A Personal History of CHIANTI

Ken Dere

CHIANTI

- A freely available database of atomic parameters needed to calculate the emission spectrum of a hot, optically-thin plasma
- Freely available IDL and Python programs
- 'CHIANTI' is simply a memorable name

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Version 1 released 1996

Version 6 released 2010

NRL SOLRAD project

- X-ray ionization chambers

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NRL ~ 1971

- Don Horan calculates response of SOLRAD detectors to a hot plasma as a function of temperature and emission measure.
  - Follows procedures outlined by Culhane (1969)
- Tucker and Koren (1971) provide the atomic data to calculate spectral line emission
- George Doschek analyzing OSO X-ray spectra

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TABLE 1

ATOMIC DATA USED TO COMPUTE THE LINE INTENSITIES

Ion	Transition	Wavelength (Å)	Excitation Energy (eV)	Effective Collision Strength	Reference*
C VI........	$1s-np$	26.4	470	0.003	(K)
	$1s-4p$	27.0	459	0.002	
	$1s-3p$	28.5	435	0.006	WS
	$1s-2p$	33.7	368	0.042	(K)
C V..........	$1s^2-1s\,np$	32.8	378	0.008	(K)
	$1s^2-1s4p$	33.4	371	0.006	(K)
	$1s^2-1s3p$	35.0–35.1	353	0.014	WR
	$1s^2-1s2p(^1P)$	40.3	308	0.084	WS
	$1s^2-1s2p(^3P)$	40.7	306	0.008	(M)
	$1s^2-1s2p(^3S)$	41.5	300	0.089	(M)
N VII.......	$1s-np$	19.4	639	0.002	
	$1s-4p$	19.8	626	0.002	
	$1s-3p$	20.9	593	0.005	RW
	$1s-2p$	24.8	500	0.031	RW
N VI........	$1s^2-1s\,np$	23.3	532	0.005	(K)
	$1s^2-1s4p$	23.8	521	0.004	
	$1s^2-1s3p$	24.9–25.0	496	0.010	(K)
	$1s^2-1s2p(^1P)$	28.8	430	0.056	(M)
	$1s^2-1s2p(^3P)$	29.1	425	0.010	(M)
	$1s^2-1s2p(^3S)$	29.5	420	0.063	(M)
O VIII.......	$1s-np$	14.8	837	0.002	RW
	$1s-4p$	15.2	816	0.002	RW
	$1s-3p$	16.0	775	0.005	RW, EP (CO)
	$1s-2p$	19.0	653	0.023	RW, EP (CO)
O VII........	$1s^2-1s\,np$	17.4	713	0.004	RW
	$1s^2-1s4p$	17.8	697	0.004	RW
	$1s^2-1s3p$	18.7	663	0.009	RW, EP (CO)
	$1s^2-1s2p(^1P)$	21.6	575	0.056	WR, EP (CO)
	$1s^2-1s2p(^3P)$	21.8	570	0.010	WR, EP (CO)
	$1s^2-1s2p(^3S)$	22.1	560	0.063	WR, EP (CO)
Ne X........	$1s-np$	9.5	1305	0.0010	RW
	$1s-4p$	9.7	1280	0.00084	RW
	$1s-3p$	10.2	1215	0.0024	RW
	$1s-2p$	12.2	1020	0.015	RW, EP (CO)
Ne IX........	$1s^2-1s\,np$	10.8	1148	0.003	(K)
	$1s^2-1s4p$	11.0	1130	0.002	(K)
	$1s^2-1s3p$	11.6	1070	0.005	RW, EP (CO)
	$1s^2-1s2p(^1P)$	13.4	925	0.030	RW, EP (CO)
	$1s^2-1s2p(^3P)$	13.6	912	0.008	RW, EP (CO)
	$1s^2-1s2p(^3S)$	13.7	905	0.025	WR
Ne VIII.......	$2s-nl$	52–65.9	188	0.050	(K)
	$2s-4l$	67.4–74.6	165	0.050	(K)
Mg XII.......	$1s-np$	6.6	1879	0.00076	(K)
	$1s-4p$	6.7	1850	0.00058	
	$1s-3p$	7.11	1740	0.0017	WR
	$1s-2p$	8.42	1470	0.010	WR, EP (CO)
Mg XI.......	$1s^2-1s\,np$	7.30	1698	0.002	(K)
	$1s^2-1s4p$	7.47	1660	0.0016	(K)
	$1s^2-1s3p$	7.85–7.86	1570	0.0035	WR
	$1s^2-1s2p(^1P)$	9.17	1350	0.022	RW, EP (CO)
	$1s^2-1s2p(^3P)$	9.23	1340	0.007	RW, EP (CO)
	$1s^2-1s2p(^3S)$	9.31	1330	0.017	RW, EP (CO)
Mg X........	$2l-nl$	33.8–43.0	290	0.04	(K)
	$2l-4l$	44.0–47.3	260	0.04	(K)
	$2s-3p$	57.9	214	0.037	WS
	$2p-3d$	63.2–63.3	215	0.09	WS
	$2p-3s$	65.7–65.9	208	0.045	WS

* Lines observed in solar corona: WS = Widing and Sandlin; WR = Walker and Rugge; RW = Rugge and Walker; EP = Evans and Pounds. Lines observed in laboratory or computed theoretically: (K) = Kelly; (C) = Chapman; (CO) = Connerade; (M) = Moore; (H) = Hydrogenic. Lines not referenced were obtained by extrapolation or interpolation.

TABLE 2—*Continued*

NiXXVI	6.14	.....	.....	.....	.....	.....	29.13	25.92	26.19	27.43
SiXIV	6.18	.....	.....	31.87	29.30	26.12	24.98	24.95	25.53	.....
MgXII	6.60	.....	.....	30.86	28.05	26.55	26.25	26.69	.....	.....
NiXXIV	6.62	.....	.....	.....	.....	30.43	26.95	25.68	27.47	30.46
SiXIII	6.65	36.58	29.74	26.83	25.47	24.73	24.57	25.53	.....	.....
SiXIII	6.69	36.97	30.15	27.25	25.90	25.17	25.01	25.98	.....	.....
MgXII	6.70	.....	.....	30.98	28.17	26.68	26.37	26.82	.....	.....
SiXIII	6.74	36.63	29.83	26.94	25.60	24.87	24.71	25.68	.....	.....
NiXXV	6.76	.....	.....	.....	.....	.....	28.48	26.30	27.35	29.46
NiXXIII	6.94	.....	.....	.....	.....	28.70	26.31	25.95	28.51	.....
NiXXVI	7.10	.....	.....	.....	.....	.....	29.05	25.92	26.22	27.48
MgXII	7.11	.....	.....	30.33	27.61	26.16	25.89	26.36	.....	.....
FeXXIV	7.21	.....	.....	.....	.....	30.43	26.58	24.95	25.29	26.58
NiXXII	7.26	.....	.....	.....	31.20	27.89	25.88	26.46	29.75	.....
MgXI	7.30	32.84	29.29	27.42	26.33	25.95	26.42	.....	.....	.....
FeXXI	7.40	.....	.....	.....	.....	26.84	25.14	26.22	.....	.....
MgXI	7.47	33.04	29.47	27.57	26.46	26.07	26.54	.....	.....	.....
NiXXV	7.50	.....	.....	.....	.....	.....	28.45	26.30	27.37	29.49
NiXXI	7.60	.....	.....	.....	29.08	26.78	25.58	27.08	.....	.....
NiXXIII	7.70	.....	.....	.....	.....	28.70	26.30	25.94	28.50	.....
MgXI	7.86	32.26	28.85	27.06	26.02	25.67	26.16	.....	.....	.....
FeXXII	7.89	.....	.....	.....	.....	27.23	24.72	24.93	26.72	.....
FeXXI	7.90	.....	.....	.....	.....	26.87	25.15	26.21	.....	.....
NiXXIV	7.94	.....	.....	.....	.....	30.35	26.91	25.68	27.49	30.49
FeXXI	8.00	.....	.....	.....	.....	26.60	24.91	25.99	.....	.....
FeXXIII	8.00	.....	.....	.....	.....	29.22	25.95	25.28	26.35	28.49
NiXIX	8.10	.....	.....	27.58	26.17	25.61	25.66	28.86	.....	.....
NiXX	8.25	.....	.....	29.84	27.29	25.84	25.30	27.65	.....	.....
NiXIX	8.30	.....	.....	27.91	26.53	25.99	26.05	29.26	.....	.....
FeXXI	8.30	.....	.....	.....	.....	26.40	24.71	25.79	.....	.....
FeXXIV	8.35	.....	.....	.....	.....	30.31	26.52	24.96	25.32	26.63
MgXII	8.42	.....	.....	29.07	26.54	25.23	25.03	25.57	.....	.....
FeXIX	8.60	.....	.....	.....	27.79	25.70	25.22	27.82	.....	.....
NiXXII	8.60	.....	.....	.....	31.04	27.80	25.85	26.47	29.77	.....
NiXXI	8.60	.....	.....	.....	28.92	26.69	25.54	27.09	.....	.....
NiXXI	8.83	.....	.....	.....	28.97	26.72	25.55	27.08	.....	.....
FeXXIII	8.86	.....	.....	.....	.....	29.16	25.92	25.28	26.37	28.52
FeXXI	8.95	.....	.....	.....	.....	26.53	24.88	26.00	.....	.....
NiXIX	9.00	.....	.....	27.31	26.01	25.53	25.63	28.86	.....	.....
NiXIX	9.10	.....	.....	27.29	26.00	25.53	25.63	28.86	.....	.....
FeXVIII	9.15	.....	33.98	28.50	26.41	25.26	25.45	28.90	.....	.....
MgXI	9.17	30.45	27.45	25.92	25.04	24.80	25.35	.....	.....	.....
FeXX	9.20	.....	.....	.....	29.03	26.16	25.09	26.89	.....	.....
NiXXVI	9.20	.....	.....	.....	.....	.....	28.85	25.81	26.16	27.44
MgXI	9.23	30.92	27.93	26.41	25.54	25.30	25.86	.....	.....	.....
NiXXII	9.25	.....	.....	.....	30.91	27.78	25.89	26.57	29.90	.....
MgXI	9.31	30.47	27.51	26.00	25.13	24.90	25.46	.....	.....	.....
NiXXIV	9.32	.....	.....	.....	.....	30.25	26.92	25.79	27.65	30.68
NiXXIII	9.35	.....	.....	.....	.....	28.64	26.36	26.11	28.73	.....
FeXXII	9.45	.....	.....	.....	.....	27.17	24.70	24.93	26.74	.....

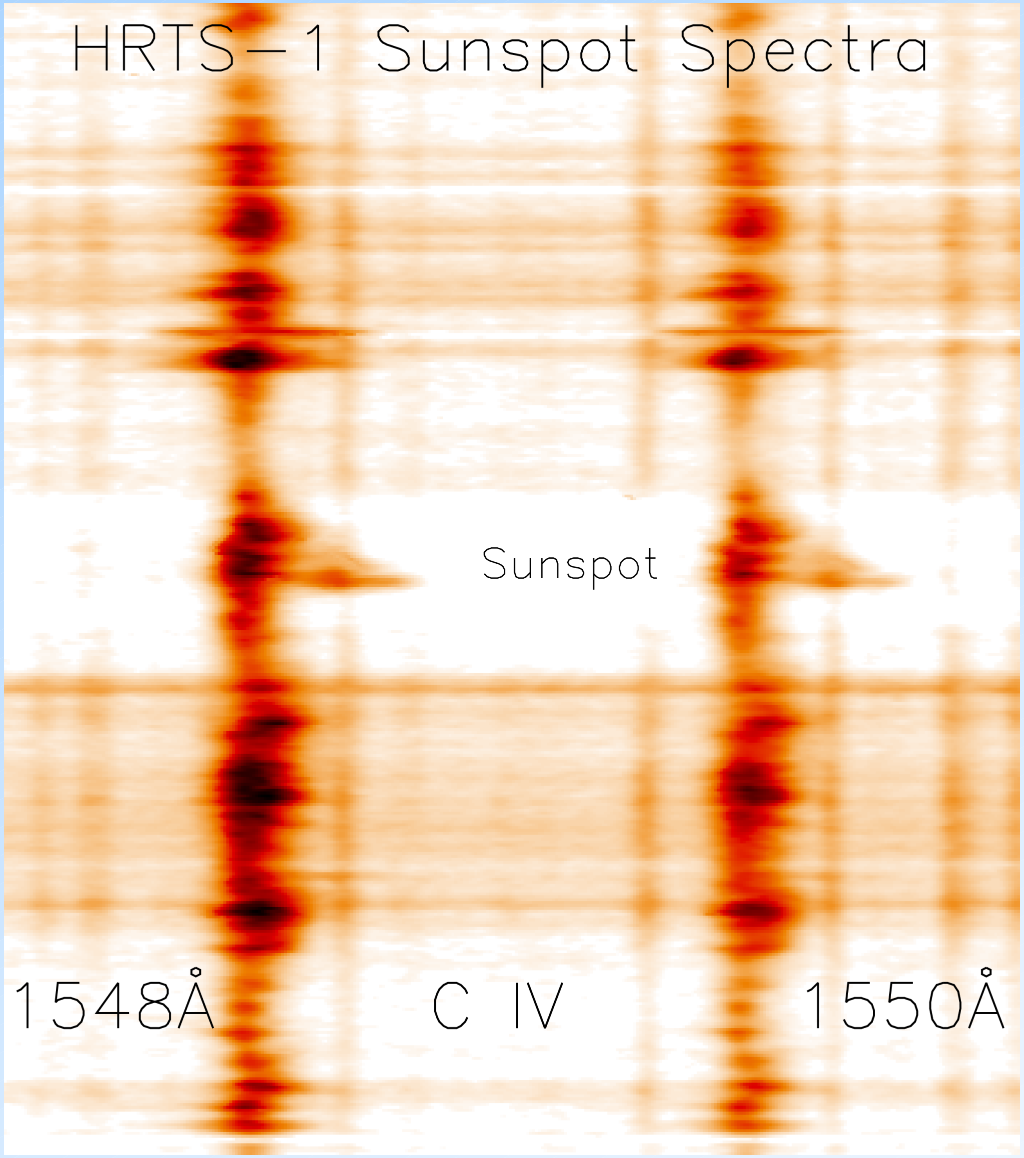
Skylab 1973-1974

- Slitless Objective grating spectrograph (S082A)
  - Or, the overlap-a-graph
  - 170 – 360 Å and 300 - 600 Å

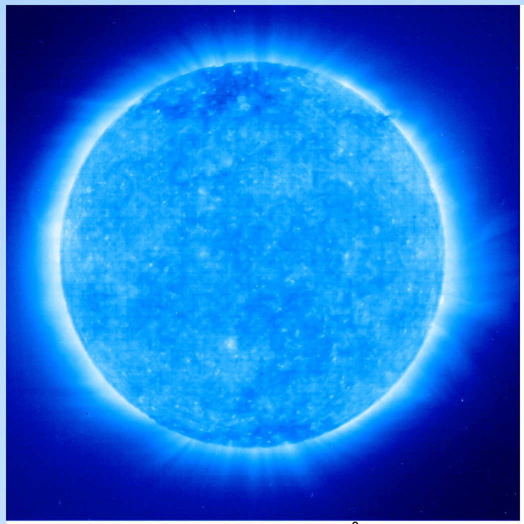
Modeling solar spectra

- Helen Mason visits George Doschek at NRL
  - Using the Distorted Wave package to calculate the necessary atomic data.
  - Density diagnostics from spectra line intensities

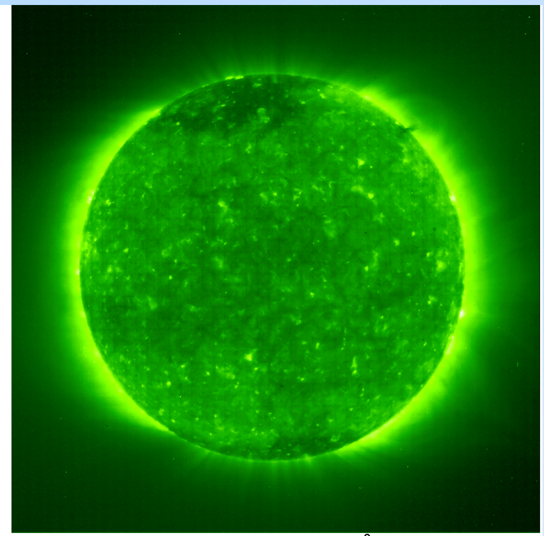
High Resolution Telescope and Spectrograph (HRTS)



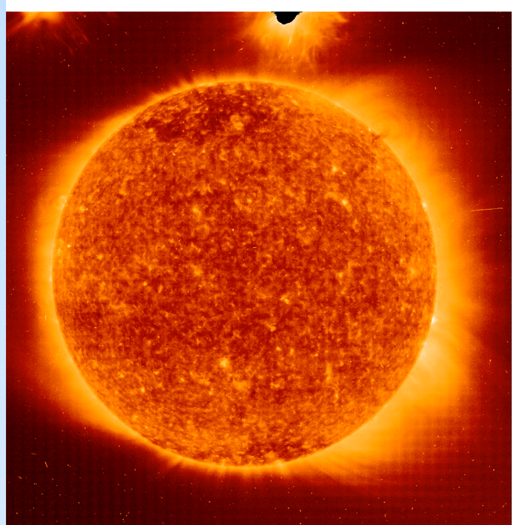
Extreme-ultraviolet Imaging Telescope (EIT) on SOHO



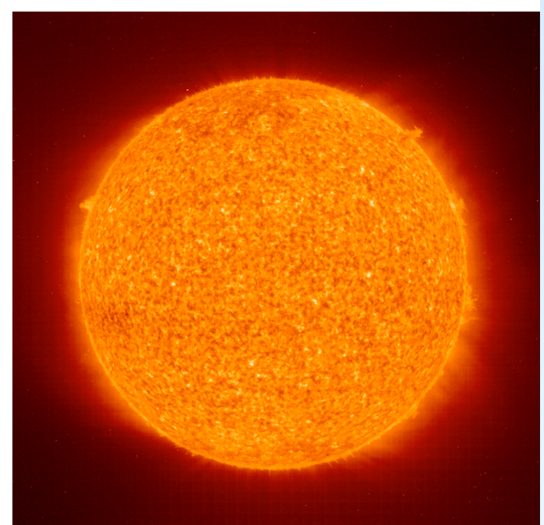
EIT Fe IX/X 171Å
1 Nov 1996 00:40



EIT Fe XII 195Å
1 Nov 1996 00:46



EIT Fe XV 284Å
1 Nov 1996 02:00



EIT He II 304Å
1 Nov 1996 01:40

EIT- narrow band imager

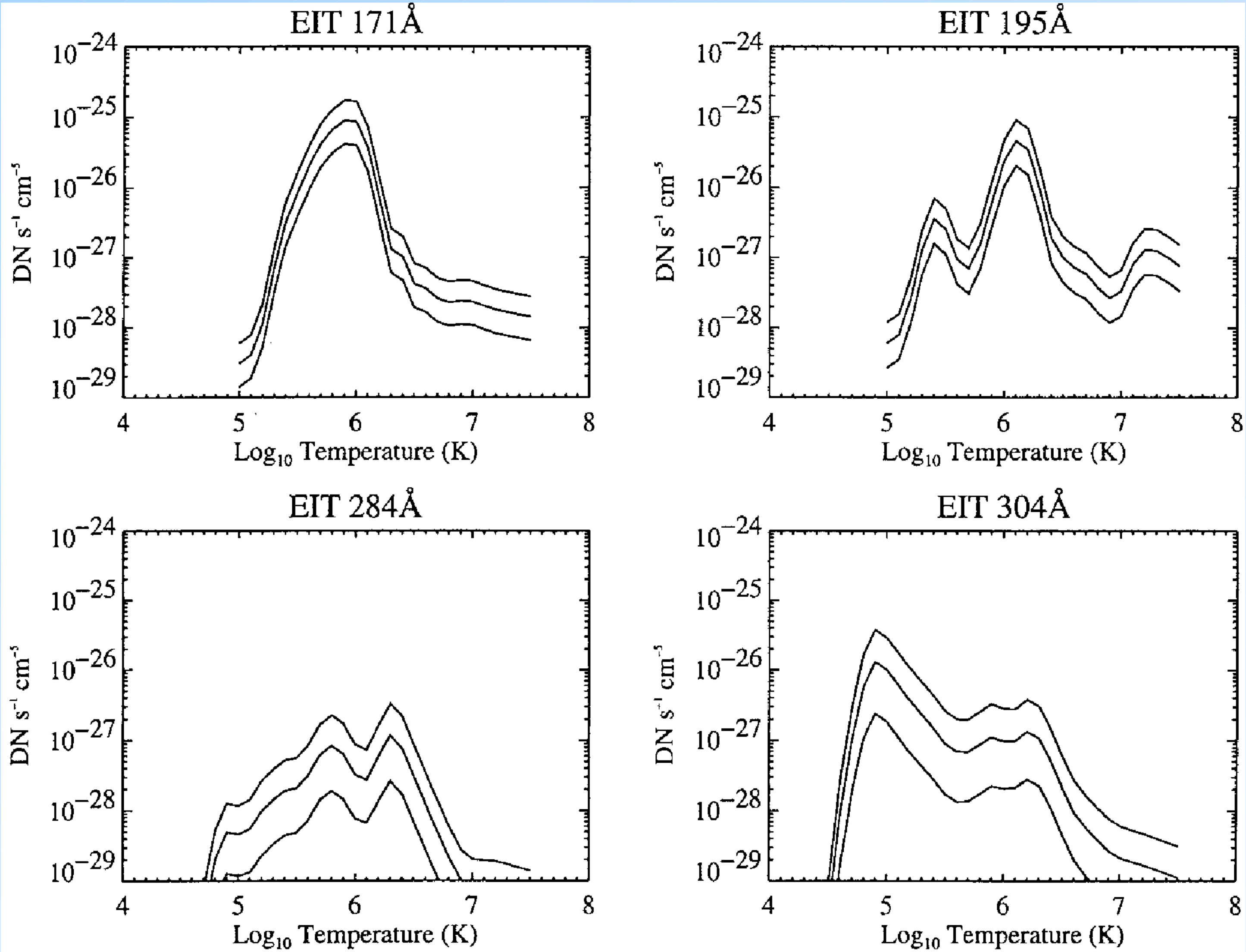
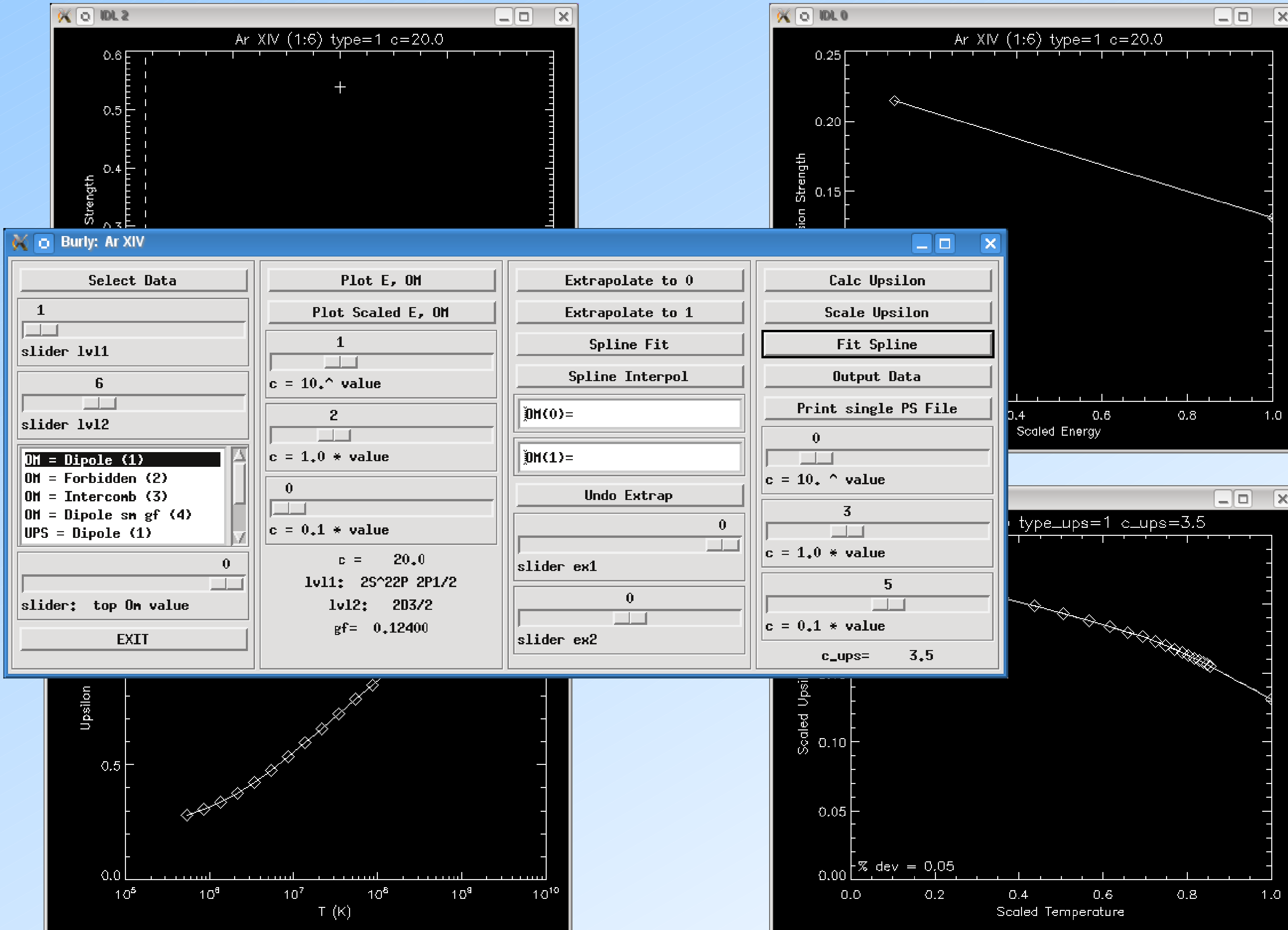


Figure 12. EIT plasma response $H(T)$ for various sector and filter-wheel combinations. In each plot, the top curve includes the clear filter-wheel filter, the middle curve the 'Al+1' filter and the bottom curve the 'Al+2' filter.

Beginnings of CHIANTI

- ~1993(?) NASA proposal accepted
- SOHO Elba meeting in 1993 – began to work together with Brunella Monsignori Fossi
- Applied the Burgess and Tully (1992) scaling laws to calculated collision strengths
- A lot of data to incorporate so that an automated widget process developed


IDL 2
Ar XIV (1:6) type=1 c=20.0
Strength
IDL 0
Ar XIV (1:6) type=1 c=20.0
Strength
Scaled Energy
Burly: Ar XIV
Select Data
slider lvl1
slider lvl2
OM = Dipole (1)
OM = Forbidden (2)
OM = Intercomb (3)
OM = Dipole sm gf (4)
UPS = Dipole (1)
slider: top Om value
EXIT
Plot E, OM
Plot Scaled E, OM
c = 10.^ value
c = 1.0 * value
c = 0.1 * value
c = 20.0
lvl1: 2S^2 2P 2P1/2
lvl2: 2D3/2
gf= 0.12400
Extrapolate to 0
Extrapolate to 1
Spline Fit
Spline Interpol
OM(0)=
OM(1)=
Undo Extrap
slider ex1
slider ex2
Calc Upsilon
Scale Upsilon
Fit Spline
Output Data
Print single PS File
c = 10. ^ value
c = 1.0 * value
c = 0.1 * value
c_ups= 3.5
type_ups=1 c_ups=3.5
Upsilon
T (K)
Scaled Upsilon
% dev = 0.05
Scaled Temperature

CHIANTI beginnings cont.

- January 1996 Brunella dies
- Late 1996 the database is first released
- 1997 – Publication of CHIANTI Version 1 paper, for wavelengths greater than 50 Å

Team

- Giulio Del Zanna (U. Cambridge)
- Ken Dere (NRL, GMU)
- Enrico Landi (Arcetri, NRL, U. Michigan)
- Massimo Landini (U. Florence)
- Helen Mason (U. Cambridge)
- Brunella Monsignori Fossi (Arcetri)
- Peter Young (U. Cambridge, RAL, NRL)

CHIANTI releases

- Version 2 – 1999: continuum and minor ions
- Version 3 – 2001: extension to shorter wavelengths
- Version 4 – 2003: proton rates
- Version 5 – 2006: new X-ray data
- Version 6 – 2009: ionization, recombination

Mozilla Firefox <2>

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http://www.chian...hianti_ADS.html

Citations to CHIANTI papers

One measure of the success of CHIANTI is through the number of citations to the CHIANTI papers in the scientific literature. The information below has been extracted from the ADS abstracts service.

Total number of citations to CHIANTI papers: **1420***.

Full list of papers that cite the CHIANTI papers.

Summary of where and when the citing papers were published:

Journal	No. of papers*
ApJ	264
ApJS	26
ApJL	55
AJ	7
A&A	200
A&AS	6
MNRAS	48
Solar Physics	56
JGR	7
J. Phys. B	10
ADNDT	17
Phys. Scripta	8
PASJ	13
Adv. Space Research	26
Sp. Sci. Rev.	13
Phys. Rev. A	3
Icarus	4
Mem. Soc. Ast. Ital.	4
Rev. Sci. Inst.	4
Ast. Lett.	8
Other	138

Year	No. of papers*
1997	10
1998	27
1999	65
2000	42
2001	56
2002	46
2003	86
2004	63
2005	100
2006	84
2007	80
2008	123
2009	98
2010	37

*- Some papers cite more than one of the CHIANTI papers, thus leading to multiple citations from a single paper. The columns above give the number of citing papers. The total number of such papers is **917**.

Now: Partly Sunny, 89 °F Wed: 89 °F Thu: 78 °F

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Observations analyzed with CHIANTI

- Solar
  - Yohkoh
  - SOHO
  - SERTS
  - TRACE
  - CORONAS
  - Hinode
  - RHESSI
  - SOXS
  - Ground-based
  - GOES
  - STEREO
  - SDO

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cont.

- Astronomy
  - IUE
  - EUVE
  - Hubble
  - FUSE
  - Chandra
  - XMM
  - GALEX
  - ESO-VLT
  - SPEAR-FIMS
  - NEAR-Shoemaker
  - EURD
  - ISO

cont.

- Planetary
  - Cassini
  - FUSE
  - Hubble
  - Chandra
- Models
  - NRL-irradiance
  - XSTAR
  - APED
  - Cloudy
  - Pint of Ale
  - MOCASSIN

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CHIANTI in the future

- Working on it