Observing Molecular Hydrogen with IRIS

Sarah A. Jaeggli Montana State University

with P. Judge, H. Uitenbroek, C. Kankelborg, A. Daw, S. Saar, and the IRIS Team





2013-12-09 AGU--SH12A-06--First Results from IRIS

Why is H₂ important in the solar atmosphere?

- May be highly abundant especially in sunspots
- Change in the equation of state within sunspots (Jaeggli, Lin, & Uitenbroek 2011)
 - Non-thermal energy storage
 - Increased heat capacity
 - Intensification of umbral magnetic field



Partial pressure calculation from RH code using Phoenix (2500-4000 K) and Kurucz (4000-7000 K) model atmospheres

Why is H₂ important in the solar atmosphere?

- May be highly abundant especially in sunspots
- Change in the equation of state within sunspots (Jaeggli, Lin, & Uitenbroek 2011)
 - Non-thermal energy storage
 - Increased heat capacity
 - Intensification of umbral magnetic field



Partial pressure calculation from RH code using Phoenix (2500-4000 K) and Kurucz (4000-7000 K) model atmospheres

Why is H₂ important in the solar atmosphere?

- May be highly abundant especially in sunspots
- Change in the equation of state within sunspots (Jaeggli, Lin, & Uitenbroek 2011)
 - Non-thermal energy storage
 - Increased heat capacity
 - Intensification of umbral magnetic field



Partial pressure calculation from RH code using Phoenix (2500-4000 K) and Kurucz (4000-7000 K) model atmospheres

H₂ florescence

- Transitions of the H₂ Lyman (1300-1600 Å) and Werner (1000-1200 Å) bands excited by nearby strong lines:
 - Ly a (1216 Å)
 - CII (1335 Å), CIV (1551 Å)
 - **O IV** (1401 Å), **O V** (1371 Å), **O VI** (1032 Å)
 - Si IV (1394 Å)
- First identifications made with HRTS, Jordan et al. (1977,1978), Bartoe et al. (1979)
 - present in a variety of features
 - umbra, light bridge, flare

Why should H₂ be bright(er) above sunspots?

- Chromospheric structure above and around sunspots
- Activity produces high intensity in exciting lines
- Opacity is lower above sunspots
- More H₂ in cool sunspot atmosphere

Observations with SUMER

- Schuhle (1999)
- Kuhn (2006)--inferred the existence of an diffusion-driven neutral wind
- Innes (2008)--excitation of H₂ 1119.1 Å by micro-flares
 - excited by O VI, see Morgan & Habbal (2005)



Innes (2008) fig.1



Innes (2008) fig.2

Observed lines

IRIS FUV short Wavelength, Branch (J), v', v", Exciting Species, Source, Comments 1333.48 R0 0 4 Si IV Bartoe79 in flare and sunspot spectra R1 0 4 Si IV, Si IV Bartoe79 in flare and sunspot spectra, blended with S I? 1333.80 1337.47 R3 0 4 ... Bartoe79 in light bridge P2 0 4 Si IV in flare and sunspot spectra, not O IV 1338.57 Bartoe79 R4 0 4 O IV in light bridge, flare, and sunspot spectra 1340.79 Bartoe79 1342.26 P3 0 4 Si IV, Si IV Bartoe79 in flare and sunspot spectra, blended with Ni II 1342.88 P7 1 4 OIV Jordan78 weak R0 2 5 ... 1345.05 in flare Bartoe79 R5 0 4 OIV in light bridge, flare, and sunspot spectra 1345.09 Bartoe79 in light bridge P4 0 4 OIV 1346.91 Bartoe79 P5 0 4 OIV in light bridge, flare, and sunspot spectra 1352.51 Bartoe79 R7 0 4 ... in light bridge 1356.49 Bartoe79 1358.01 P4 2 5 Bartoe79 in flare ...

IRIS FUV long

Wavelength, Branch (J), v', v", Exciting Species, Source, Comments

1393.47	P100	4	CII	Jordan78	blended
1395.20	R2 0	5	C II, O IV	Bartoe79	in flare
1396.22	P1 0	5		Bartoe79	in flare and sunspot spectra, blended w/ Fe II
1397.42	R3 0	5		Bartoe79	in flare and sunspot spectra, blended w/ Fe II?
1398.96	P2 0	5	Si IV	Bartoe79	in flare and sunspot spectra
1403.98	P110	4	ΟV	Bartoe79	in light bridge, flare, and sunspot spectra

NOAA 11861

- 30 sec exposure, 400 step, dense raster, no AEC
- Oct 11, 2013, 23:55 03:29
- Flares: C3.0 at 23:59, C1.5 at 00:46, C5.2 at 01:54

slit-jaw Si IV

FUV2 Si IV















Closing remarks and future plans

- H₂ emission is dominated by the excitation source
 - O VI in sunspots
 - C II and Si IV in flares
- Detailed modeling
 - How much is there? Where is it? What temperature is it?
 - Is there a cool, ubiquitous, non-magnetic chromosphere (Carlsson & Stein, 1995)?
- Further observations with IRIS
 - Go deeper? More summing on CCD!

H₂ in other stars

- What is H₂ like in:
 - cooler stars?
 - younger stars?
- With:
 - more frequent activity
 - stronger magnetic fields
 - brighter chromospheres



young Sun, EK Dra, T. Ayres