Temperatures of Stars

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ARCS Winter Workshop

Yerkes Observatory

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Temperatures of Stars

✦1 what is a stellar temperature?

✦2 why is temperature important?

✦3 where can I find temperature measurements?

✦4 example of using temperature measurements: look for Sun-like stars

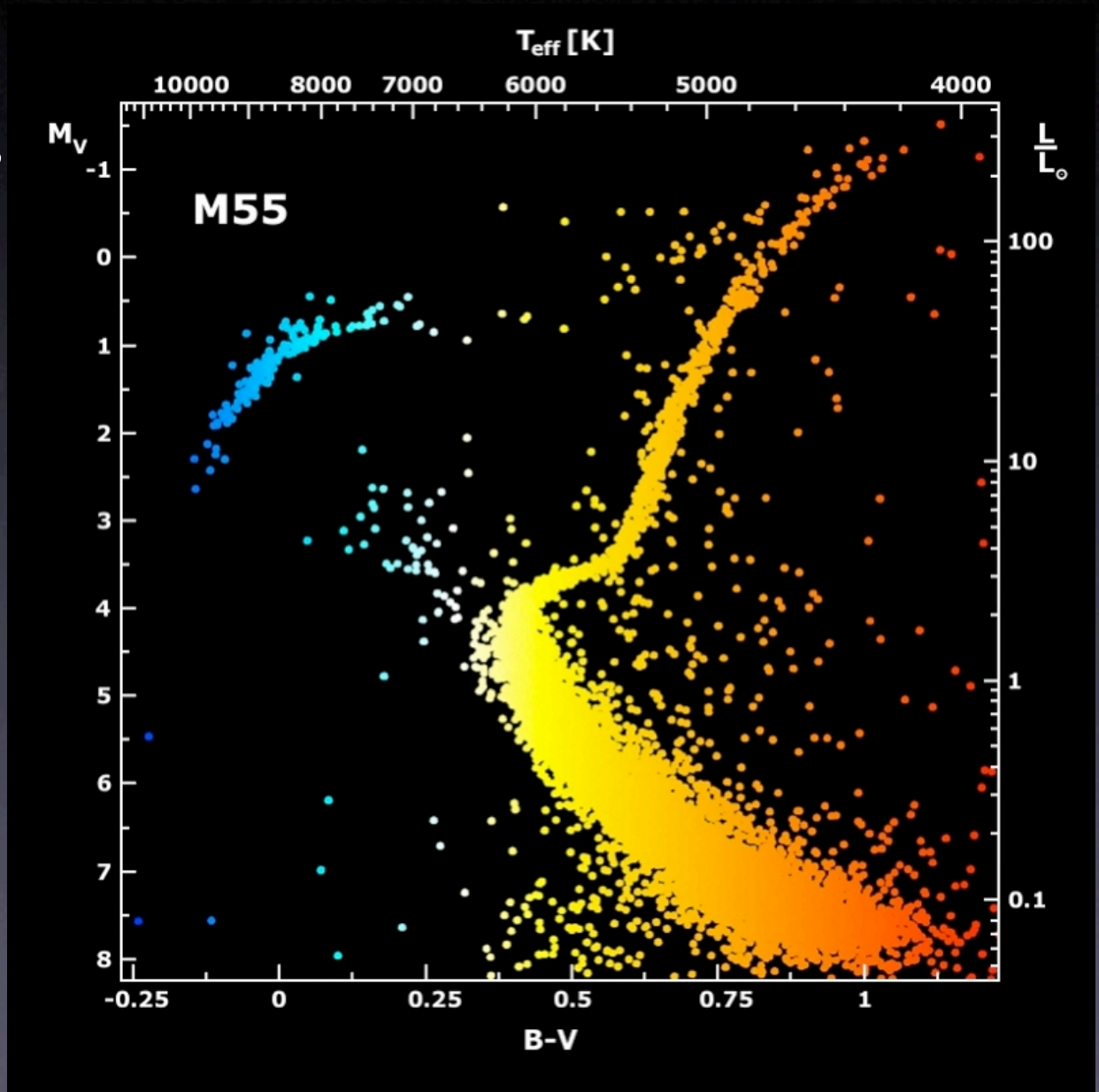
✦5 color and temperature

what do I want to know?

✦1 what is a stellar temperature?

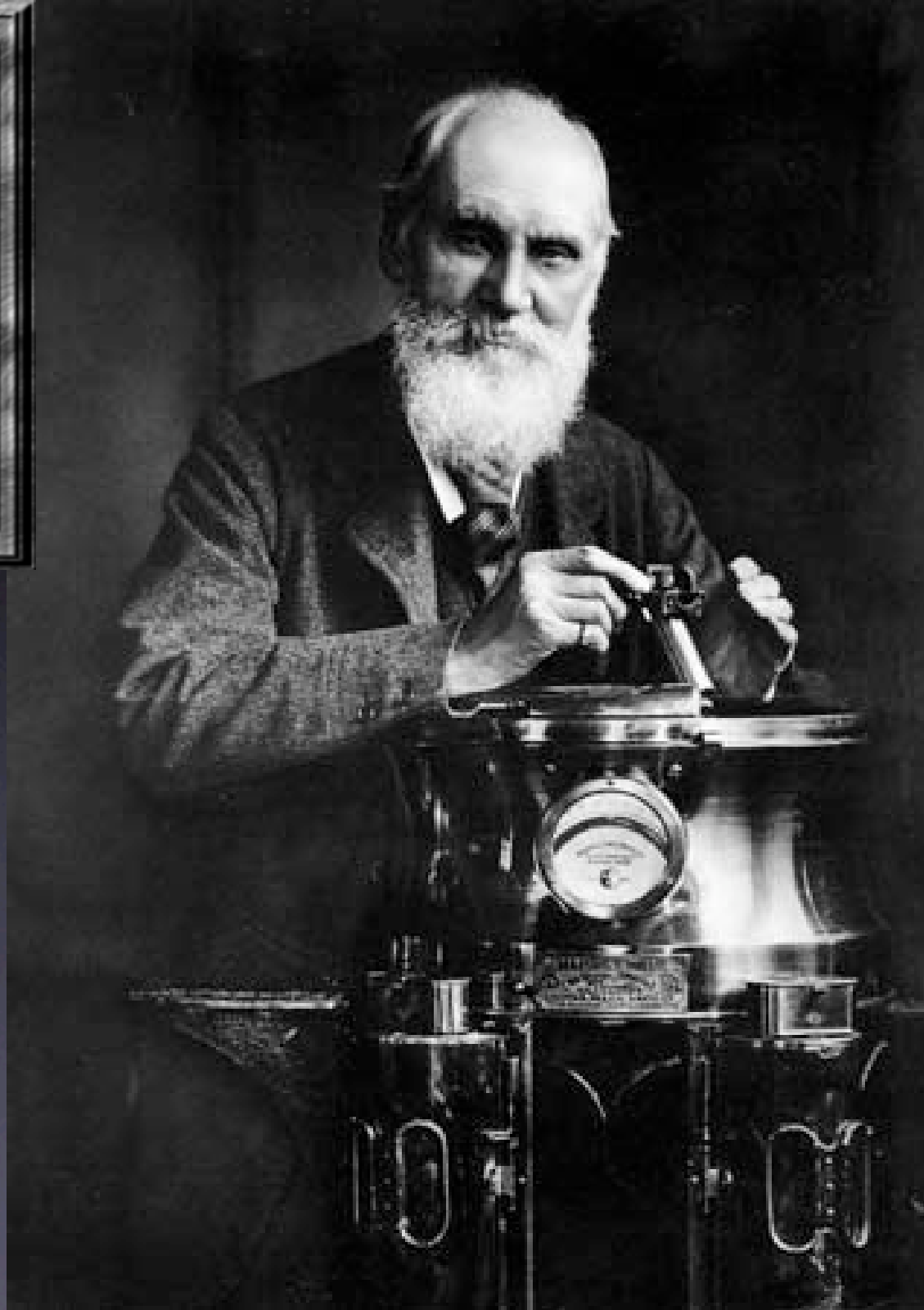
temperature characterizes the random speed of particles in a substance

the higher the temperature, the higher the average speed of the particles



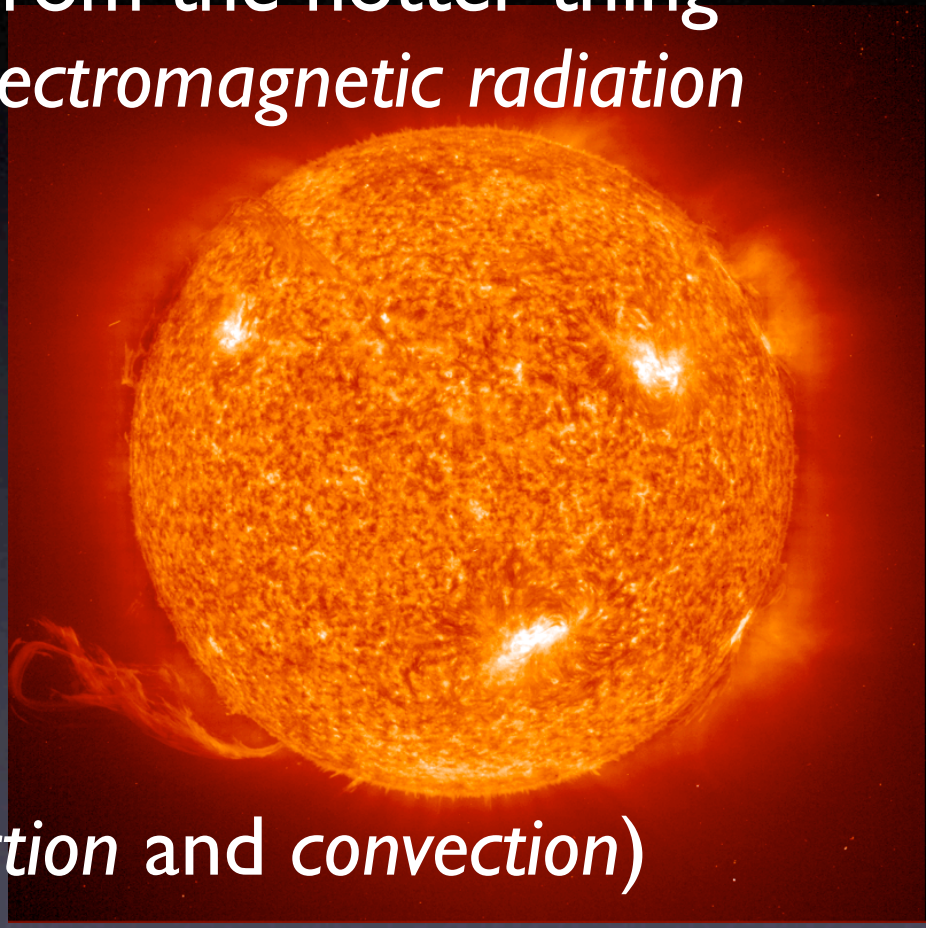
Lord Kelvin (William Thomson) 1824 - 1907

absolute zero temperature (Kelvin scale) corresponds to zero random motion



things that are hotter than their surroundings *radiate*

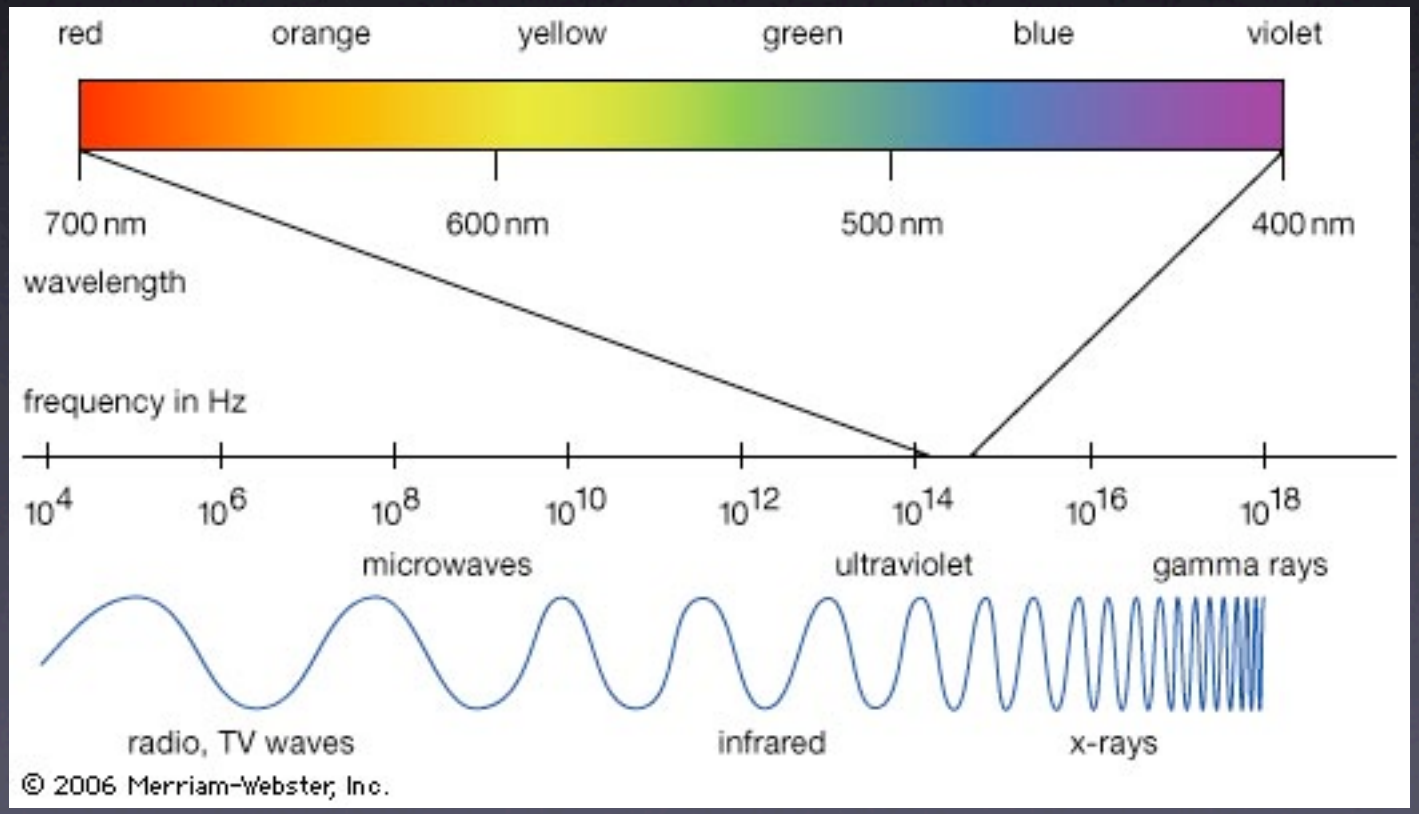
"radiate" means: energy flows from the hotter thing to its cooler surroundings via *electromagnetic radiation*

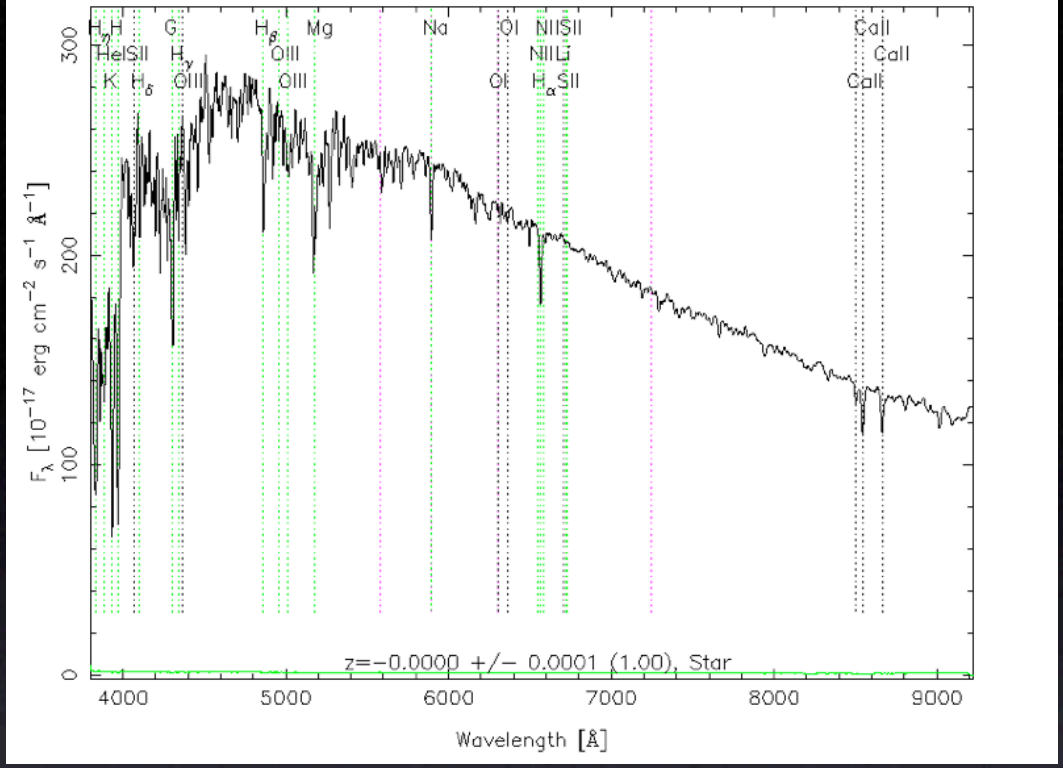


(energy can also flow via *conduction* and *convection*)

radiation can travel across a vacuum and thus is important in astronomy

electromagnetic radiation includes visible light, radio waves, X-rays, ultraviolet, infrared, microwaves, etc.

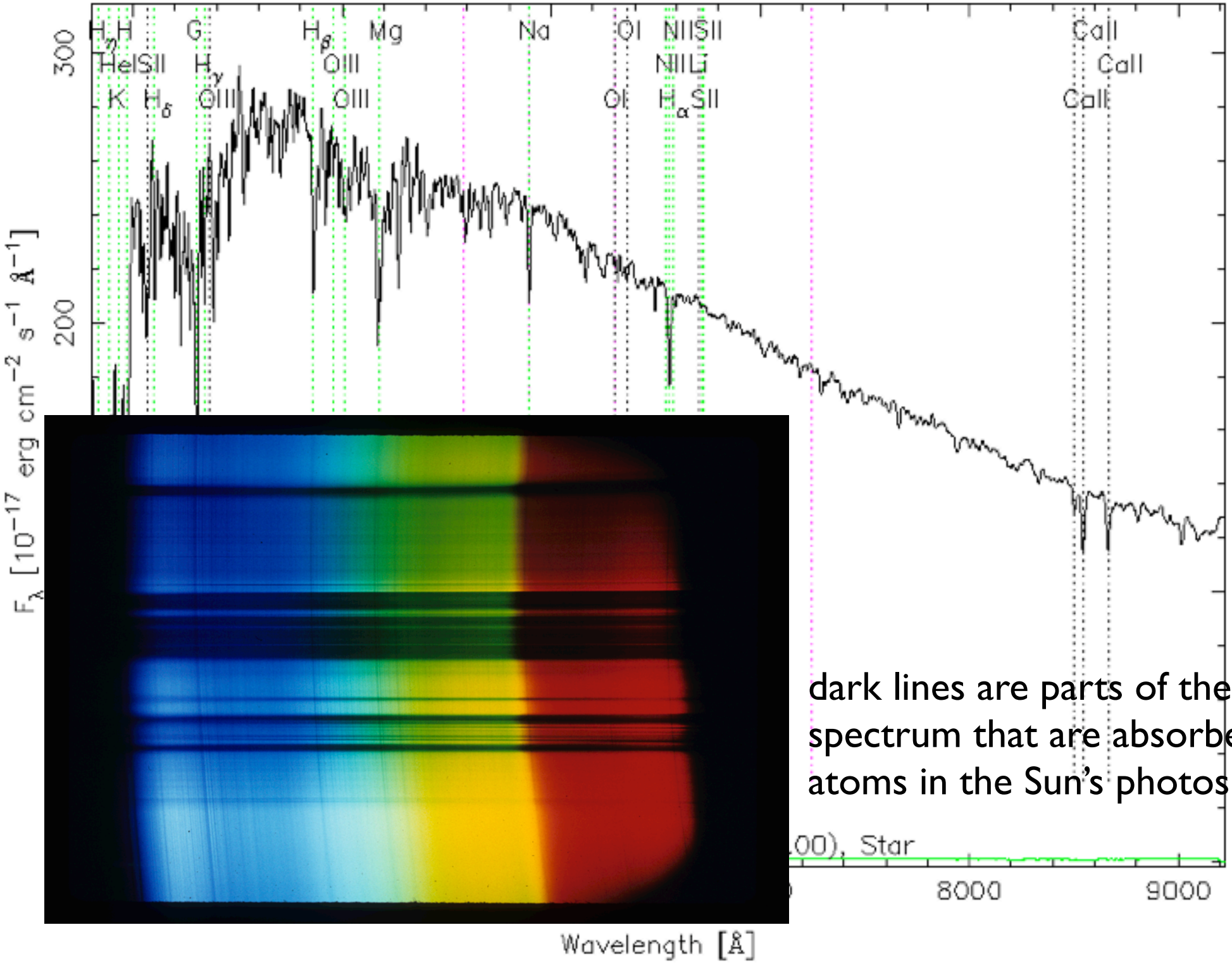




a *spectrum* is a representation of how much energy is radiated at each wavelength

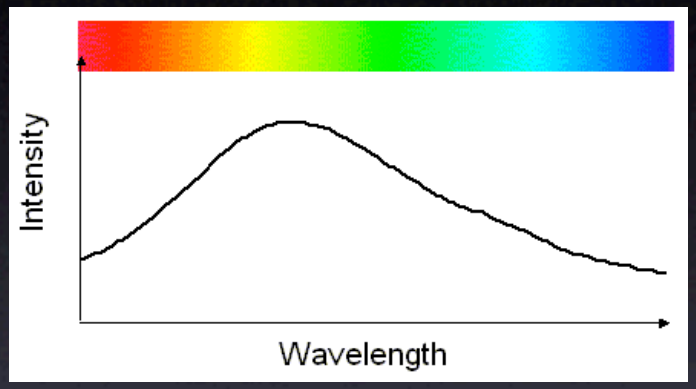
different kinds of things emit light with different spectra

by measuring the spectrum of an object, we can tell a lot about how it radiates (how it "works")



dark lines are parts of the spectrum that are absorbed by atoms in the Sun's photosphere

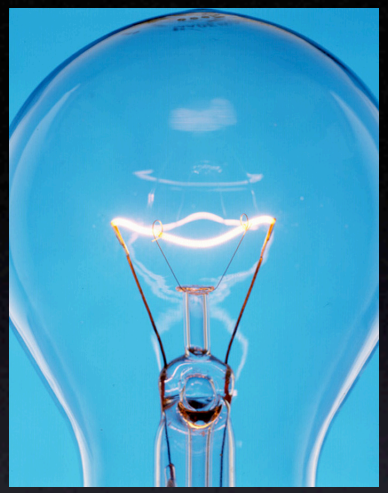
hot things radiating into their cooler surroundings have a very special kind of spectrum:



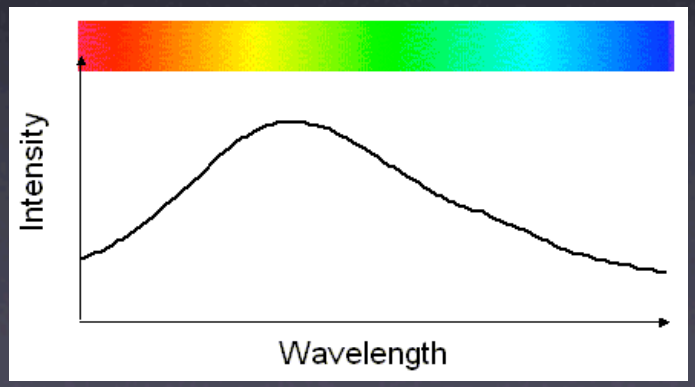
the spectrum is called a *blackbody* or *thermal* spectrum; it is completely described by a single number, T

Max Planck
1858 - 1947
German physicist

example: a light bulb filament has a temperature of 2800 K



the spectrum of the light is characterized by a number that is equal to 2800 K

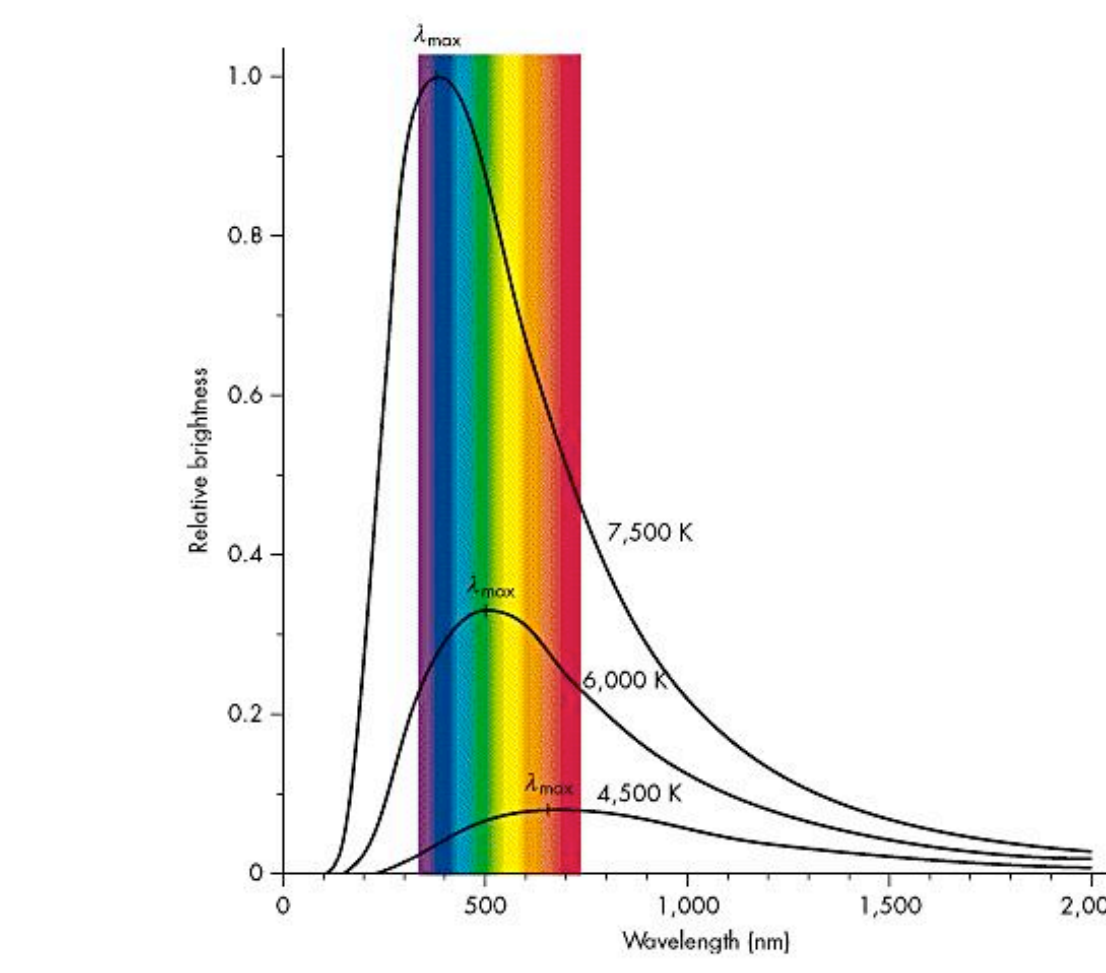


these numbers **are the same** because the emitted radiation depends on the temperature of the thing that is emitting

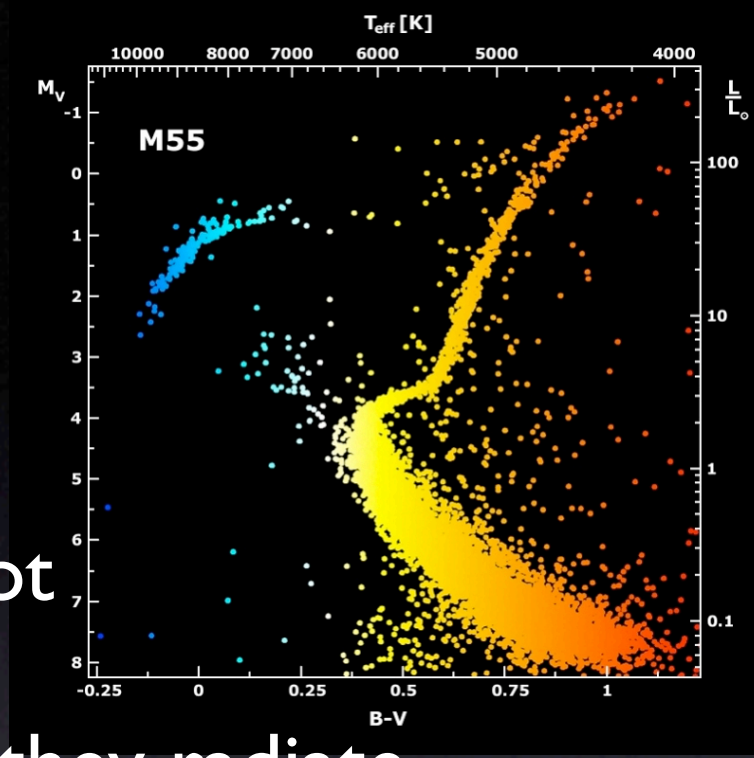
you can measure the temperature of the filament from a distance (and through a vacuum):

measure the spectrum, and find the value of T that matches

when we say that "the temperature of the Sun is 5800 K," we mean this is the temperature of its radiating surface (*photosphere*)



✦2 why is temperature important?



stars, like light bulb filaments,
radiate into space because they are hot

the hotter they are, the more energy they radiate

the more energy they radiate, the more energy needs to flow from their interior out to their surface (if the star is to sustain itself)

→ *temperatures of stars are intimately linked to their internal structures, and how long they will live*

the amount of energy radiated per second by a star is called its *luminosity*, L

L is measured in Watts (= Joules / sec)

L depends on how much *area* is radiating, namely $4\pi R^2$

L depends on temperature T

altogether, L depends on (area) $\times T^4$

$$L = 4\pi R^2 \times \sigma T^4$$

σ = Stefan-Boltzmann constant

$$= 5.67 \times 10^{-8} \text{ Watts meter}^{-2} \text{ K}^{-4}$$

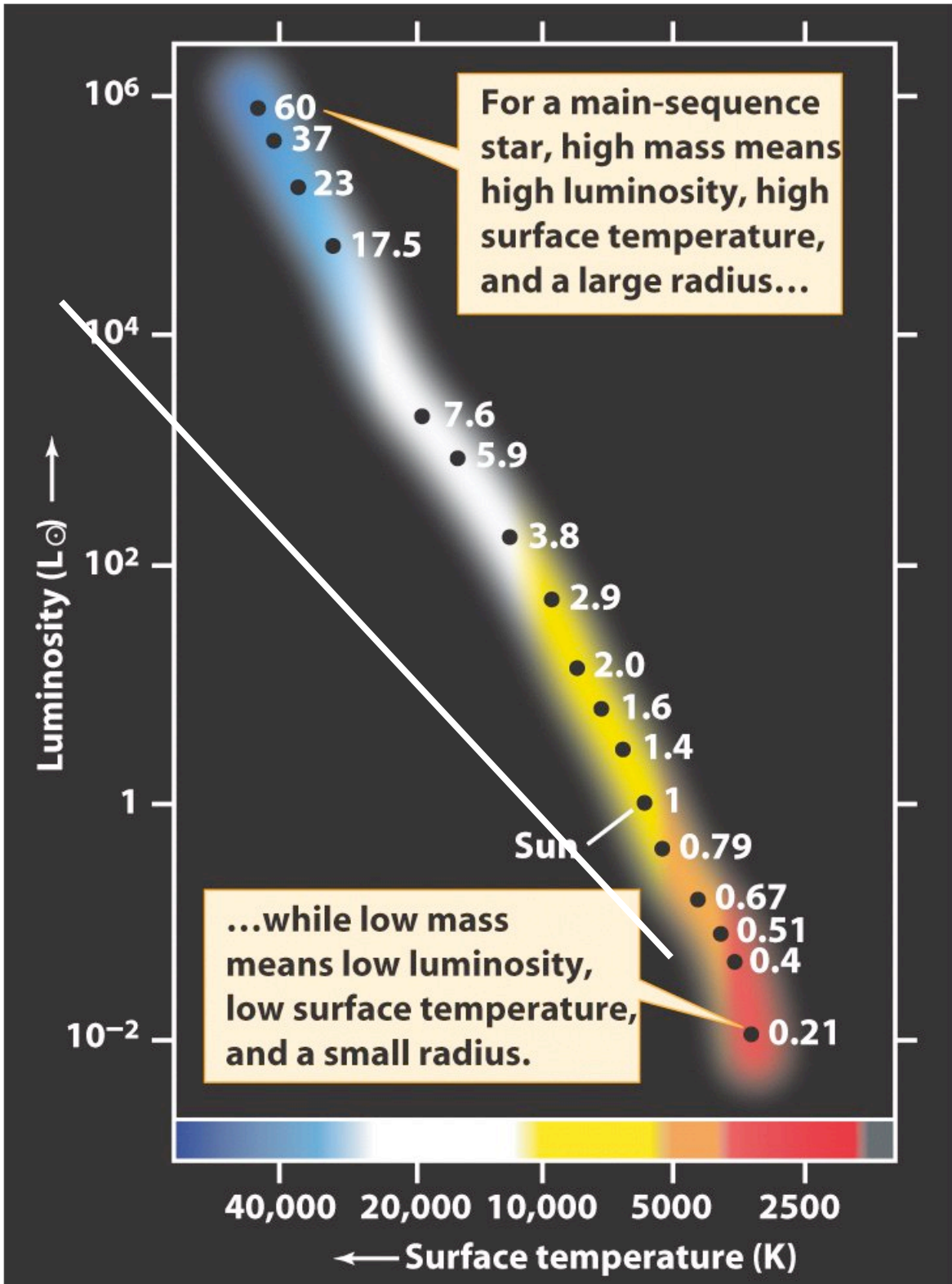
suppose we controlled a light bulb with a dimmer switch:

we measure its brightness and its temperature, and we plot these quantities (say temperature on the x-axis, and brightness on the y axis)

what does the plot look like for a bunch of different settings of the dimmer switch?

line shows hypothetical spheres, all with the same radius R

$$L = 4\pi R^2 \times \sigma T^4$$



$$L = 4\pi R^2 \times \sigma T^4$$

$L_{sun} = 3.9 \times 10^{26}$ Watts, $R = 6.9 \times 10^8$ meters

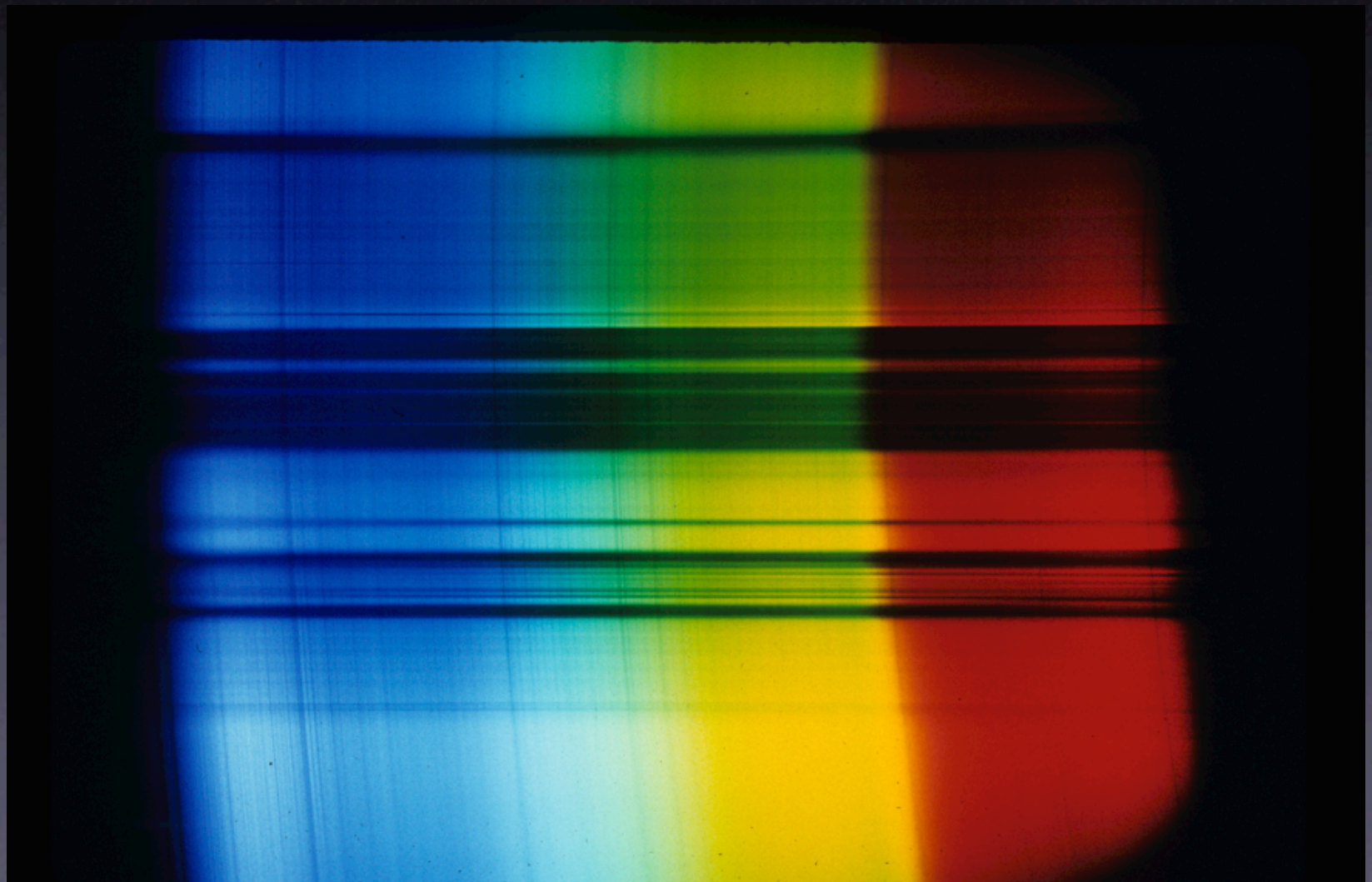
→ solve for T ; $T_{sun} = 5800$ K

this is called the *effective temperature*, T_{eff}

→ *T_{eff} is the temperature that the Sun would have if it radiated as a blackbody*

✦3 where can I find temperature measurements?

http://cas.sdss.org.astrodr6



SDSS SkyServer DR6

http://cas.sdss.org/astrodr6/en/

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Welcome to the **DR6 Catalog Archive Server** site providing public access to SDSS data for professional astronomers.

The following databases are available	
BestDR6	[Default] The best version photo (imaging), spectro and tiling data
SegueDR6	The SEGUE photo (imaging) data. See **the SEGUE CAS site.**
TargDR6	The version of the data from which spectroscopic targets were chosen

News

This site contains data from **Data Release 6 (DR6)**. Please see the **Site News** page, **What's New in DR6** page and the **Known Problems** page for more information.

To run a query on one of the DR6 DBs other than BESTDR6, name the database explicitly in the query:

```
SELECT TOP 100 * FROM TARGDR6..PhotoObj
WHERE r<17 and r-i>2
```

SDSS is supported by

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- Archive Intro
- FAQ
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- Algorithms
- Table Descriptions
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- Sample SQL Queries
- Details of SDSS Data
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SkyServer Schema Browser

http://cas.sdss.org/astrodr6/en/help/browser/browser.asp

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Schema Browser

Glossary
Algorithms

Search for

Go

Tables

- Algorithm
- Ap7Mag
- BestTarget2Sector
- Chunk
- DataConstants
- DBColumns
- DBObjects
- DBViewCols
- Dependency
- Diagnostics
- DR3QuasarCatalog
- DR5QuasarCatalog
- ELRedShift
- Field
- FieldProfile
- FileGroupMap
- First
- Frame

The data in the database is contained in **Tables**, organized in columns and rows. We have defined **Views** over the tables. These represent special subsets of the original table.

Most of the tables also have one or more **Indices** defined on them to speed up searches on them. Please see the **Archive Intro** Help page for more information on the types of indices.

Functions and stored **Procedures** take a number of parameters, and execute a previously defined sequence of commands. Usually, their names are prefixed by *f* or *sp*, like in *fPhotoStatus* or *spGetFiberList*.

The table **SDSSConstants** contains most of the parameters relevant to the SDSS. Their values can be displayed by clicking on the link in the left hand panel.

The table **DataConstants** contains most of the bit-flags and enumerated quantities relevant to the SDSS. Their values can be displayed by clicking on the link in the left hand panel. There are several access functions to make ineterpretations and the back and forth conversions easier. They are displayed when you look at the individual enumerated fields.

Click on the **[+]** sign in front of the categories on the left to get an expanded view, on the **[-]** to collapse the list, on the name to get a summary, and on the individual items to get their detailed description.

Enter a keyword into the search box on the top, and press Enter or the **Go** button to search through the descriptions and units stored in the database.

SkyServer Schema Browser

http://cas.sdss.org/astrodr6/en/help/browser/browser.asp

Sloan Digital Sky Survey / SkyServer

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Schema Browser

PlateX
ProfileDefs
ProperMotions
PubHistory
QsoBest
QsoBunch
QsoCatalogAll
QsoConcordanceAll
QsoSpec
QsoTarget
RC3
RecentQueries
Region
Region2Box
RegionArcs
RegionPatch
Rmatrix
Rosat
RunQA
RunShift
SDSSConstants
Sector
Sector2Tile
Segment
SiteConstants
SiteDBs
SiteDiagnostics
SpecLineAll
SpecLineIndex
SpecObjAll
SpecPhotoAll
sppLines
sppParams
Stetson

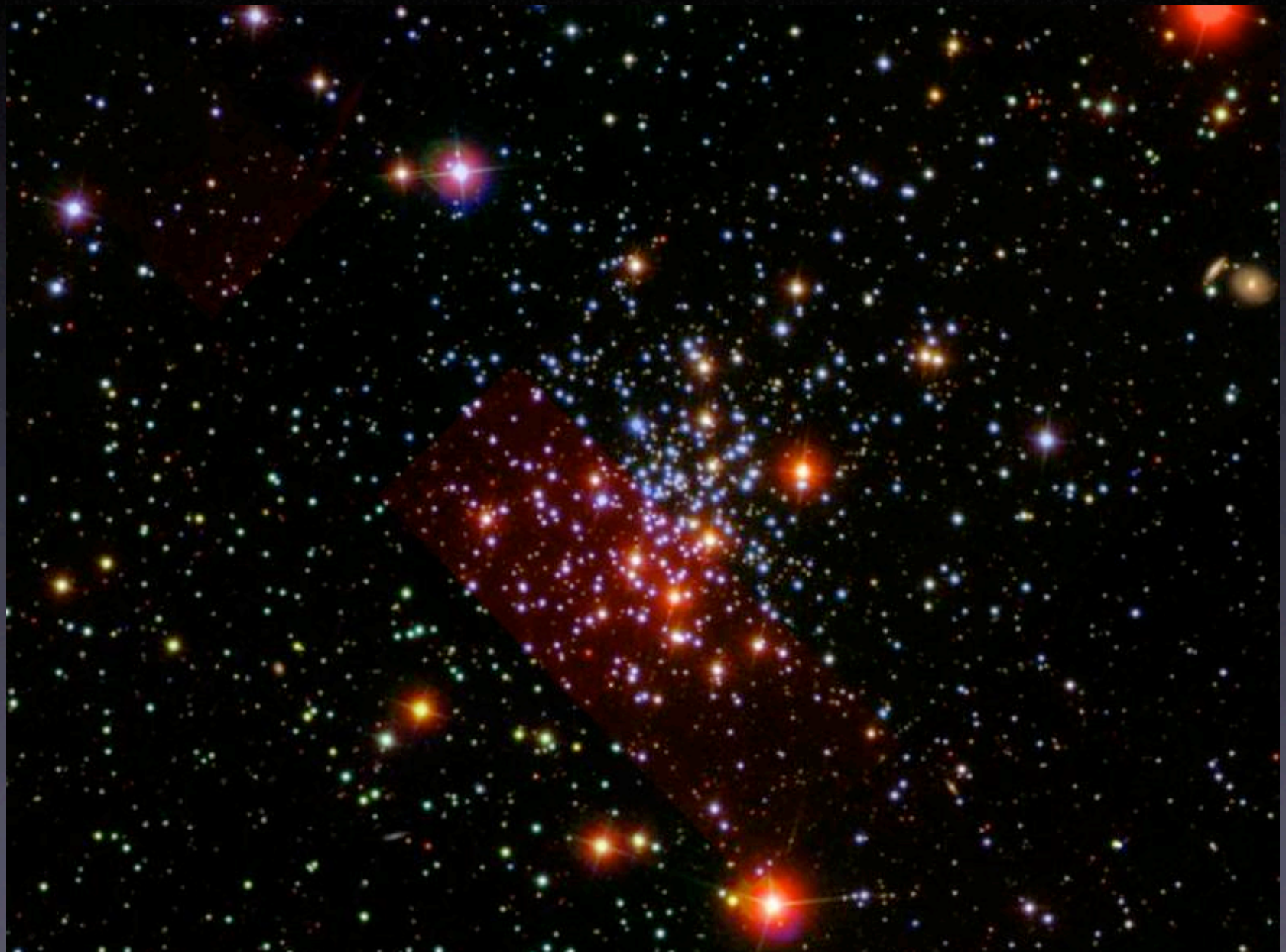
TABLE sppParams

Contains outputs from the Spectro Parameter Pipeline (spp).

Spectra for over 250,000 Galactic stars of all common spectral types are available with DR6. These Spectra were processed with a pipeline called the 'Spectro Parameter Pipeline' (spp) that computes standard stellar atmospheric parameters such as [Fe/H], log g and Teff for each star by a variety of methods. These outputs are stored in this table, and indexed on the 'specObjID' key index parameter for queries joining to other tables such as specobjall and photoobjall. See the Sample Queries in SkyServer for examples of such queries.

name	type	length	unit	ucd	description
specobjid	bigint	8			64 bit unique spectrum id f(p,mjd,fiber)
plate	int	4			plate number
mjd	int	4			Modified Julian Date of (last) observation
fiberid	int	4			Fiber number (1-640) 1-320 on spec#1
fehspectype	varchar	32			SEGUE or SDSS target type abbrev.
hammersptype	varchar	32			Stellar Type Classification -- UW
sptypea	varchar	32			Stellar Type Classification -- SSPP
flag	varchar	32			SSPP flags dDEhHInNSV, x -- not a star
feha	real	4	dex		adopted [Fe/H] value
fehan	int	4			number of estimators combined into feha
fehaerr	real	4			error/sigma on the [Fe/H] value, or -9.999

# NGC 2420 - open cluster in Gemini
age = 1.7 billion years



SkyServer DR6 Search

http://cas.sdss.org/astrodr6/en/tools/search/sql.asp

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DR6 Tools

- Getting Started
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- Get images
- Scrolling sky
- Visual Tools
- Search
  - Radial
  - Rectangular
  - SQL
  - Imaging Query
  - Spectro Query
- Object Crossid
- CasJobs

SQL Search

Please note: To be fair to other users, queries run from SkyServer search tools are restricted in how long they can run and how much output they return, by **timeouts** and **row limits**. Please see the **Query Limits help page.** To run a query that is not restricted by a timeout or number of rows returned, please use the **CasJobs batch query service.**

```
-- this query gets data for well-observed stars in the open cluster NGC 2420

select ra, dec, g0, gmr0, sna, teffa, logga, feha, rva,  pmra, pmdec, sptypea, distCAP

from sppParams

where (plate = 2078 or plate = 2079) and sna > 10
```

Submit | Check Syntax Only? | Output Format ○ HTML ○ XML ◉ CSV | Reset

To find out more about the database schema use the **Schema Browser.**

For an introduction to the Structured Query Language (SQL), please see the **SQL Intro** help page. In particular, please read the **Optimizing Queries** section. If your query is timing out or running much slower than you think it should, please see also the **the BookMark Lookup bug** section of the SQL Intro.

```
select ra, dec, g0, gmr0, sna, teffa,
logga, feha, rva,  pmra, pmdec, sptypea,
distCAP

from sppParams

where (plate = 2078 or plate = 2079)
and sna > 10
```

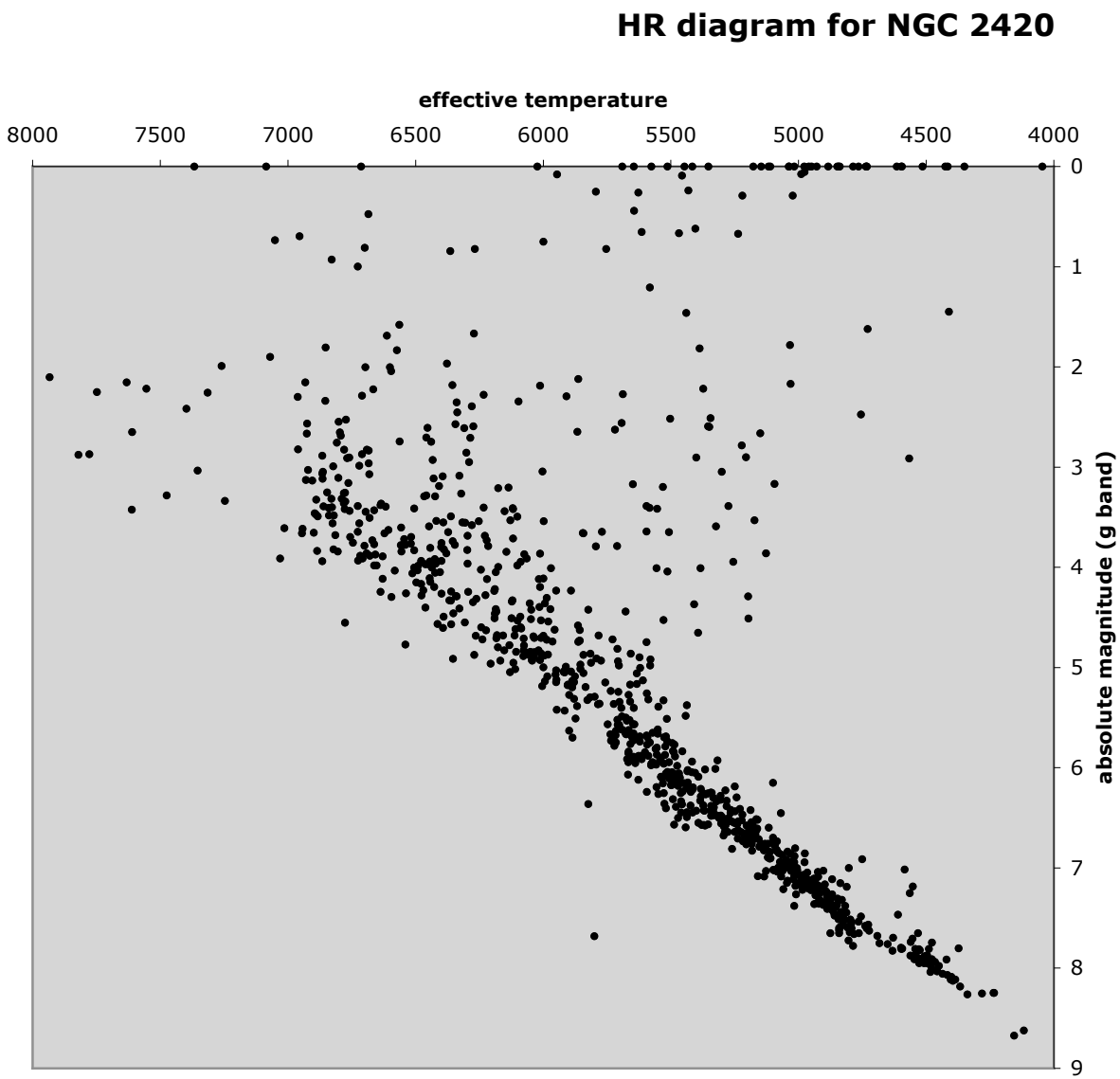
Excel File Edit View Insert Format Tools Data Window Help

Verdana 10

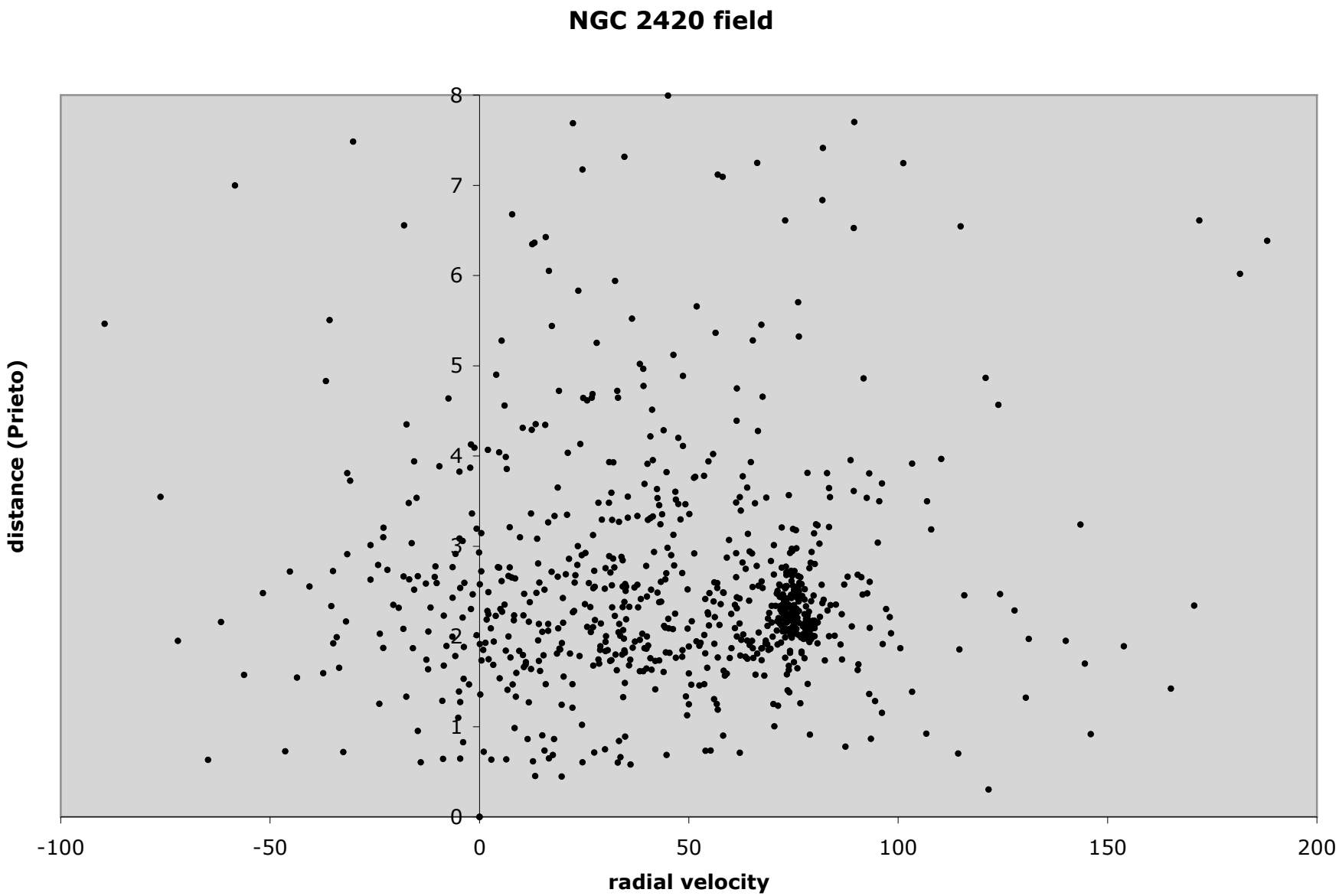
N2 =C2 - 10 - 5*LOG10(M2)

new2420.xls

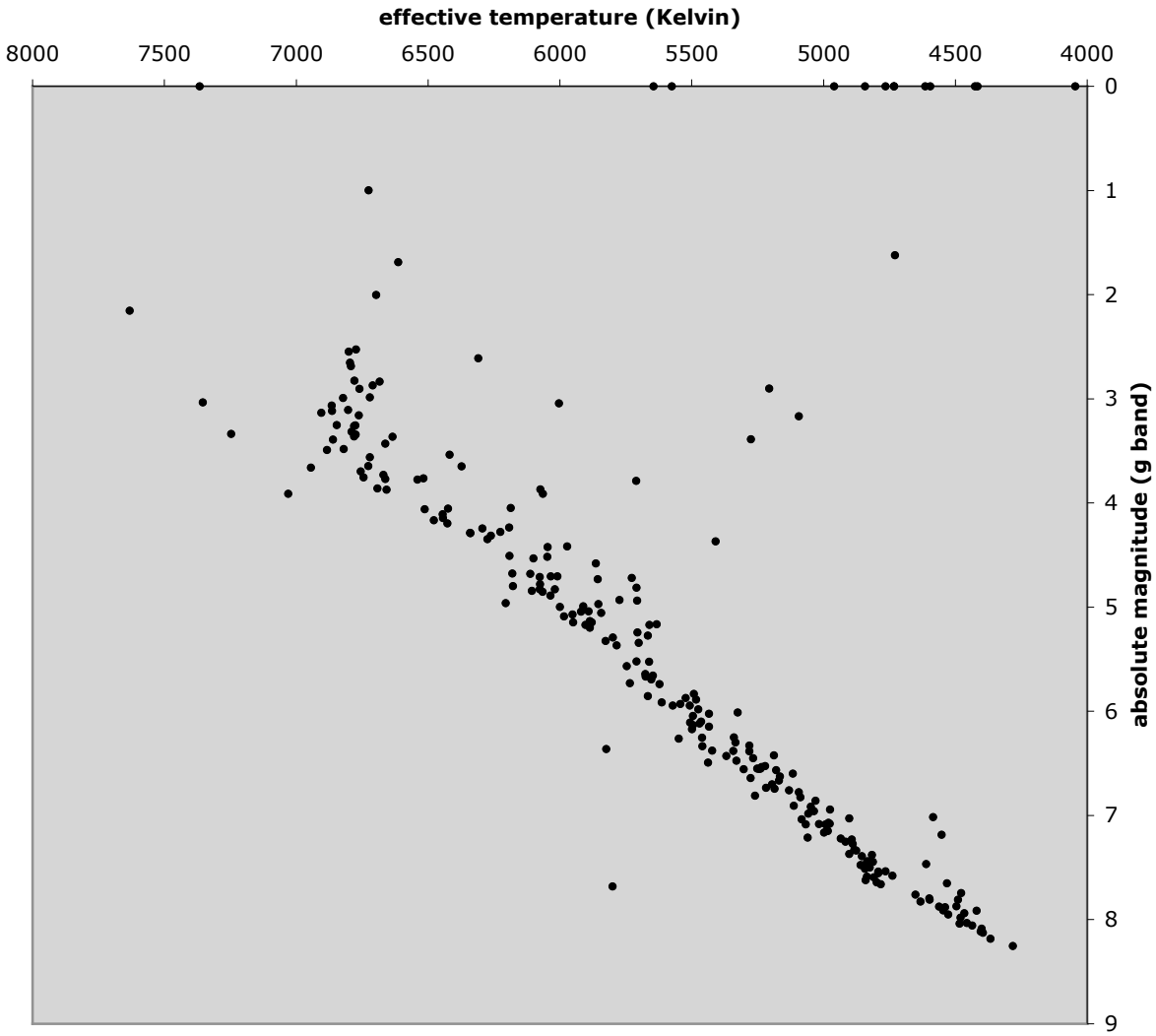
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	ra	dec	g0	gmr0	sna	teffa	logga	feha	rva	pmra	pmdec	sptypea	distCAP	abs g mag
2	115.501	22.6643	16.3	0.275	114.1	6776	4.098	-3.57	8.3	3	-4	F5	2.234	4.553
3	114.849	21.5212	13.86	0.25	86.2	6361	4.272	-0.635	33.3	2	1	F5	0.841	4.24
4	115.3552	21.4947	14.33	0.204	81.4	6710	3.842	-0.267	31.6	0	0	F5	2.566	2.286
5	114.5822	21.5984	14.62	0.181	81	6781	4.151	-0.383	67.3	0	0	F5	1.867	3.262
6	113.3179	20.8261	14.46	0.172	78.1	6930	4.114	-0.429	30.6	4	4	F5	1.847	3.129
7	114.5458	21.4817	14.83	0.219	77.2	6776	4.089	-0.531	71	21	2	F5	2.066	3.256
8	115.615	21.7543	15.28	0.314	76.3	6184	4.359	-0.32	53.7	2	-2	F2	1.471	4.441
9	115.0541	21.4973	15.4	0.119	73.7	6889	3.907	-0.602	93.2	0	0	F5	2.604	3.325
10	114.2907	22.406	15.62	0.271	70.9	6423	4.017	-0.196	65.1	2	2	F5	2.921	3.291
11	115.2721	21.4235	15.39	0.359	70	6074	4.039	-0.215	84.8	1	2	G2	2.009	3.87
12	114.8035	21.5068	13.63	-0.131	69.3	8383	3.91	0	30.9	0	4	A0	3.483	0.921
13	114.849	21.5212	13.86	0.25	68.6	6390	4.372	-0.675	30	2	1	F5	0.749	4.492
14	114.5735	20.5616	14.03	0.158	67.4	6852	3.584	-0.394	39.8	1	2	F5	2.782	1.807
15	114.6335	21.9403	14.31	-0.023	67.3	7748	3.97	0	-12.8	3	-3	A0	2.585	2.252
16	114.7414	21.7168	14.29	0.093	67	7314	3.874	-0.552	27.5	0	-3	F5	2.552	2.258
17	115.2708	22.2928	14.42	0.089	66.9	7367	4.636	-0.239	83.2	0	0	A0	-9.999	#NUM!
18	114.8049	20.5956	15.93	0.377	66.8	6015	4.203	-0.672	38.9	0	-2	F2	2.029	4.395
19	114.4696	20.982	14.28	0.254	66.4	6394	3.913	-0.858	14.2	1	-3	F5	1.728	3.092
20	114.419	21.6728	14.44	-0.013	66.3	7778	4.24	-0.52	16.4	1	0	A0	2.063	2.872
21	115.0432	21.632	14.46	0.261	66	6408	3.937	-0.786	32.5	1	-1	F5	1.799	3.189
22	113.8043	22.1115	15.91	0.259	66	6478	4.314	-0.252	42.5	1	5	F5	2.485	3.935
23	115.7745	22.442	14.3	-0.227	65.8	9132	-9.999	-9.999	-18	-1	-2	A0	6.557	0.217
24	114.5822	21.5984	14.62	0.181	65.7	6780	4.01	-0.416	72.9	0	0	F5	2.282	2.826
25	114.4749	21.6631	14.71	0.242	65.3	6635	4.155	-0.42	69.5	0	-3	F5	1.863	3.363
26	114.6589	21.7794	14.61	0.162	65.2	6803	4.144	-0.3	70	0	-4	F5	1.997	3.106
27	114.7736	21.645	14.55	0	65	7632	4.088	#####	70.3	2	0	A0	3.011	2.155
28	115.3552	21.4947	14.33	0.204	65	6691	3.898	-0.33	30.2	0	0	F5	2.002	2.825
29	114.5524	21.6482	14.45	0.218	64.8	6613	3.601	-0.475	73.9	0	-3	F5	3.567	1.688
30	114.1201	20.4136	14.41	0.189	64.8	6713	3.622	-0.597	51.9	1	8	F5	-9.999	#NUM!

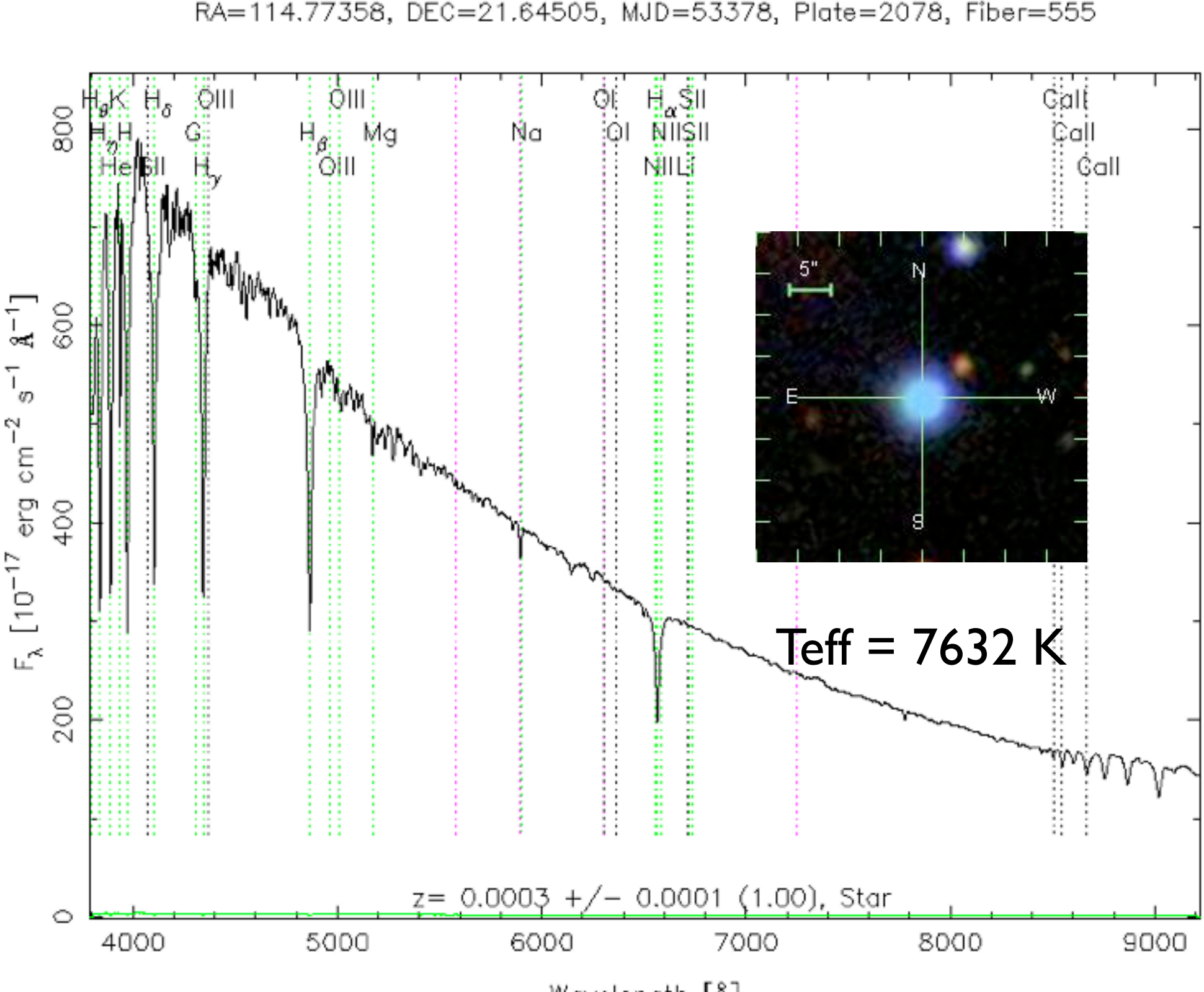

HR diagram for NGC 2420
effective temperature
8000
7500
7000
6500
6000
5500
5000
4500
4000
0
1
2
3
4
5
6
7
8
9
absolute magnitude (g band)

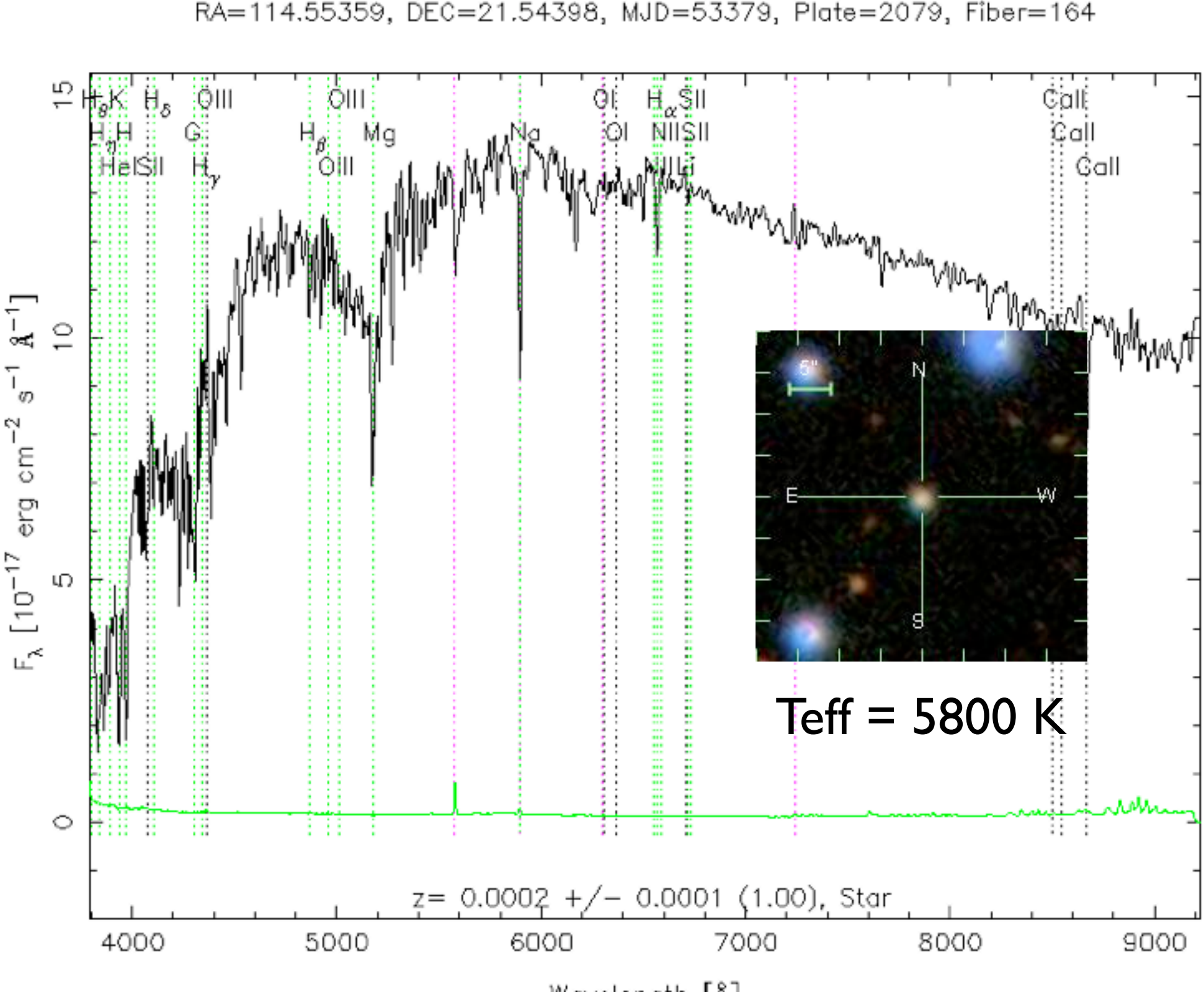
members of the star cluster should have the same distance and velocity (with respect to us)



HR diagram for NGC 2420 w/ cut on velocity



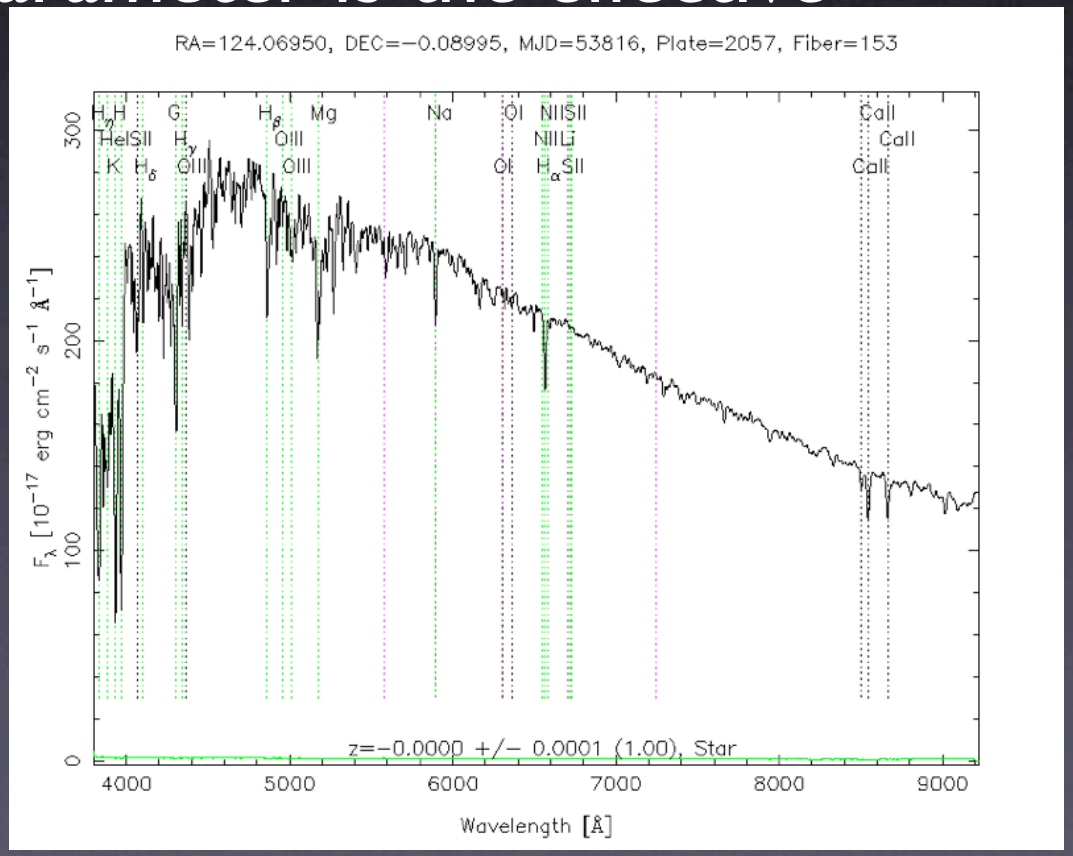

RA=114.77358, DEC=21.64505, MJD=53378, Plate=2078, Fiber=555
Hε K Hδ OIII OIII OI Hα SII CaII
Hη H G Hβ Mg Na OI NII SII CaII
He SII Hγ OIII NII LI CaII
5"
N
E
W
S
Teff = 7632 K
z= 0.0003 +/- 0.0001 (1.00), Star
F_λ [10^{-17} erg cm^{-2} s^{-1} Å^{-1}]
0
200
400
600
800
4000
5000
6000
7000
8000
9000
Wavelength [Å]


RA=114.55359, DEC=21.54398, MJD=53379, Plate=2079, Fiber=164
Teff = 5800 K
z= 0.0002 +/- 0.0001 (1.00), Star
Wavelength [Å]
F_λ [10^{-17} erg cm^{-2} s^{-1} Å^{-1}]
5"
N
E
W
S

✦4 example of using temperature measurements: look for Sun-like stars

a star like the Sun will have a spectrum like the Sun

one spectroscopic parameter is the effective temperature, T_{eff}



not all stars with T_{eff} = 5800 K are like the Sun

other parameters include the chemical composition, more specifically the proportion of heavy elements with respect to hydrogen

in astronomical jargon this parameter is called [Fe/H]

for the Sun, [Fe/H] = 0. For a star with an abundance of iron and other heavy elements ten times smaller than in the Sun, [Fe/H] = -1

another parameter that can be derived from the spectrum is the *pressure* of the gas

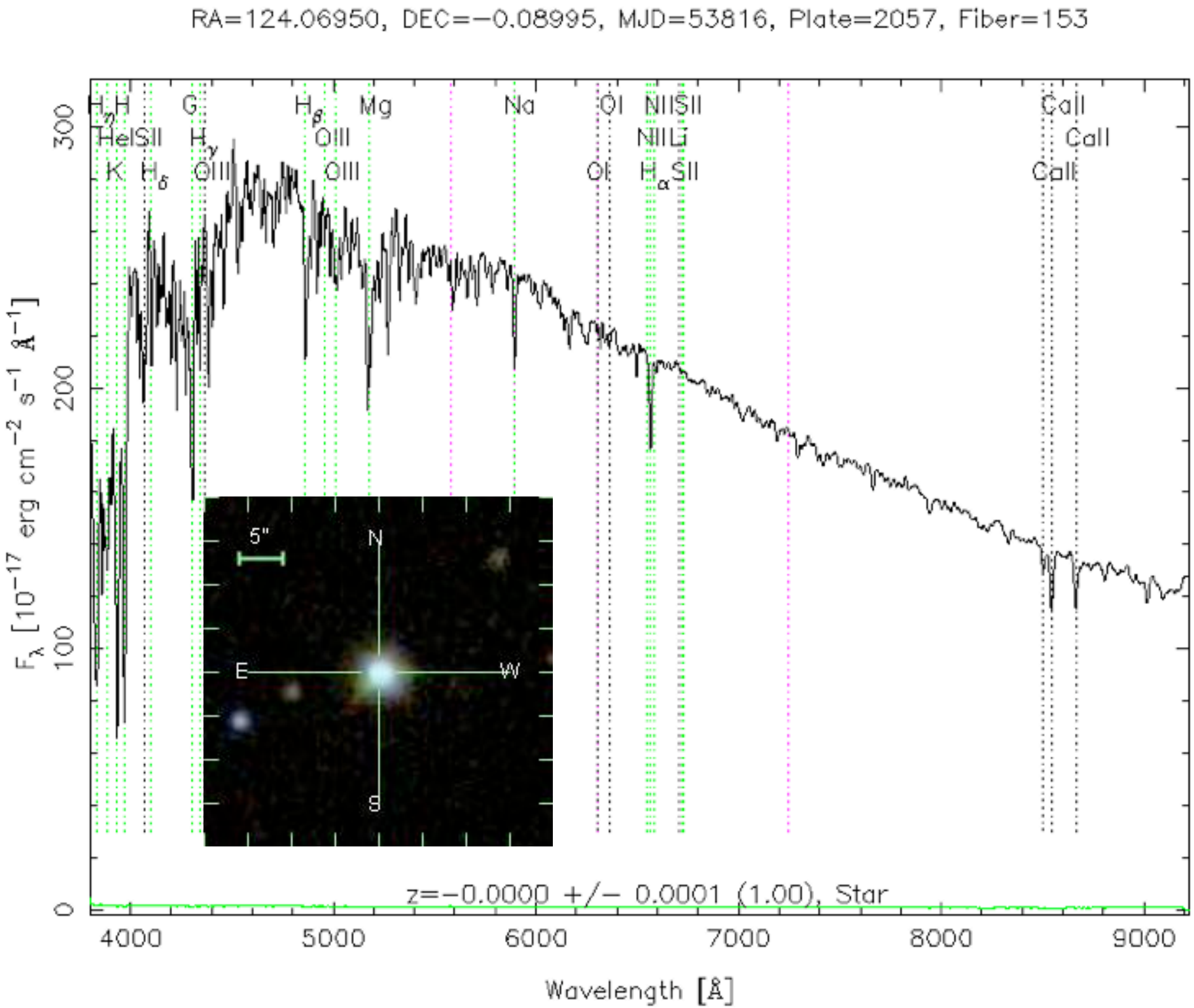
more directly, we measure the *acceleration due to gravity in the photosphere of the star*

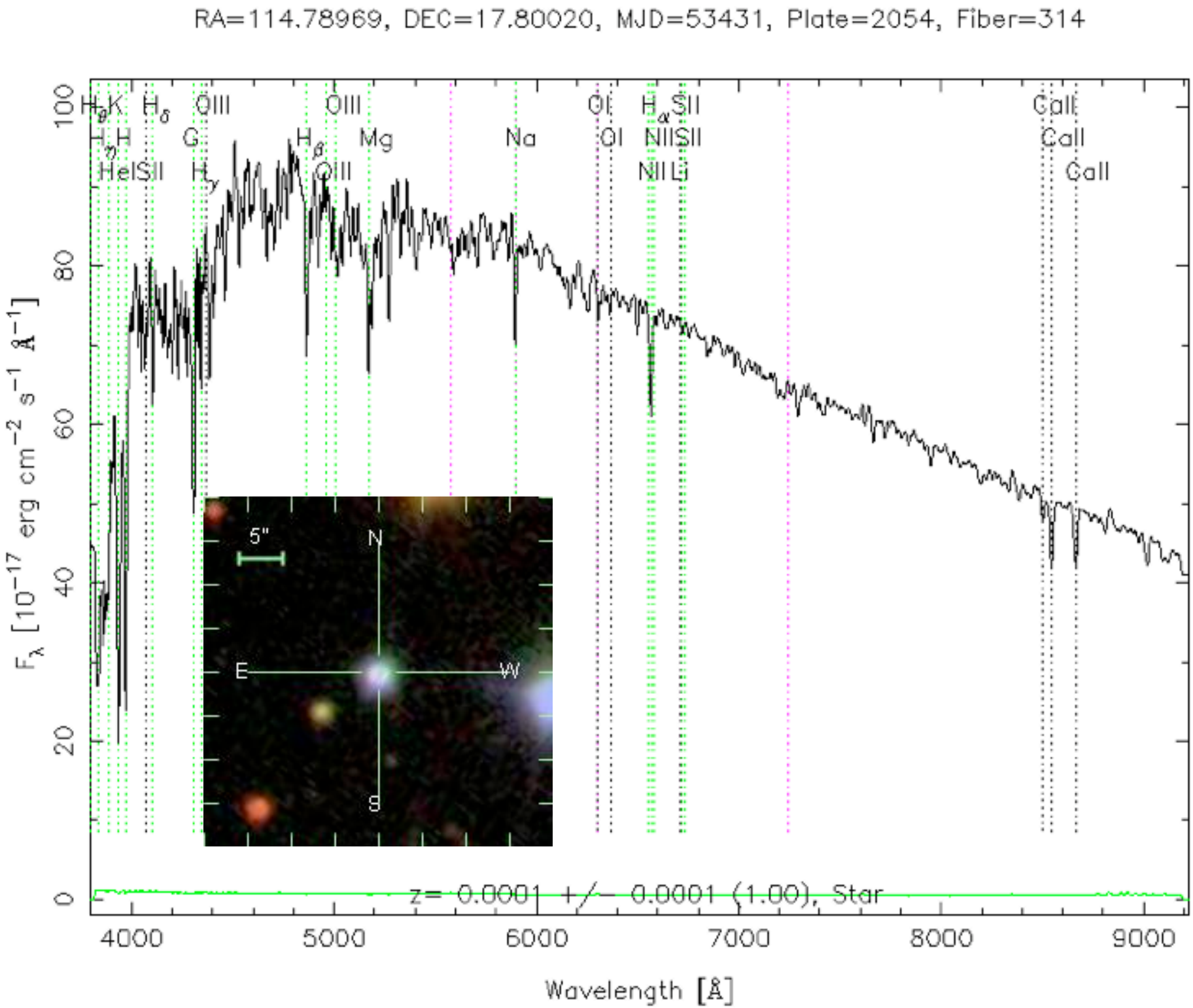
g (surface of earth) = 981 centimeters per sec per sec, so log g = 3

stars like the Sun have log g near 4 (as opposed to giant stars which have log g near 2, and white dwarfs which have log g near 8)

normal nomenclature	SDSS database
T_{eff}	teffa
[Fe/H]	feha
log g	logga

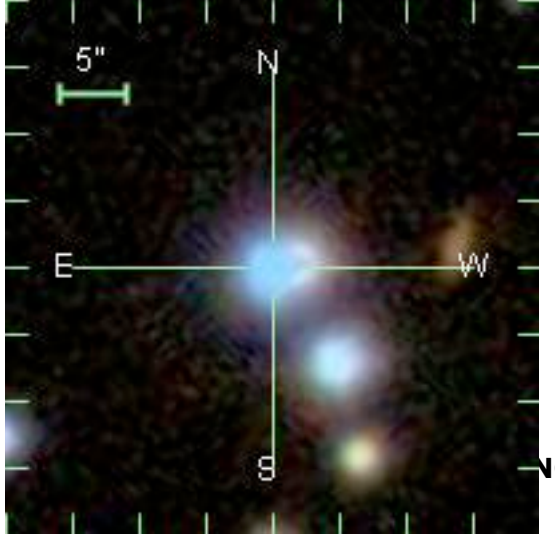
```
-- select Sun-like stars

select ra, dec, g0, gmr0, sna, teffa, logga, feha,
rva, pmra, pmdec, sptypea, distCAP

from sppParams

where teffa between 5700 and 5900 and
logga between 4 and 5 and
feha between -0.2 and 0.0 and
b between -20 and 20 and
sna > 30
```


RA=124.06950, DEC=−0.08995, MJD=53816, Plate=2057, Fiber=153
Hη H
HeI SII
K Hδ
G
Hγ
OIII
Hβ
OIII
OIII
Mg
Na
OI
OI
NII SII
NII Li
Hα SII
CaII
CaII
CaII
5"
N
E
W
S
z=−0.0000 +/− 0.0001 (1.00), Star
F_λ [10^−17 erg cm^−2 s^−1 Å^−1]
Wavelength [Å]
0
100
200
300
4000
5000
6000
7000
8000
9000

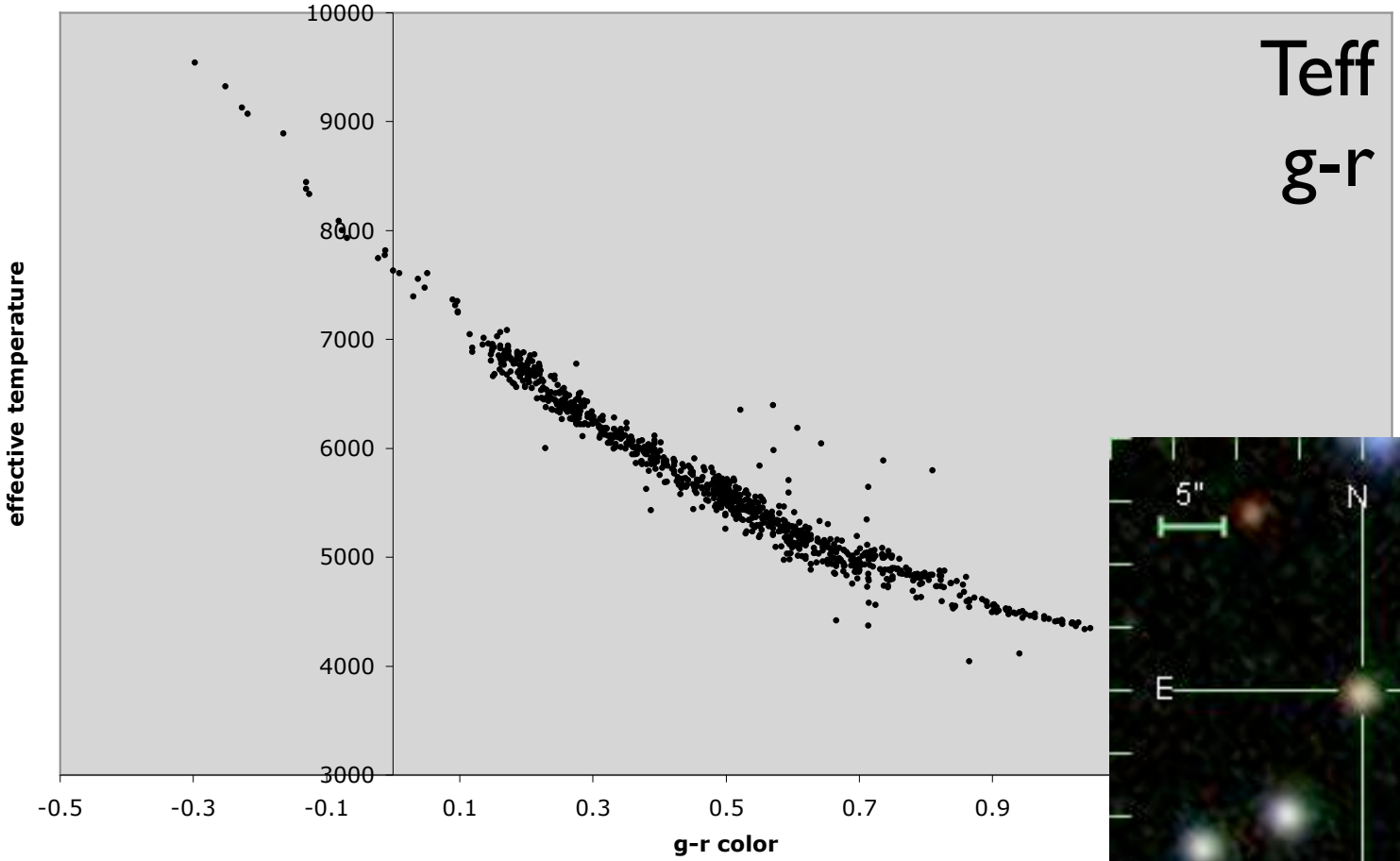

RA=114.78969, DEC=17.80020, MJD=53431, Plate=2054, Fiber=314
Hθ K Hδ OIII OIII OI Hα SII CaII
Hη H G Hβ Mg Na OI NII SII CaII
HeI SII Hγ OIII NII Li CaII
5"
N
E
W
S
z= 0.0001 +/- 0.0001 (1.00), Star
F_λ [10^{-17} erg cm^{-2} s^{-1} Å^{-1}]
Wavelength [Å]
0
20
40
60
80
100
4000
5000
6000
7000
8000
9000

✦5 color and temperature

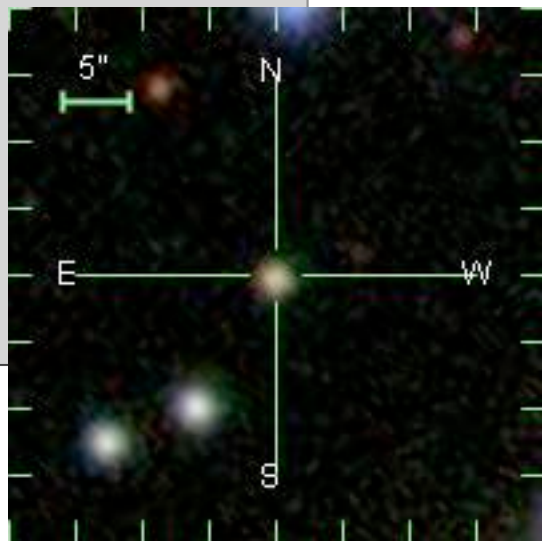
Teff = 7367
g-r = 0.089



NGC 2420



Teff = 4404
g-r = 1.02



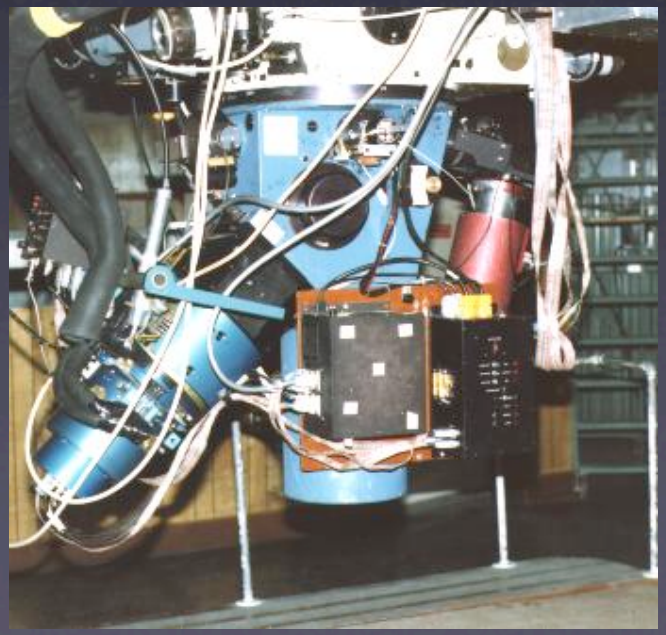
the previous plot tells you that you can derive temperatures from *colors*

a color is the ratio of energy passing though one filter with respect to another filter (eg how much red light there is with respect to blue light)

by astronomical convention, the *larger* the numerical value for the color, the *cooler* (redder) the temperature

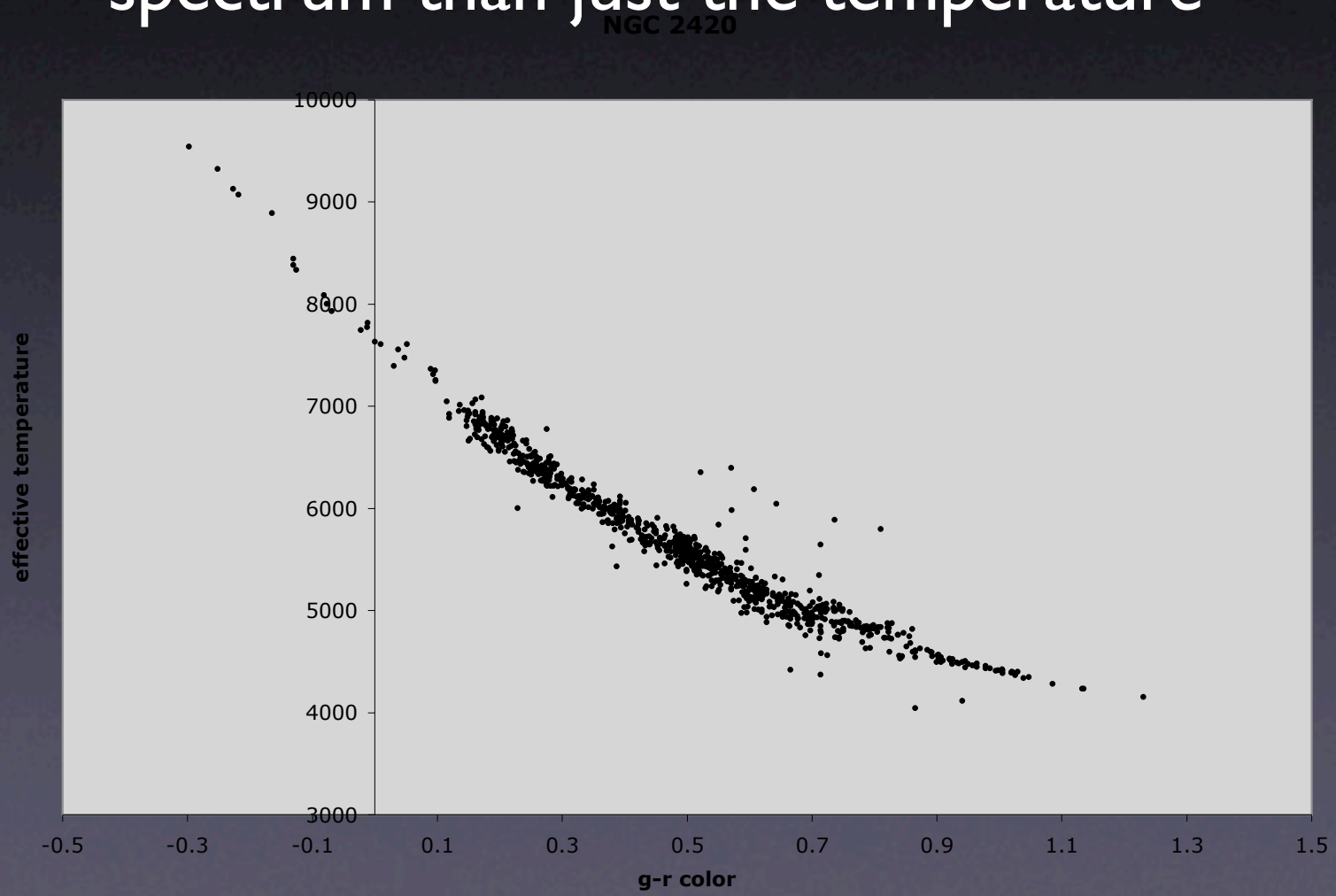
you can measure a color with a camera and 2 filters

you can measure colors for fainter stars (and more of them) than you can with a spectrograph



however, the correlation of color with temperature is not perfect (why not?)

and, you can get more information from a spectrum than just the temperature



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Hero Member
★★★★★
Posts: 6627

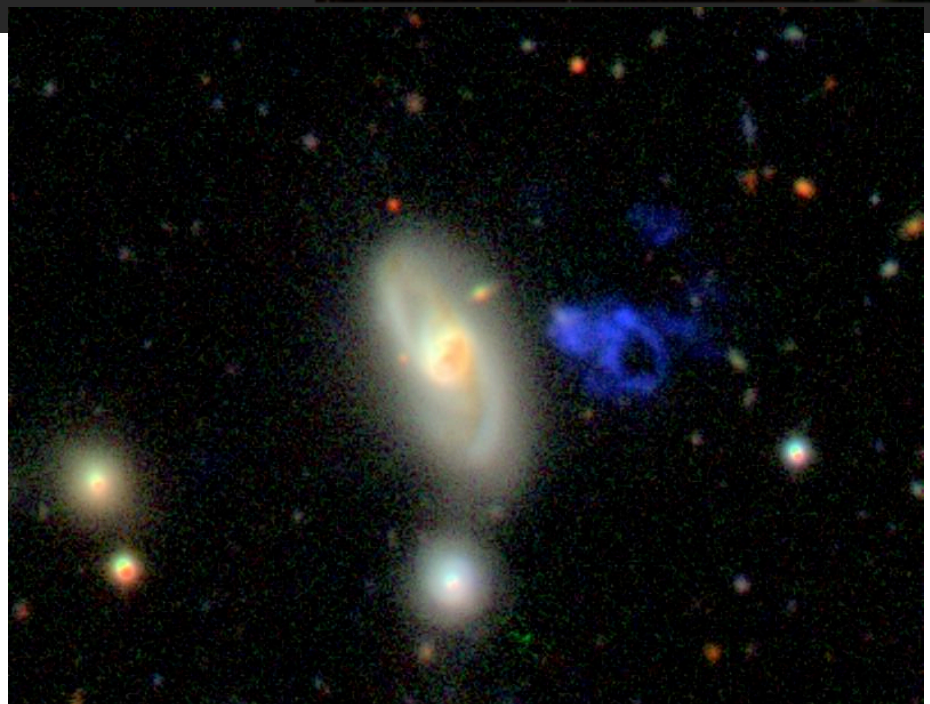
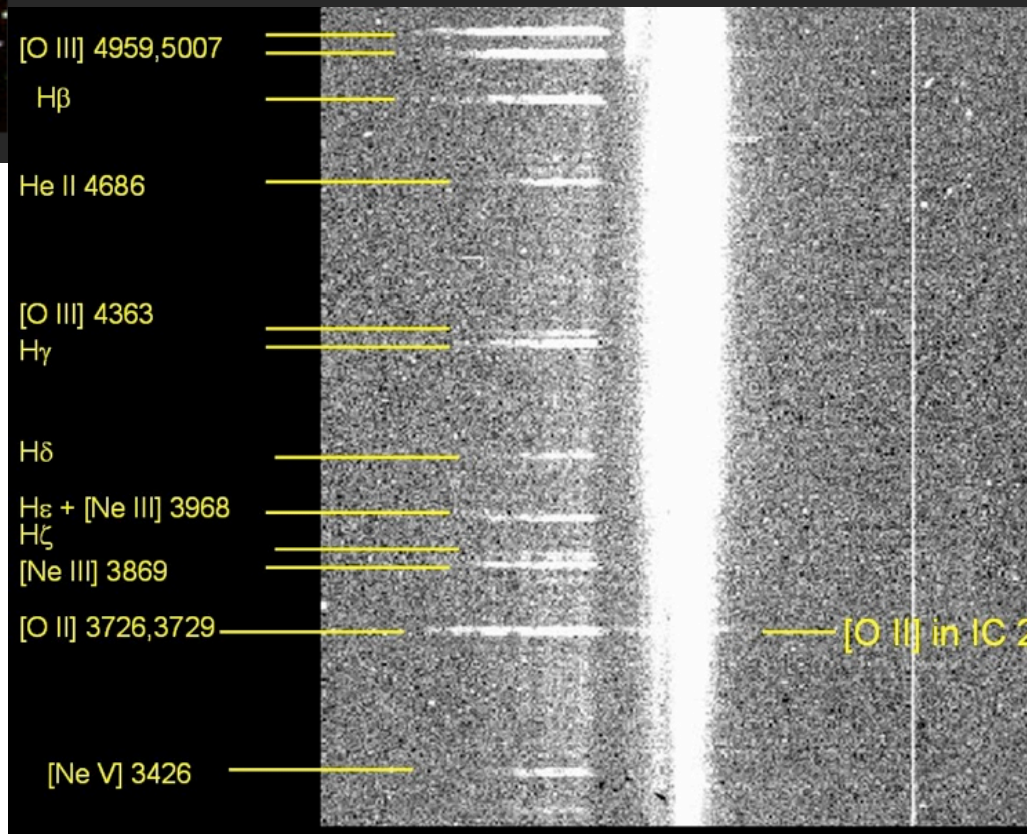
PEAKEEPER

The Hanny's Voorwerp.

« on: August 13, 2007, 06:16:40 AM »

What's the blue stuff below?

Anyone?

http://cas.sdss.org/astro/en/tools/chart/chart.asp?ra=145.2671505&dec=34.73290502

« Last Edit: February 08, 2008, 07:57:07 AM by Hanny »