## Preparing for observations

# S/N

Signal to noise ratio should be calculated in the continuum.

- Use parts where "no" lines are present
- Linear fit or, if normalization is good enough,  $I_{mean} = 1$
- $\bullet\,$  Calculate standard deviation  $\sigma$
- $SNR=I_{mean}/\sigma$

Ways to increase SNR:

- longer exposure time
- sum up spectra
- combine similar lines (LSD technique)

http://www.ast.obs-mip.fr/users/donati/multi.html Least Squares Deconvolution (LSD) technique (Donati et al. 1997)

based on slides by Richard Neunteufel



I<sub>mean</sub> = 0.99808

=> SNR =  $I_{mean}$  /  $\sigma$  = 97.3

 $\sigma = 0.01026$ 





## Normalization

#### Hydrogen lines:

 Continuum normalization tricky
 (→ interpolate continuum between uncontaminated echelle orders; check quality of normalization by checking line symmetry)



## Normalization



Line broadening leads to underestimation of continuum!





The very first steps:

<u>What do I want to study?</u> (Example: `the awesome stellar magnetic fields')

What objects? (Example: roAp stars, Haerbig Ae stars, active FGK stars, ...)

What do I need to know?

1) check literature!!!

2) time series phot./spect. or just a single/few measurements ? how do I want to measure magnetic fields: spectropolarimetry vs. Ca H & K line emission? what about X-rays? ...depends on the object!

e.g. roAp pulsate with periods of few minutes=>

telescope large enough with a CCD fast enough to sample pulsation cycle. does it have a polarimeter? (is my target visible from that hemisphere?)

I need the software to analyze the data! (e.g. Least Square Deconvolution code)

### In general:

Think about what you want to understand and which objects will tell you what you want to know.

Think broader! Maybe you need different types of observations at different wavelengths? (Example: identify a PMS star!) Think about the implications of your observations...

Example: Simon (2002) showed that stars show emission in UV up to a Teff ~8500K. So what? They just have magnetic fields like the sun! True, but if you have the magnetic fields they need a dynamo to drive those!... and a dynamo needs diff. rotation between a convective envelope and the radiative layers! => Does this mean that the convective envelope disappears only at Teff~8500K?

Think broader but think critically!!! "Keep their minds open, but not so open that your brains fall out." – Prof. Walter Kotschnig

Do not forget to search public archives for data... maybe your favourite target was already observed!

Do tests if you can! Do tests on artificial data and on other stars (e.g. Sun), prove, if needed, that your method is good and works! Otherwise very hard to get telescope time!

#### Observing facilities

#### <u>Some archives...</u>

European Southern Observatory: http://archive.eso.org NRAO Very Large Array, http://archive.nrao.edu Royal Greenwich Observatory on La Palma http://archive.ast.cam.ac.uk Gemini, CFHT: CADC http://cadcwww.dao.nrc.ca Subaru (NAO-JP): SMOKA Archive Facility http://smoka.nao.ac.jp NOAO (Cerro Tololo, Kitt Peak): http://archive.noao.edu NARVAL archive: <u>http://tblegacy.bagn.obs-mip.fr/narval.html</u> Hubble Space Telescope: STScI http://www.stsci.edu and ST-ECF http://ecf.hq.eso.org Infrared missions: IPAC http://www.ipac.caltech.edu High-energy: NASA HEASARC http://heasarc.gsfc.nasa.gov, Harvard ISO, IUE: VILSPA http://www.vilspa.esa.es Multipurpose: https://archive.stsci.edu/

#### Observing facilities

#### Photometric sky surveys:

Two-Micron All Sky Survey (2MASS):

Sloan Digital Sky Survey (SDSS):

Deep Near Infrared Survey of the Southern Sky (DENIS):

Massive Compact Halo Objects (MACHO) <u>http://wwwmacho.anu.edu.au</u>

OGLE

ASAS

Etc. etc.

### Some useful information

A very useful talk on the Virtual Observatory, including MANY links, also the ones provided on the last 2 slides.

http://www.das.uchile.cl/~mhamuy/courses/AS750/talk-calan-vo-mario.pdf

R.O. Gray's 'Digital Spectral Classification Atlas'

List of space telescopes on Wikipedia: <u>http://en.wikipedia.org/wiki/</u> <u>List\_of\_space\_telescopes</u>

List of largest optical telescopes: <u>http://astro.nineplanets.org/bigeyes.html</u>

#### Observing facilities

#### <u>Multi-wavelengths servers</u>

HEASARC (server for multi-wavelengths search), mainly X-ray and gamma-ray. <u>http://heasarc.gsfc.nasa.gov/cgi-bin/W3Browse/w3browse.pl</u>

IRSA (Infrared Science Archive) <u>http://irsa.ipac.caltech.edu/</u>

MAST (Mikulski Archive for Space Missions)

#### **MAST Missons**

- ASTRO ASTRO Observatory
  - <u>HUT</u> Hopkins Ultraviolet Explorer
  - UIT Ultraviolet Imaging Telescope
  - WUPPE Wisconsin Ultraviolet Photo-Polarimeter Experiment
- Copernicus
   Copernicus
- DSS Digitized Sky Survey
- EPOCH Extrasolar Planet Observations and Characterization
- EUVE Extreme Ultraviolet Explorer
- FUSE Far Ultraviolet Spectrographic Explorer
- GALEX Galaxy Evolution Explorer
- GSC Guide Star Catalogs
- HPOL Halfwave Spectropolarimeter
- HST Hubble Space Telescope
- IUE International Ultraviolet Explorer
- KEPLER Kepler (search for earth-size planets)
- ORFEUS Orbiting Retrievable Far and Extreme Ultraviolet Spectrometers-SPAS
  - BEFS Berkeley Extreme and Far-UV Spectrometer
  - TUES Tübingen Ultraviolet Echelle Spectrometer
  - IMAPS Interstellar Medium Absorption Profile Spectrograph
- VLA-FIRST Very Large Array Faint Images of the Radio Sky at Twenty-cm
- XMM-OM Xray Multi-Mirror Telescope Optical Monitor data

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Variable Star Naming

Catalogues: e.g., the General Catalogue of Variable Stars (Kukarkin et al., Fourth Edition 1985–1995, Fifth Edition: extragalactic variables)

Naming: first double capital letters according to the following scheme:



then further with V335, V336, ...

V5556: highest number in the GCVS

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Content	Statistics
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measurements for astronomical objects outside the solar system.	7,034,619 objects
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scripts can be submitted.	276,457 bibliographic references
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53 Aq1       GEM* +1.00187642       24AS5 J19004698+0852060       SKY# 37134         51 13009 A       GEM* +1.00187642       N30 4388       TD1 25537         61 2009 A       GEC 01058-03399       NAME ALTAIR       TTC 1058-3399-1         CC 1075038       HD 187642       NLTT 48314       UBV N 24205         +08 4236       HC 97649       NSV 24910       UBV 16885         VM J19508-0852A       HE 97649       SC 194.44       USNO-B1.0 0988-00511792         20 1169       HR 7557       PLX 4665       USNO 891         4294       ID5 19459+0836 A       PLC 4665.00       USNO 891         4294       IRAS 19484+0844       PMC 90-93 530       MD5 J19508+0852A         4294       IRAS 19484+0844       PMC 90-93 530       MD5 J19508+0852A         1948+0847       IRC +10441       PM 19484+0844       Kb 297         1948+0847       JP11 3142       PPM 168779       FM 168779         745       LF 1499       RAPCL 2463       RC 1044         1950       S490       ROT 2857       FM 146334
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CC 1075038         HD 187642         HLT 48314         DBV H 24205           +08 4236         HIC 97649         N5V 24910         USV 16885           09 J19508+0852A         HIP 97649         Spc 194.44         USNo-B1.0 0988-00511792           20 1169         HR 7557         FLX 4665         USNo 891           1+08 4236 1         ID5 19459+0836 A         PLX 4665.00         uvby98 100187642           4294         IRAS 19483+0844         PM 90-93 530         MDS J19508+0852A           1948.3+0844         IRC +10441         PM 19484+0844         Z97           1948.4+08.7         JP11 3142         PPM 168779         Eth 297           1948.4+08.4         LF2 1499         RAFGL 2463         Eth 3490           5 745         LF2 1499         RAFGL 2463         Eth 3490
HIC 97649         HIC 97649         NSV 24910         UEV 16885           DM J19508+0852A         HIP 97649         Spc 194.44         USNO-B1.0 0988-00511792           20 1169         HR 7557         PLX 4665         USNO 891           1408 4236 1         ID5 19459+0836 A         PLX 4665         USNO 891           4294         IRAS 19483+0844         PLC 90-93 530         MDS J19508+0852A           1948.3+0844         IRC 104411         PM 90-93 530         MDS J19508+0852A           1948.4+0844         IRC 104411         PM 19484+0844         Zkh 297           1948+08.7         JP11 3142         PPM 168779         Immediate PM 168779           5         745         LF7 1499         RAPGL 2463         Immediate PM 168779           5         549         LHS 3490         ROT 2857         Immediate PM 168779
Inf 9508-052X     Inf 9564     Bpc 194.44     Date B1.6 058-051792       20 1169     E8 757     PLX 4665     USN0 891       1-08 4236 1     ID5 19459-0836 A     PLX 4665.00     uvby98 100187642       4294     IRAS 19483-0844     PMC 90-93 530     MD5 J19508+0852A       1948.3-0844     IMC 90-93 530     MD5 J19508+0852A       1948.4-0844     IMC 90-93 530     MD5 J19508+0852A       1948.4-084     IMC 90-91 530     MD5 J19508+0852A       1948.4-084     IMC 90-91 530     MD5 J19508+0852A       1948.4-084     IMC 90-91 530     IMC 90-91 530       1948.4-084     IMC 90-91 530
I +08     4236     I ID5     19459+0836 A     PLX     465.00     uvby98     100187642       4294     IRAS     19481+0844     PMC     90-93     530     MDS     J19508+0852A       1948.3+0844     IRC     +10441     PM     19484+0844     IRC     2kh     297       5     1948+08.7     JP11     3142     PPM     168779     IRAS     1499       5     745     LPT     1499     RAFIL     2463     IRAS     IRAS     1495       5 49     LBS     3490     ROT     2857     IRAS     IRAS     IRAS     IRAS     IRAS
4294     IRAS     19483+0844     PMC     90-93     530     MDS     J19508+0852A       19484     IRC     +10441     PM     19484+0844     IRC     2kh     297       1948+08.7     JP1     3142     PPM     168779     IRC     1499       5     745     LPT     1499     RAPEL     2463       5     549     LBS     3490     ROT     2857
Inv
5         LPT         1499         RAPGL 2463           5         549         LHS         3490         ROT 2857
<u>r</u> 549 <u>LHS</u> 3490 <u>ROT</u> 2857

### What wavelength to choose?\*

Gamma rays	> 10^6 K	Accretion disks around black holes, Pulsars and Neutron Stars,	
X-rays	10 <sup>6</sup> -10 <sup>8</sup> K	Stellar corona, Supernova remnants, regions of hot, shocked gas,	
UV	10 <sup>4</sup> -10 <sup>6</sup> K	hot stars, activity (stellar coronae), Supernova remnants,	
Visible	10^3-10^4	Stars, stars, stars,	
IR	10-10 <sup>^</sup> 3 K	cool stars, planets, dust (disks),	
Radio	< 10 K	regions near WD, Supernova remnants,	

\*in this table I list only stellar related info

#### Julian Date and light time correction

Julian Date 1: January 1, 4713 BC, introduced by Joseph Scaliger in 1582

e.g. 26.09.2009 at midnight: JD 2455100.5

HJD = JD + Heliocentric correction

Heliocentric correction given by (max 8.3 min):

-T \* R \* (Cos L \* Cos A \* Cos D + (Sin L \* Sin E \* Sin D + Cos E \* Cos D \* Sin A))

T =Light travel time for one astronomical unit (499.0052 seconds or 0.005775523 days)

R = Earth - Sun distance in astronomical units for date of observation

L = Longitude of the sun

- A = Star's Right Ascension (in decimal degrees)
- E = Obliquity of the ecliptic = 23.43917 degrees
- D = Star's declination (in decimal degrees)
- R and L must be found from the AMERICAN EPHEMERIS AND NAUTICAL ALMANAC for each observing night. Online calculation: http://www.physics.sfasu.edu/astro/javascript/hjd.html

#### BEWARE! HJD ≠ BJD!

HJD: times at the centre of the Sun; BJD: times at the barycenter of the Sun

 $HJD-BJD = \pm 4 sec$ 

#### Some tools

Time-series of periodic variable stars are almost always analysed using Fourier transforms. The function (time series of whatever measurements) is approximated by a sum of sinusoids.

Frequency, amplitude and phase

```
interrupted data are a problem ...gaps due to day/night, bad weather, ...
```

several different algorithms

significant differences between coherent and non-coherent signal! (beware! diff. communities use diff. terms e.g. amplitude ≠ amplitude !

example Period04 (<u>http://www.univie.ac.at/tops/Period04/</u>)

ALWAYS have a look at the window function!

```
Time resolution: 1./ \Delta T (T<sub>end</sub>-T<sub>begin</sub>)
```