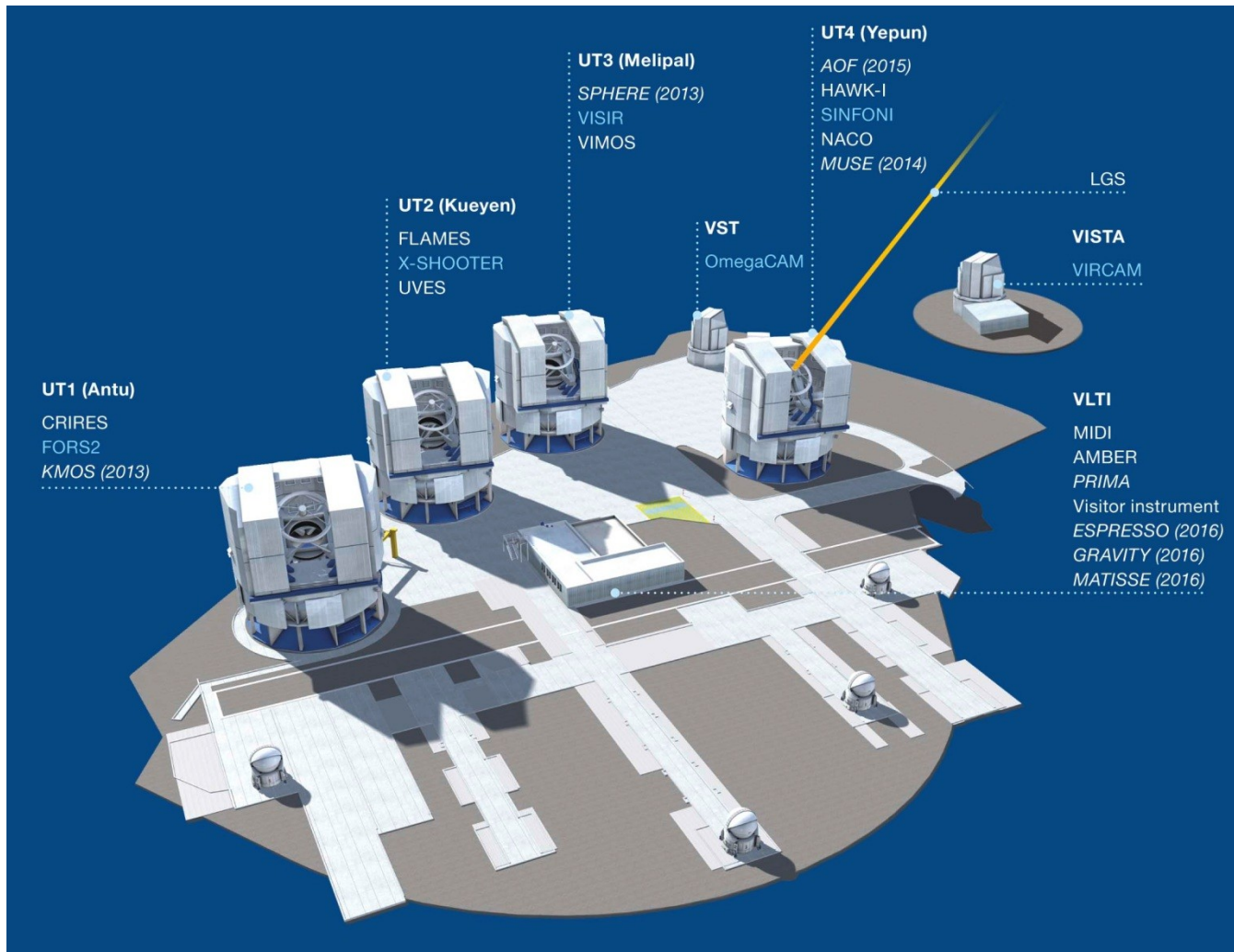
- 2635 m hoch, ca. 120 km südlich von Antofagasta und 12 km von der Pazifikküste entfernt
- Errichtung des Very Large Telescope ab Anfang der 1990er



Die vier Schutzbauten des VLT  
auf der eingeebneten  
Beobachtungsplattform des  
Paranal

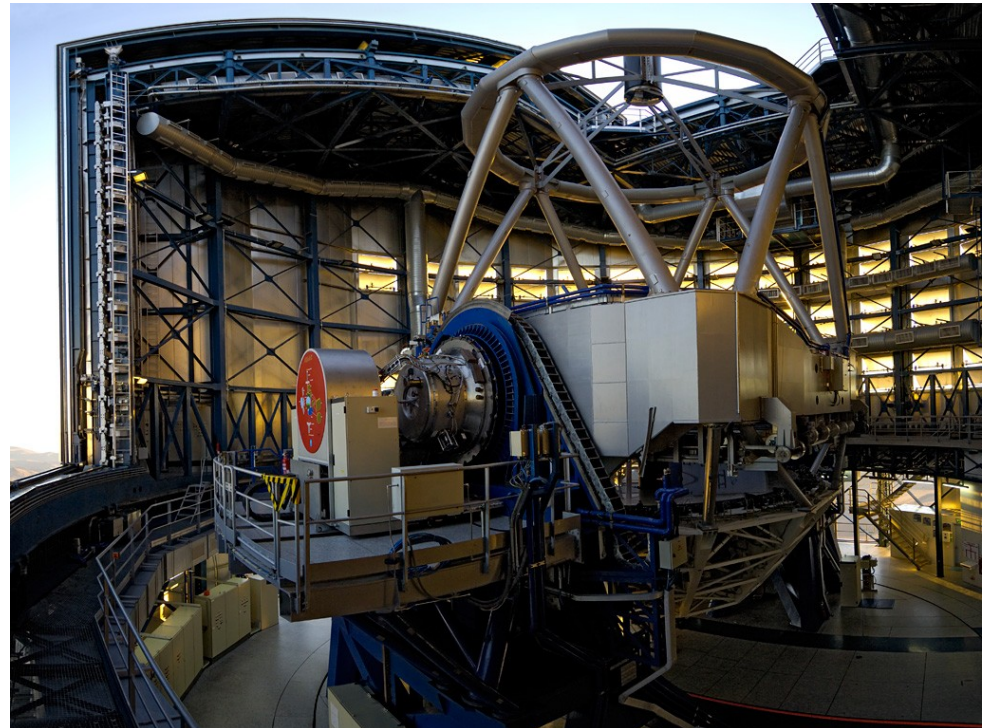
Eigenes Bild

# Das Observatorium



# Die VLT-Hauptteleskope

- Vier Einzelteleskope mit 8,2 Metern Spiegeldurchmesser
- Auch als Interferometer zusammenschaltbar
- Jeweils 3 Instrumente

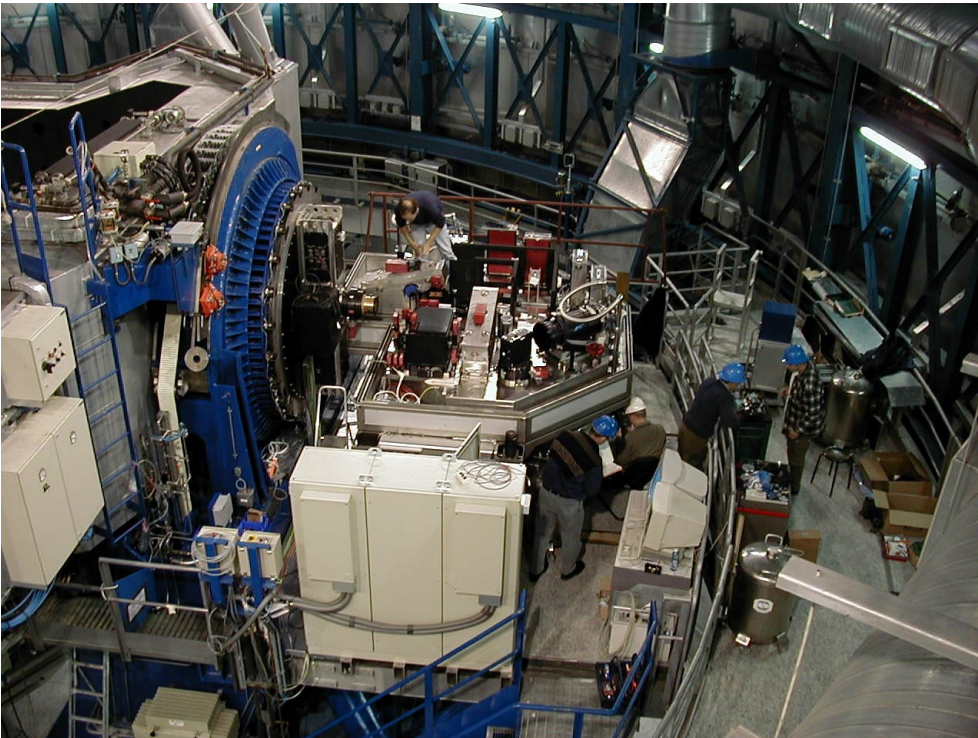


VLT-Hauptteleskop 1. Foto: ESO



# Der UVES-Spektrograf

- Spektralanalyse liefert Informationen über Temperaturen, Rotationsgeschwindigkeit, Elementhäufigkeiten, Sternflecken, Vorhandensein von Planeten...



Installation des UVES-Spektrografen im Jahr 1999. Foto: ESO

# Im Kontrollzentrum



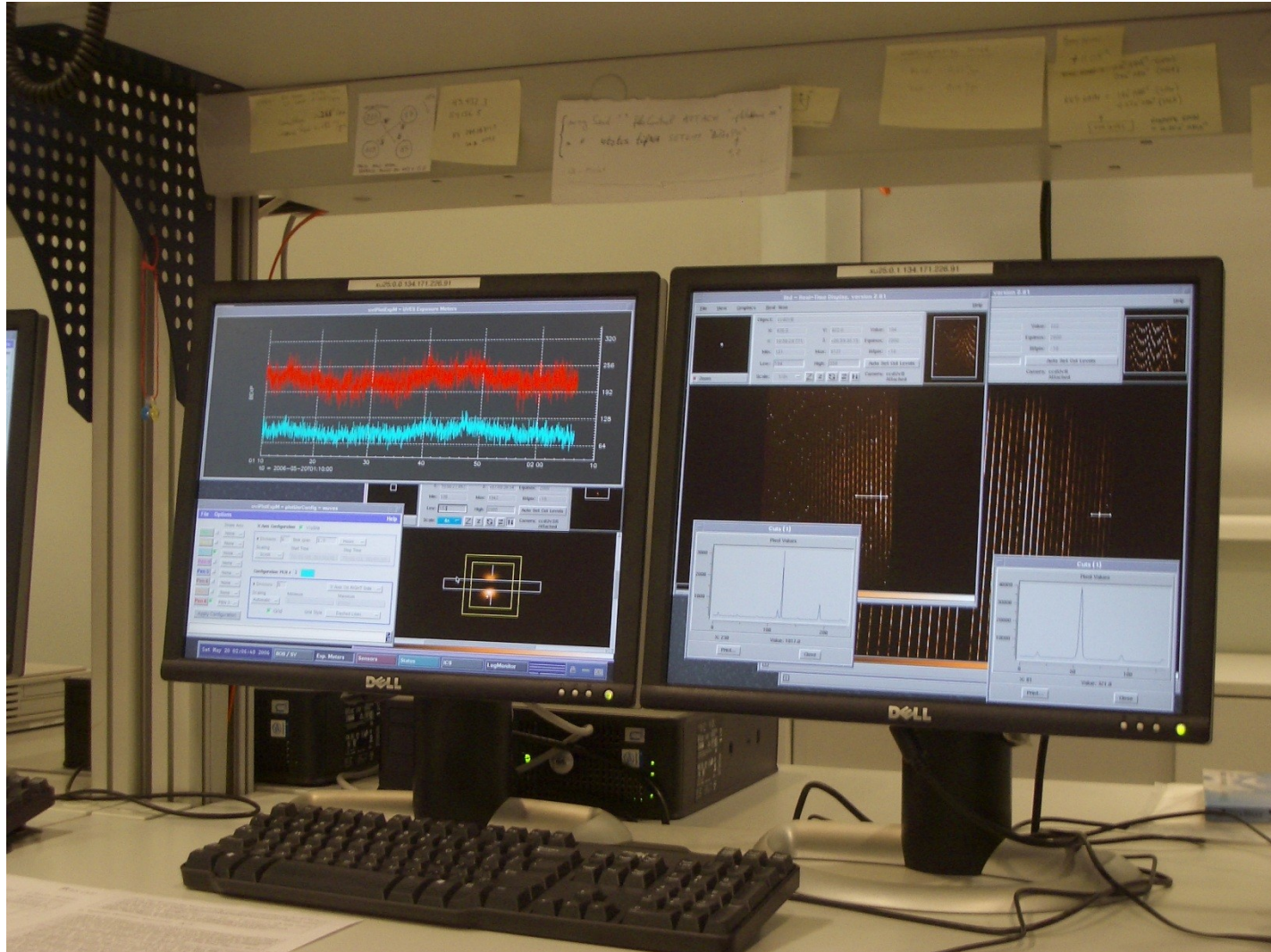
Bild: ESO

# Bei der Arbeit...



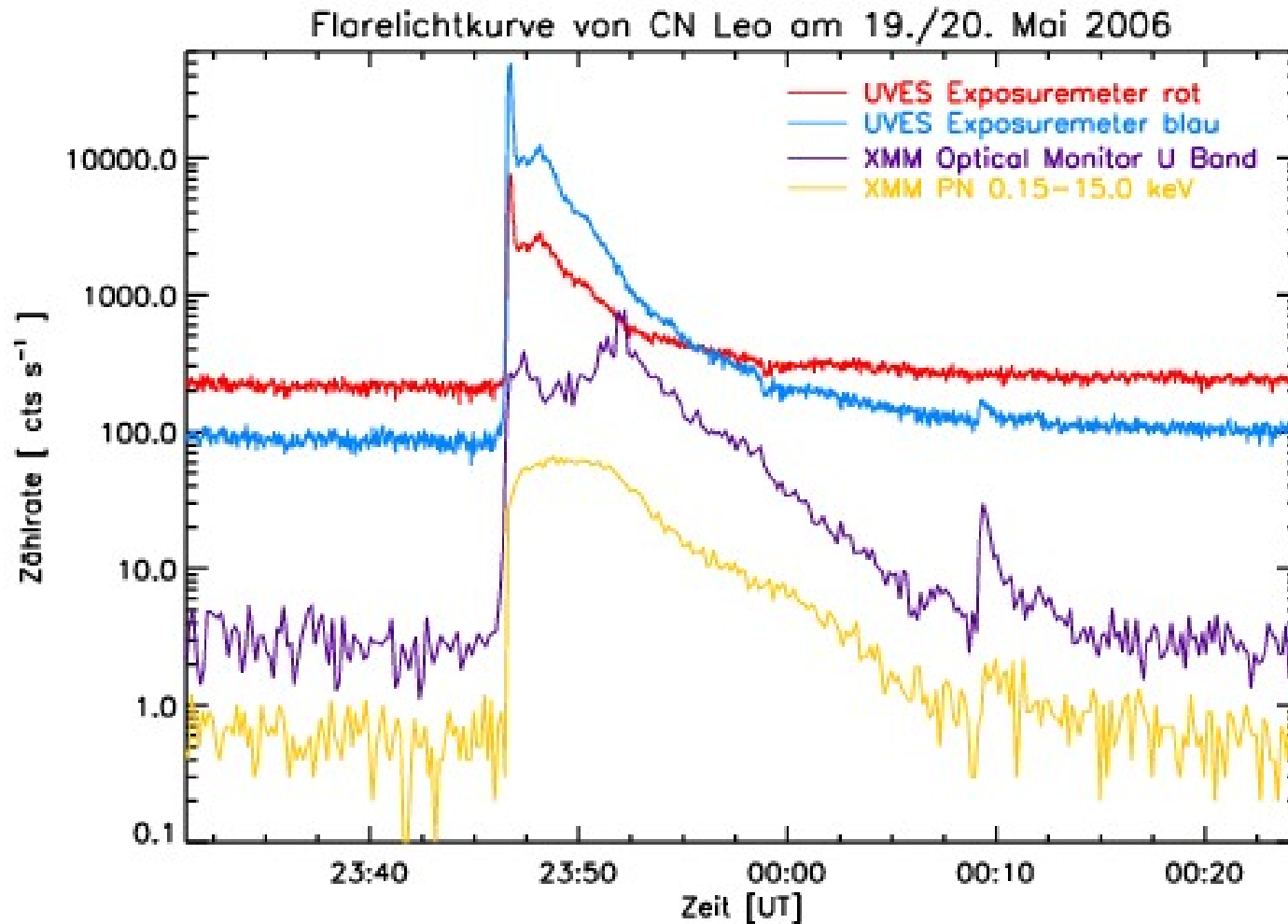
Bild: ESO/H.H.Heyer

# CN Leo fest im Blick

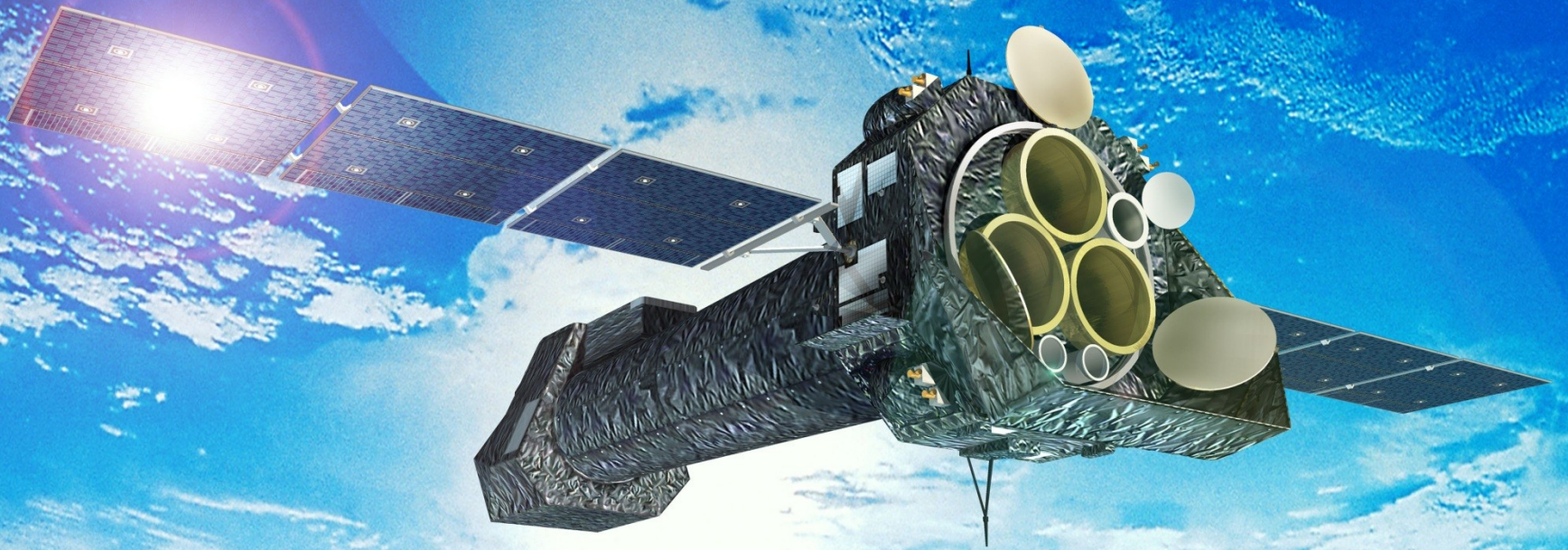


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# Ein Helligkeitsausbruch...



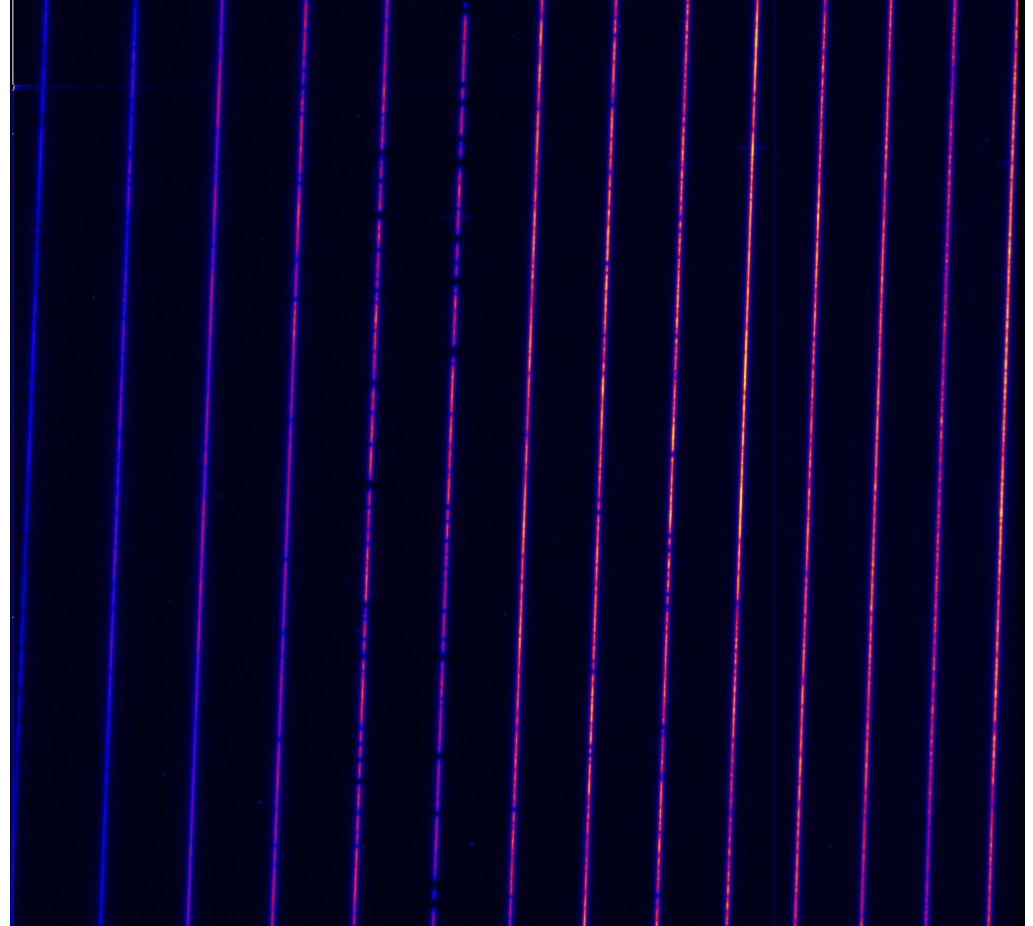
# Röntgensatellit XMM-Newton



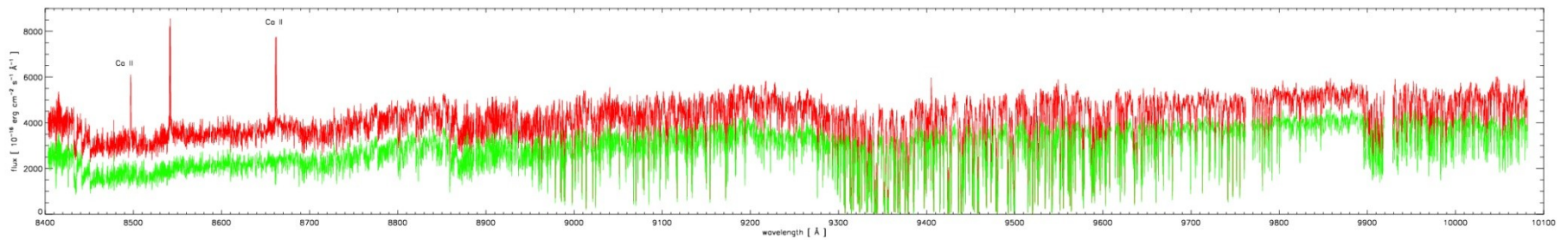
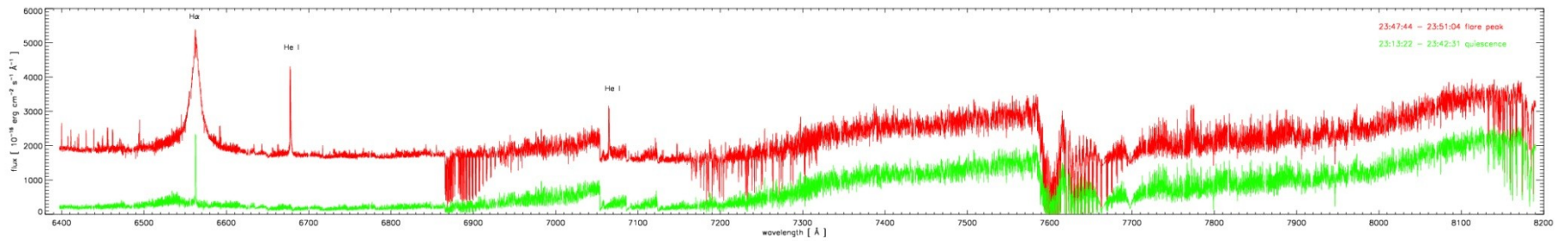
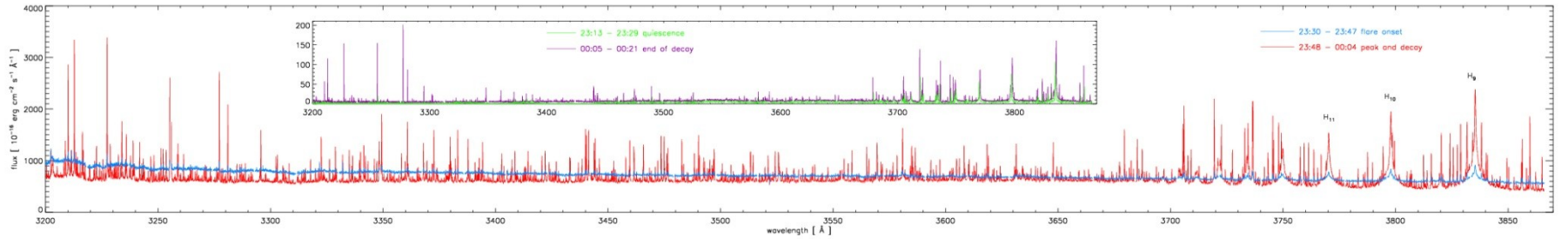
# Datenreduktion

Auch bei Spektren:

- Bias und Flatfield
- Korrektur von Cosmics, Bad Pixeln und Dead/Hot Columns
  
- Sternspektren und Himmelshintergrund extrahieren
- Flußkalibration (Standardstern)

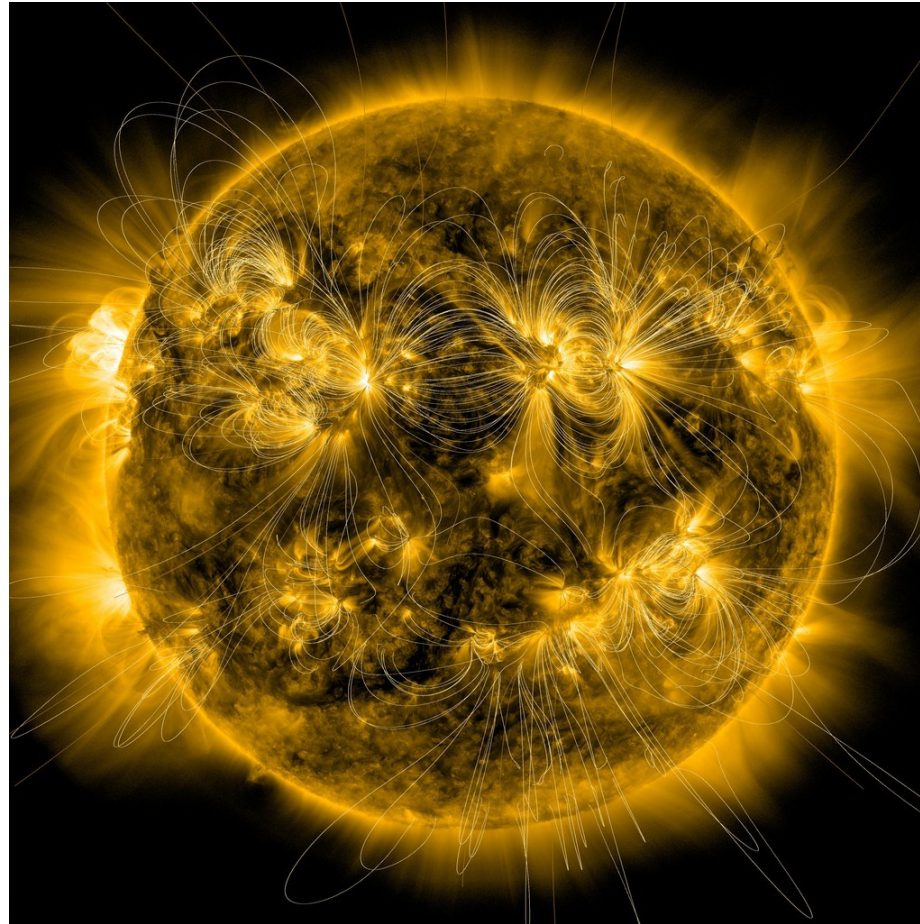


# ... und deren Ergebnisse





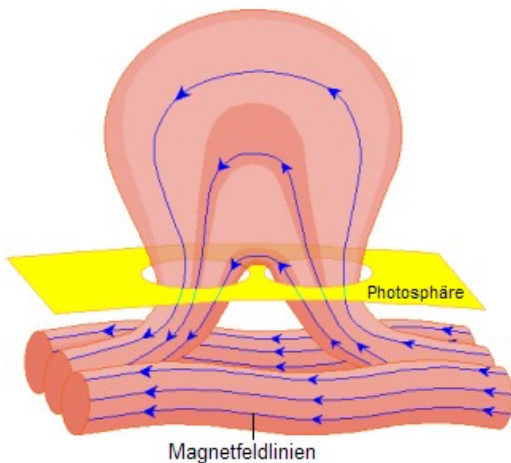
# Knoten in Magnetfeldern



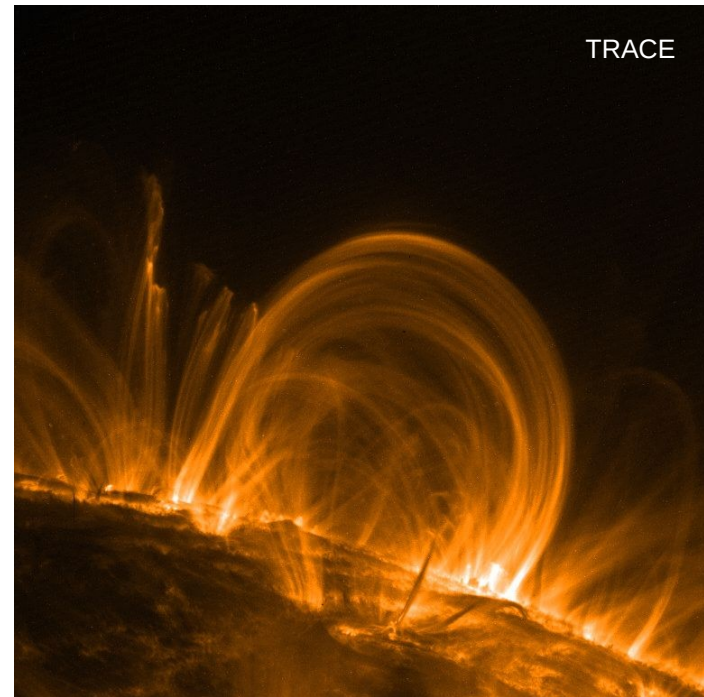
SDO AIA 171 Å Röntgenaufnahme der Sonnenkorona mit rekonstruierten Magnetfeldlinien. Bild: NASA/SDO and the AIA and HMI science teams

# Koronale Bögen

- Bögen über Flecken/aktiven Regionen
- Arkaden: Anordnungen von Bögen
- Veränderungen innerhalb von Minuten
  - Neue Bogenverbindungen
  - Wachstum von Arkaden



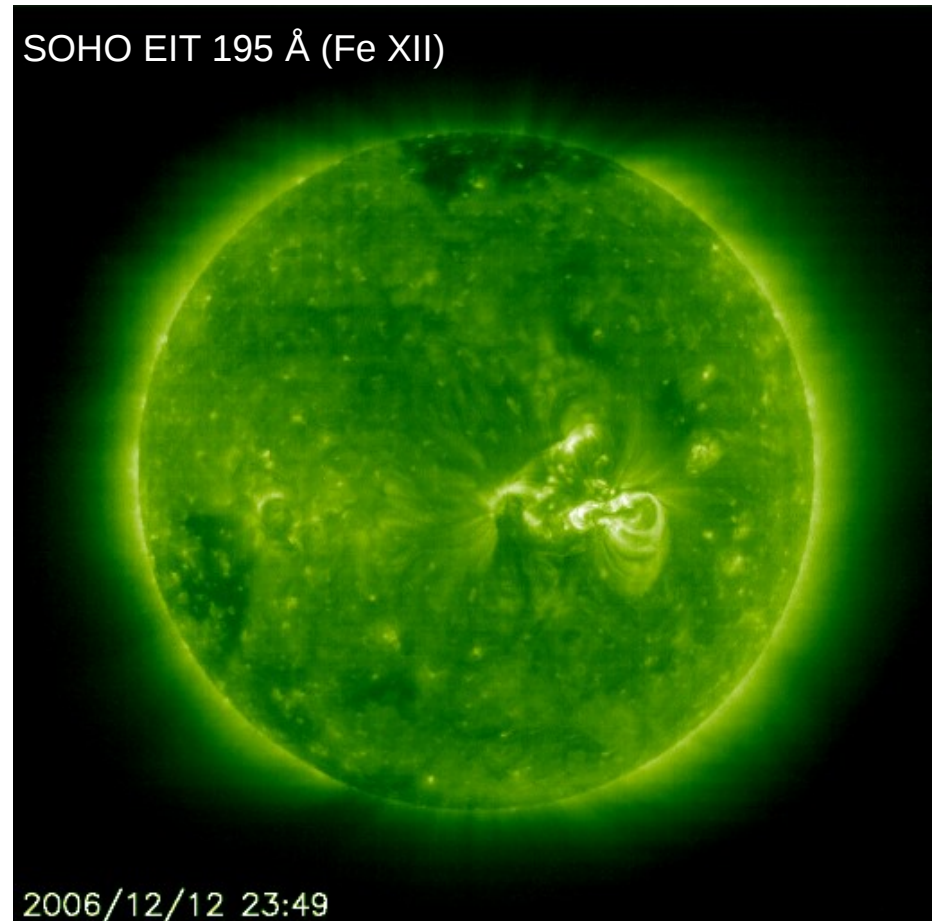
Benutzer Lmb via Wikimedia Commons (Public Domain)



- Magnetische Flußröhren: Geladene Plasmateilchen folgen Magnetfeldern
- Streamer: offene Magnetfeldlinien

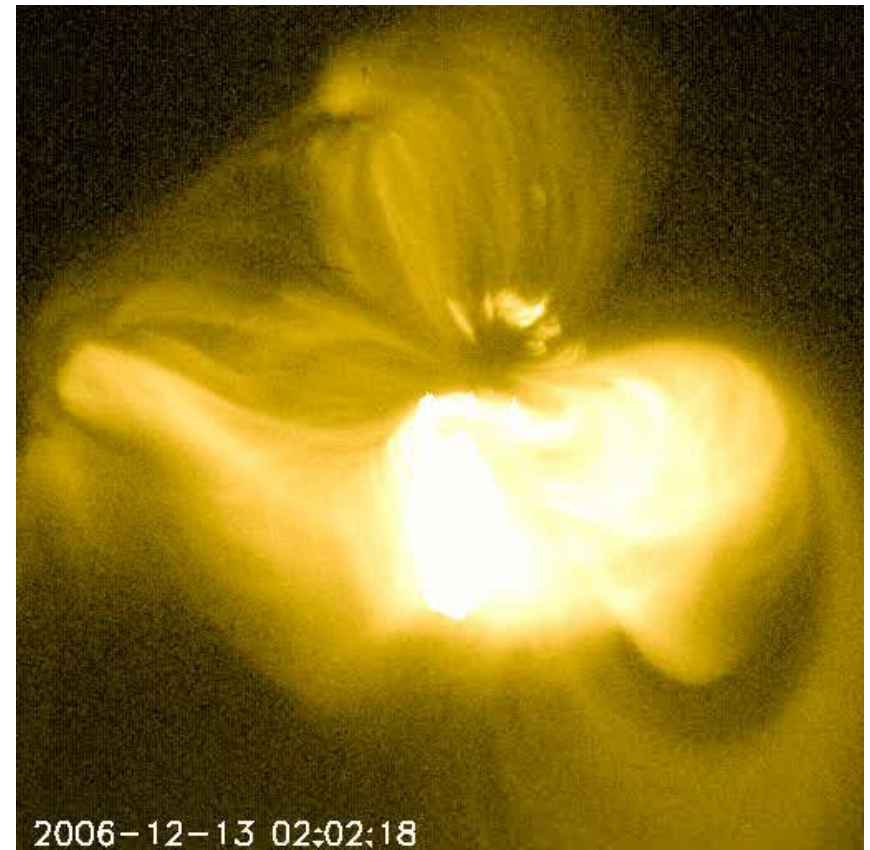
# Flares auf der Sonne

- „Magnetische Rekonnektion“ in der Korona
- Beschleunigte Teilchen treffen auf die unteren Atmosphärenschichten und heizen sie auf
- Abkühlung durch Aussendung von Strahlung: Linienemission und Kontinuum
- „Chromosphärische Evaporation“ trägt frisches Material in die Korona, das Röntgenstrahlung aussendet



# Flares auf der Sonne

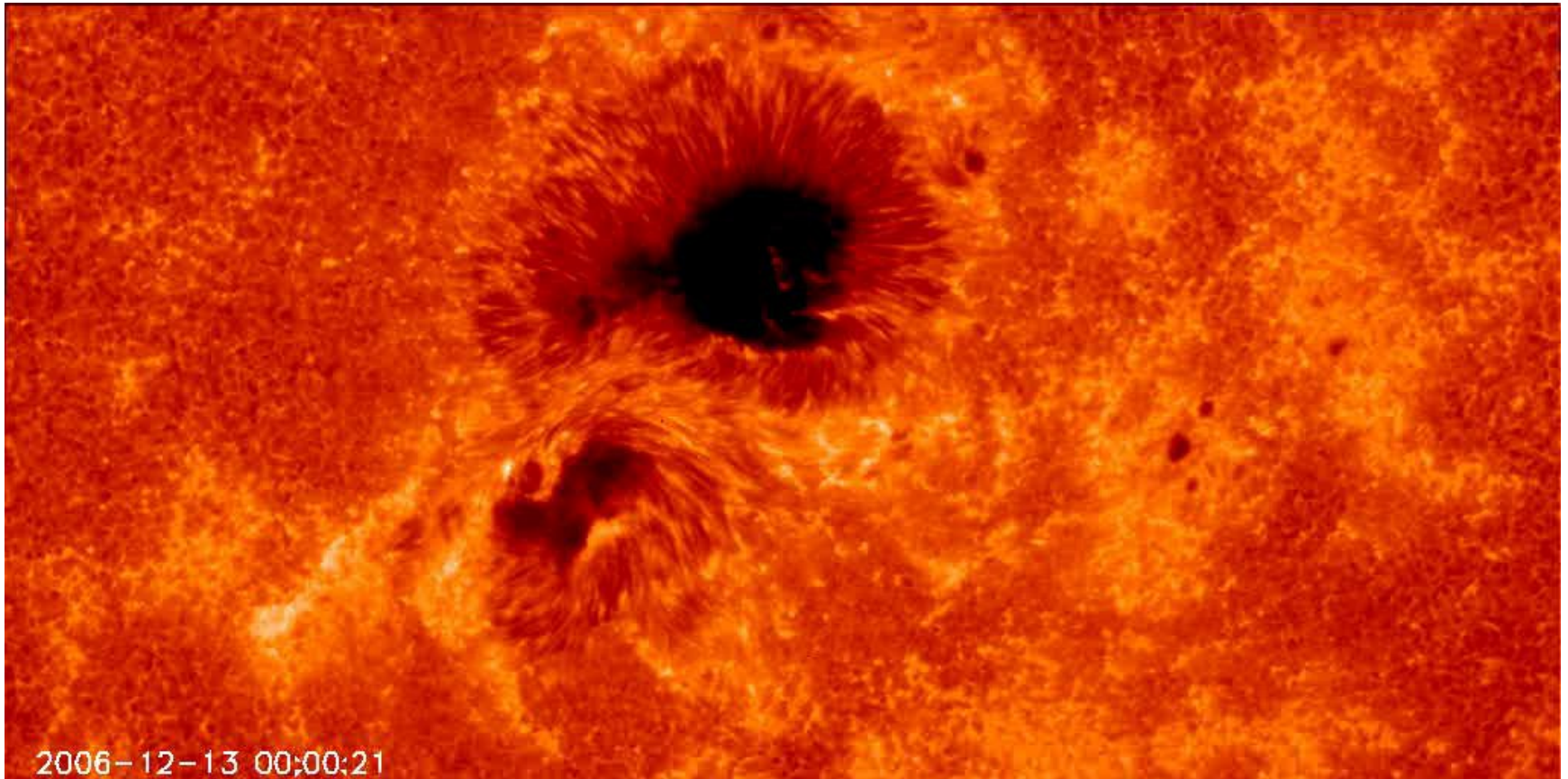
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Hinode XRT

# Flares auf der Sonne

Hinode SOT



# Resultate

- Eigenschaften des Flare-Plasmas: Änderungen von koronale Temperaturen und Dichten, chromosphärischen Dichten, Elementhäufigkeiten
- Aussehen der Flareregion: Länge des koronalen Bogens, Querschnittsfläche in der Photosphäre, Aufheizen der Sternoberfläche
- Auf- und Abbewegungen von Materie
- Möglicherweise Veränderungen im Magnetfeld des Sterns in Zusammenhang mit dem Flare
- ...

# Konferenzen I

- Aktuelle Forschungsergebnisse werden auf (internationalen) Fachtagungen vorgestellt
- Alle zwei Jahre findet die Konferenz „Cool Stars, Stellar Systems, and the Sun“ statt, zum Beispiel 2006 in Pasadena, 2008 in St. Andrews und 2010 in Seattle



# The many faces of a giant flare

Multiwavelength observations of CN Leo with high spectral and high time resolution

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### Abstract

The MS star CN Leo has been observed simultaneously with XMM-Newton and XIS-2 on 1920 May 2006. A giant flare occurred at 2:47 UT on 19 May and is covered in detail by instruments. This study reports on the multiwavelength observations of the flare from the optical to the X-ray. The flare was observed with XMM-Newton and XIS-2 on 1920 May 2006. The flare was observed with XMM-Newton and XIS-2 on 1920 May 2006. The flare was observed with XMM-Newton and XIS-2 on 1920 May 2006.

### Lichtcurves

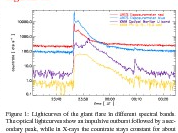


Figure 1: Lightcurves of the flare in different spectral bands. The plot shows flux in units of 10^-14 W m^-2 nm^-1 versus time in minutes. Multiple lines represent different spectral bands, showing a sharp peak at approximately 2:47 UT.

### EPIC spectra

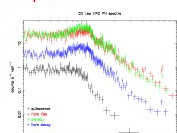


Figure 2: EPIC spectra covering the full phase of the flare. The plot shows flux in units of 10^-14 W m^-2 nm^-1 versus wavelength in nm. The spectra show a clear transition from a soft to a hard state during the flare.

### Coronal densities

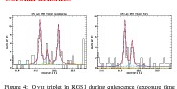


Figure 4: Core optically thin emission component. The plot shows flux in units of 10^-14 W m^-2 nm^-1 versus wavelength in nm. The data points are fitted with a model, showing a clear emission line.

Figure 2: Zoom into the lightcurve for the first 30 seconds of the flare, showing the different amplitudes. The plot shows flux in units of 10^-14 W m^-2 nm^-1 versus time in minutes. Multiple lines represent different spectral bands, showing a sharp peak at approximately 2:47 UT.

Figure 3: XMM EPIC spectra covering the full phase of the flare. The plot shows flux in units of 10^-14 W m^-2 nm^-1 versus wavelength in nm. The spectra show a clear transition from a soft to a hard state during the flare.

### References

- Faloutsos, C., LaRoche, P., & Schmitt, J. H. M. M., 2006, A&A, 468, 221
- Lehrke, C., Faloutsos, C., Schmitt, J. H. M. M., & Retner, A., 2008, A&A, 471, 271
- Schmitt, J. H. M. M., 2006, A&A, 468, 221

# The CN Leo flare census

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### Abstract

We investigate the frequency and amplitude distribution of flares on the active M dwarf CN Leo observed simultaneously in coronal X-rays, chromospheric line emission, and the photospheric optical continuum. We find that most of the large flares are visible in all atmospheric layers, there are equivalent to solar light flares. Several smaller events are only visible in the chromospheric lines, which we interpret as solar H-alpha flares. One event is very strong in X-rays, but only weak in the chromospheric lines and invisible in the photospheric continuum, indicating a rather large scale height of the flaring loop. We find no obvious correlation of the flare amplitude and decay times in the different atmospheric layers. We also search for time lags between the different wavelength bands and probe the occurrence of the Neupert effect.

### Observations

- 112 ks of data in six XMM-Newton observations (1x May 2004, 2x December 2005, 3x May 2006)
- simultaneous optical photometry and high-resolution spectroscopy with VLT/FORS

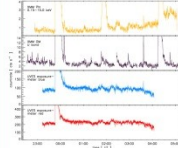


Figure 1: Multiband photometry of CN Leo, 1920 May 2006.

### Three large flares in X-rays in the observation on 1920 May 2006

- A giant flare at 2:47 UT (Schmitt et al. 2006; Faloutsos et al. 2006; Lehrke et al. in preparation)
- A second strong event at 3:45 shows an unusually symmetric X-ray lightcurve with a rather slightly longer than the decay (see Fig. 4b) and exhibits comparably weak signatures of optical wavelengths, indicating that the flare does not penetrate down to the lower layers of the stellar atmosphere.
- A third strong flare is simultaneously missed by the UVES data any more.

### Flare statistics

Most of the 27 flares observed during the six observations are of short duration (< 3 hours in X-rays, optical flare duration are even shorter). In Fig. 2 we search for dependencies of the exponential decay times and the times from the optical level for the blue optical band, the U band, and in X-rays.

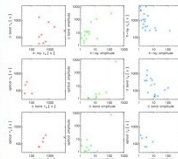


Figure 2: Correlation of flare decay times (first row) and asymptotic second row in different spectral bands, and decay times vs. amplitude (third row). The plots show decay time in minutes versus amplitude in units of 10^-14 W m^-2 nm^-1. Multiple lines represent different spectral bands, showing a clear correlation.

### Flare evolution and loop half lengths

Only the three large X-ray flares on May 1920 May 2006 allow resolved spectroscopy. Fig. 3 shows the evolution of emission-measured temperature and total emission measure of 2 temperature-sensitive EPIC models.

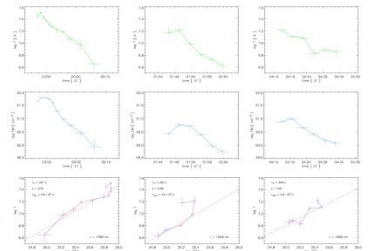


Figure 3: Temporal evolution of flare temperature (first row) and total emission measure (second row), and density temperature phase (third row) for the flare flare (left column), the 'symmetric' flare at 3:45 UT (middle column), and the flare at 4:15 UT (right column).

### Time lags and the Neupert effect

For the majority of flares we do not observe delays in the onset of optical/UV and X-ray emission at an accuracy of a few seconds. This concerns especially the short and very short duration events. No obvious trends are visible for the flares where time lags are observed.

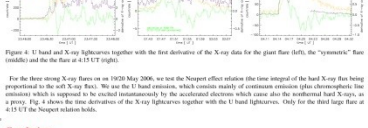


Figure 4: U band and X-ray lightcurves together with the first derivative of the X-ray data for the flare flare (left), the 'symmetric' flare (middle) and the flare at 4:15 UT (right).

### Conclusions

- We observe 27 flares on the MS star CN Leo in 112 ks of X-ray data and six half nights of multi-wavelength optical spectroscopy and photometry (19x in X-rays, 27x in U band, 20x in the optical blue band)
- Average flare duration is 28 minutes in X-rays, 321 seconds in the U band, and 106 seconds in the optical blue band
- The flare decay times and amplitudes in the different spectral bands do not show strong correlations
- The total cooling loop lengths exceed 10000 km for three larger flares occurring within 6 hours, suggesting that the events originate from the same loop
- Flare observations do not seem to show delays in the onset of optical, U-band, and X-ray emission
- The Neupert effect is only visible for the last of the three large flares

### References

- Faloutsos, B., LaRoche, P., Schmitt, J. H. M. M., 2006, A&A, 468, 221
- Faloutsos, B., LaRoche, P., Schmitt, J. H. M. M., & Retner, A., 2008, A&A, 471, 271
- Schmitt, J. H. M. M., 2006, A&A, 468, 221

# Konferenzen II

- Kleine Workshops bis hin zu internationalen Veranstaltungen mit mehreren 100 Teilnehmern
- Vorträge im Plenum
- Poster mit neuesten Forschungsergebnissen
- „Splinter Meetings“
- Allgemeiner Informationsaustausch

...



