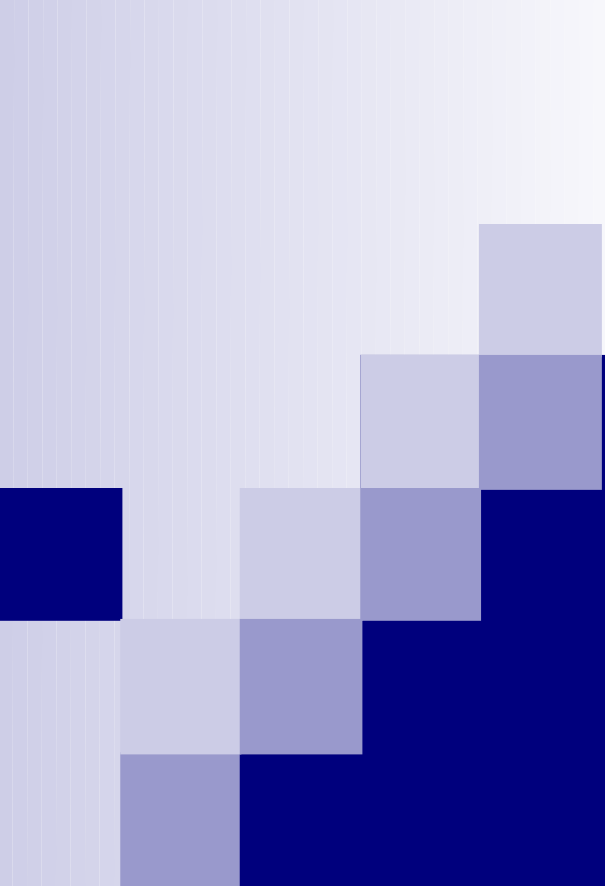




Apparent Places of Fundamental Stars (APFS)

Past and present status

Preview:

- Early astronomical ephemerides
- Predecessors of APFS (1776 – 1959)
- The "early years" of APFS (1960 – 1983): FK3 and FK4
- A time of change (1984 – 1988): IAU 1976 System of Astronomical Constants, 1980 Theory of Nutation, FK5, Celestial Ephemeris Pole (CEP)
- New theories and concepts in astrometry (2000 – 2006): Adoption of the ICRS instead of FK5-System, IAU 2000/2006 nutation theory, Celestial Intermediate Pole (CIP) and Celestial Intermediate Origin (CIO)
- APFS today



Early astronomical ephemerides

- "Connaissance des temps ou des mouvements celestes", 1679, published by Jean Picard, France
- "Astronomische Ephemeriden", 1757, published by Maximilian Hell, Austria
- "Nautical Almanac", 1767, published by the Astronomer Royal Nevil Maskelyne, U.K.
- "Berliner Astronomisches Jahrbuch", 1776, more details subsequently
- "Almanaque Nautico", 1792, San Fernando (Cadiz), Spain



Predecessors of APFS

- Berliner Astronomisches Jahrbuch (1776 – 1959).
- First Volume: "Astronomisches Jahrbuch oder Ephemeriden für das Jahr 1776".
- Edited 1774 in Berlin by Johann Elert Bode (1747 – 1826), who became 1786 director of the "Berliner Sternwarte"

Berliner Astronomisches Jahrbuch

BAJ 1776

- From preface BAJ 1776:

"Es erscheint hiermit der erste Jahrgang der Ephemeriden welche nach dem von der Königl. Preussischen Akademie der Wissenschaften gefassten Beschlusse und unter ihrer Aufsicht jährlich herauskommen sollen. Die Veranlassung dazu war vielfach und ungezwungen."
- Attempt of a translation:

"Hereby appears the first volume of ephemerides which shall be published annually according to the decision of (and supervised by) the Royal Prussion Academy of Sciences. The motive was manifold and informal."

BAJ 1776

- The first volume contained the ephemerides of 280 stars for January 1, 1776. They were based on observations from James Bradley and Nicolas Louis de Lacaille.
- Together with formulas for aberration and nutation tables – provided by Johann Heinrich Lambert in the same volume - "**scheinbare Örter**" (=apparent places) could be determined
- This list of 280 stars was extended in the next volumes by observations from E. Zanotti, N. de Lacaille and T. Mayer, but due to the immense computational work later volumes contained less stars

Star catalogues used for the BAJ

- Charles Mason (1730 – 1787) published a catalogue of 389 stars based on Bradley's observations in the Nautical Almanac for 1773. (3222 stars with an assumed accuracy of 2 arcseconds were published later by Friedrich Wilhelm Bessel 1798 and 1805. James Bradley (1693 – 1762) published no catalogues himself).
- Nicolas Louis de Lacaille (1713 – 1762): Star catalogue of southern stars (observed at the Cape of Good Hope) containing 9766 stars (Coelum Australe Stelliferum, published 1763)
- Eustachio Zanotti (1709 – 1782): 413 stars (zodiac belt and other prominent stars), published 1750.
- Tobias Mayer (1723 – 1762): catalogue of 998 zodiacal stars, published 1775.

BAJ 1779

- For BAJ 1779 a new list of some 400 stars was added, based on Zanotti's star catalogue. Zanotti's positions were averaged with Lacaille's and Mayer's positions, e.g. for Regulus 1779.0:

Bradley (Mason)

RA: 149° 8' 55.9" DE: 13° 2' 18.7"

Zanotti, Lacaille, Mayer

RA: 149° 9' 4" DE: 13° 2' 29"

BAJ 1874 - 1879

- The Astronomisches Rechen-Institut (ARI) was established in 1874 as "Recheninstitut zur Herausgabe des Berliner Astronomischen Jahrbuchs".
- It was mentioned for the first time in BAJ 1878:
Königliches Institut zur Herausgabe des Berliner Astronomischen Jahrbuchs und zur wissenschaftlichen Ausbildung im Rechnen
- The BAJ was issued by the Königliche Sternwarte Berlin until 1896 the ARI became autonomous.

An incidental remark: Fundamental Catalogues

- Arthur Auwers (1838 - 1915) published 1879 the **first Fundamental Catalogue** (579 stars of the northern sky)
- In the Berliner Astronomisches Jahrbuch (1907) 925 stars were published (northern and southern sky) based on Auwers' Catalogue (**Neuer FK**)
- For the **FK3** (1937) 52 Auwers' stars were omitted, only the remaining 873 stars + 662 additional stars (FK3sup, 1938) were taken (=1535 stars). These stars are the base for the APFS from 1960 to 1999.

BAJ (1959)



APFS

- From 1941 – 1959 the "modern" APFS were prepared by six principal almanac offices (Heidelberg, Herstmonceux, Leningrad, Paris, San Fernando, Washington). The data were compiled and published by H.M. Nautical Almanac Service, Royal Greenwich Observatory.
- In parallel the "Berliner Astronomisches Jahrbuch" was published annually until 1959. The last volume contained apparent places of 560 10-day-stars and 20 circumpolar stars. Added are four stars close to the northern (3) and southern celestial pole in a particular rectangular coordinate system.



First APFS from ARI: 1960 (1)

- At the 1955 IAU meeting in Dublin it was agreed that the computational work for ephemerides should be redistributed in order to concentrate this work in a small number of ephemeris offices
- The ARI was, beginning for the year 1960, responsible for the production of the volume "Apparent Places of Fundamental Stars"

First APFS from ARI: 1960 (2)

- The first volume of the APFS edited by the ARI was based on the **FK3**
- It listed apparent places for 1535 stars:
 - 853 10-day and 20 circumpolar Auwer's stars
 - 630 10-day and 32 circumpolar additional stars
- The 10-day stars were computed at ARI
- The 52 circumpolar stars were computed by the Bureau de Longitudes, Paris. This cooperation was noted in the prefaces until 1983.

First APFS from ARI: 1960 (3)

- Woolard's (1953) nutation series was used from the 1960 volume onward (nutation in longitude $d\psi$ with 69 terms, nutation in obliquity $d\epsilon$ with 40 terms)
- Before Newcomb's nutation theory had been applied ($d\psi$ 27 and $d\epsilon$ 15 terms)
- The system of astronomical constants used for the reduction to apparent places was still that from the "Conference Internationale des Etoiles Fundamentales" (Paris 1896).

APFS 1964 – 1968

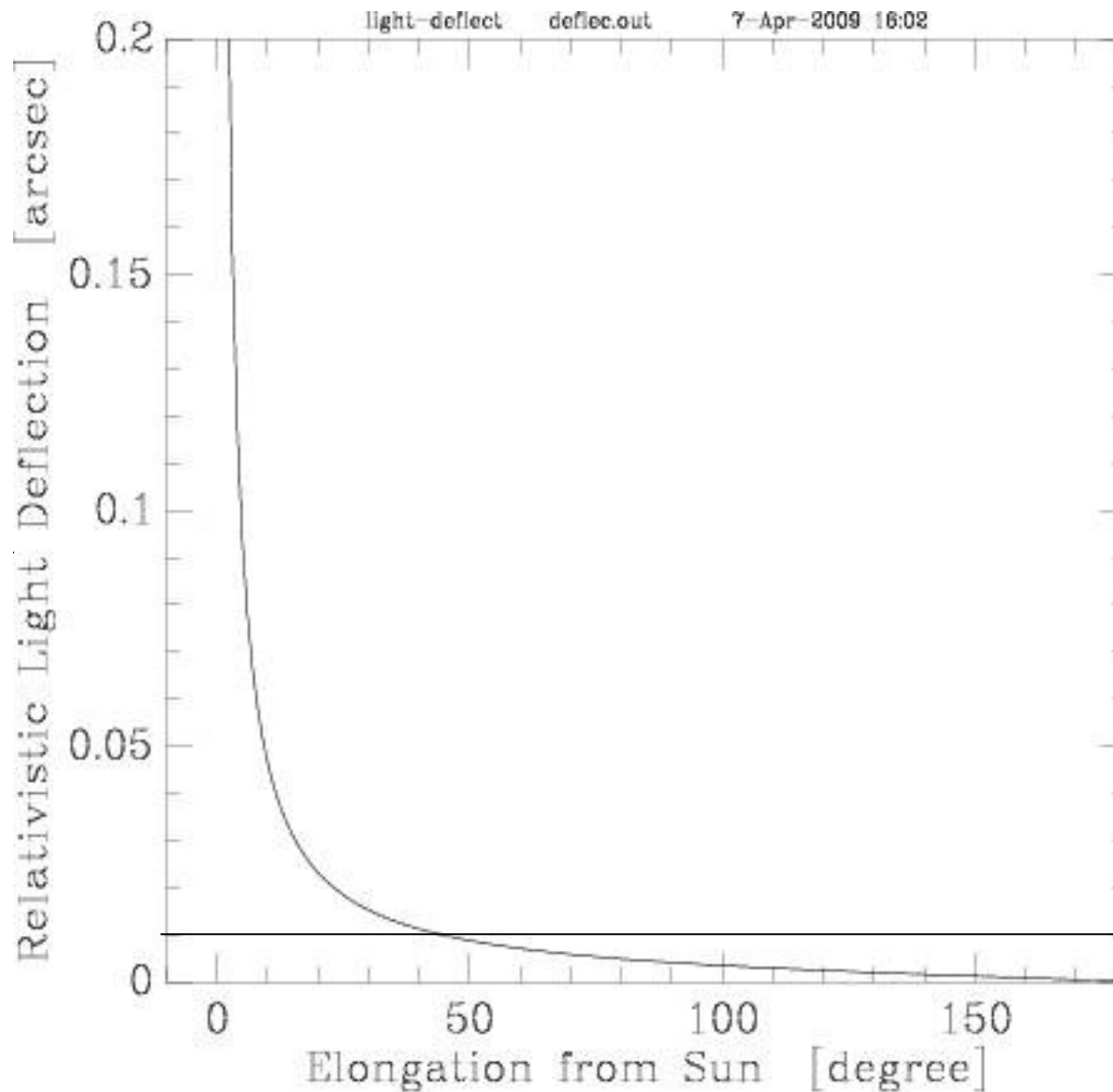
- 1964: apparent and mean places are now based on the [FK4](#) which was published in 1963. The total number of stars (1535) was maintained. A supplement for APFS 1962 and 1963 was available, with reduction tables from FK3 to FK4
- 1968: a new constant of annual aberration is introduced: 20.496 arcsec instead of formerly 20.47 arcsec (= Paris 1896 value)
- This was the only constant to be changed in accordance with the recommendations of the 12th General Assembly of the IAU in Hamburg (1964).
- Other constants of precession and nutation retained the values of the Paris (1896) system.

APFS 1984-1988 (1)

- 1984: The [IAU 1980 Theory of Nutation](#) was introduced; 106 lunisolar terms have to be considered, planetary terms were discussed but became not part of the theory.
- 1984: The [IAU \(1976\) System of Astronomical Constants](#) was applied, in particular the new values of precession, aberration and obliquity of the ecliptic (Trans. I.A.U. 16 B, 58)
- 1984: A correction to the zero point of right ascensions of the FK4 and a correction to the motion of the equinox was applied

APFS 1984-1988 (2)

- 1984: Relativistic effects were included rigorously
- 1988: APFS are completely based on the 1535 stars of the **Basic FK5**
- This should have been done already for volume 1984 but the **FK5** had not yet been completed. A supplement for the years 1984 – 1987 contained corrections FK5 – FK4.



Last decimal
in APFS
(10 mas)

APFS 2000 - 2005 (1)

- The extensive volumes were replaced by a booklet containing only 52 10-day-stars and 2 circumpolar stars (1 southern)
- From now on the (Internet-) APFS have been based on the 878 single stars of the [Sixth Catalogue of Fundamental Stars \(FK6\)](#) - Part I.
- For the same subset of stars also apparent places based on [Hipparcos](#) data are available

APFS 2000 - 2005 (2)

- The **FK6** is referred to the Hipparcos Reference System and consequently to the **International Celestial Reference System (ICRS)** which is represented at the optical wavelengths by a part of the Hipparcos stars.
- The 878 stars of the **FK6 Part I** are a subset of assumed single stars of the 1535 **Basic FK5** stars
- Polaris – having a solved binary orbit – is available within the APFS

APFS 2006

- From 2006 onwards a radical change took place: the **IAU 1976 Precession** and the **IAU 1980 Nutation** were replaced by the **IAU 2000A Precession-Nutation** model with an assumed accuracy of 0.2 mas. The nutation series have 678 lunisolar and 687 planetary terms.
- As part of this change, the "**Celestial Ephemeris Pole**" (**CEP**) was superseded by the "**Celestial Intermediate Pole**" (**CIP**). This transit is smooth – if seen from the celestial reference frame.
- The booklet contains now 60 10-day stars (instead of 52) and 4 circumpolar stars (instead of 2)

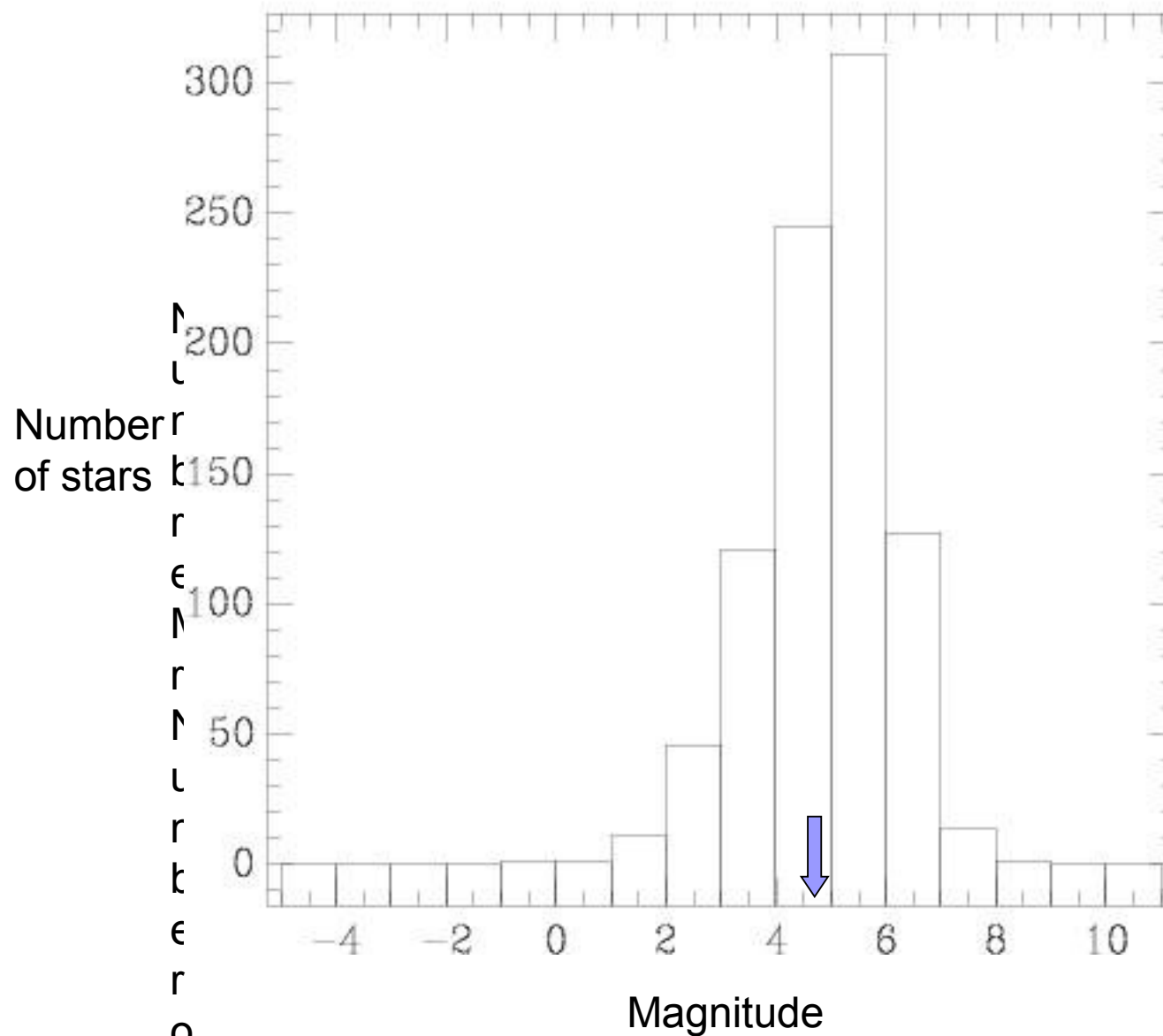
APFS 2006

- But even more dramatic was the new definition of the zero-point for right ascensions: The **equinox** was replaced by the "**Celestial Intermediate Origin**" (CIO).
- As a consequence the ecliptic plane is no longer required for the definition of the origin of right ascensions
- **Apparent right ascensions** (referred to the **equinox**) and **intermediate r.a.** (referred to the **CIO**) are incompatible, and their difference increases year by year by about 50"
- ...**but** for people having difficulties with this new world: for the time being old and new apparent places (the new ones are better called: **intermediate places**) are offered

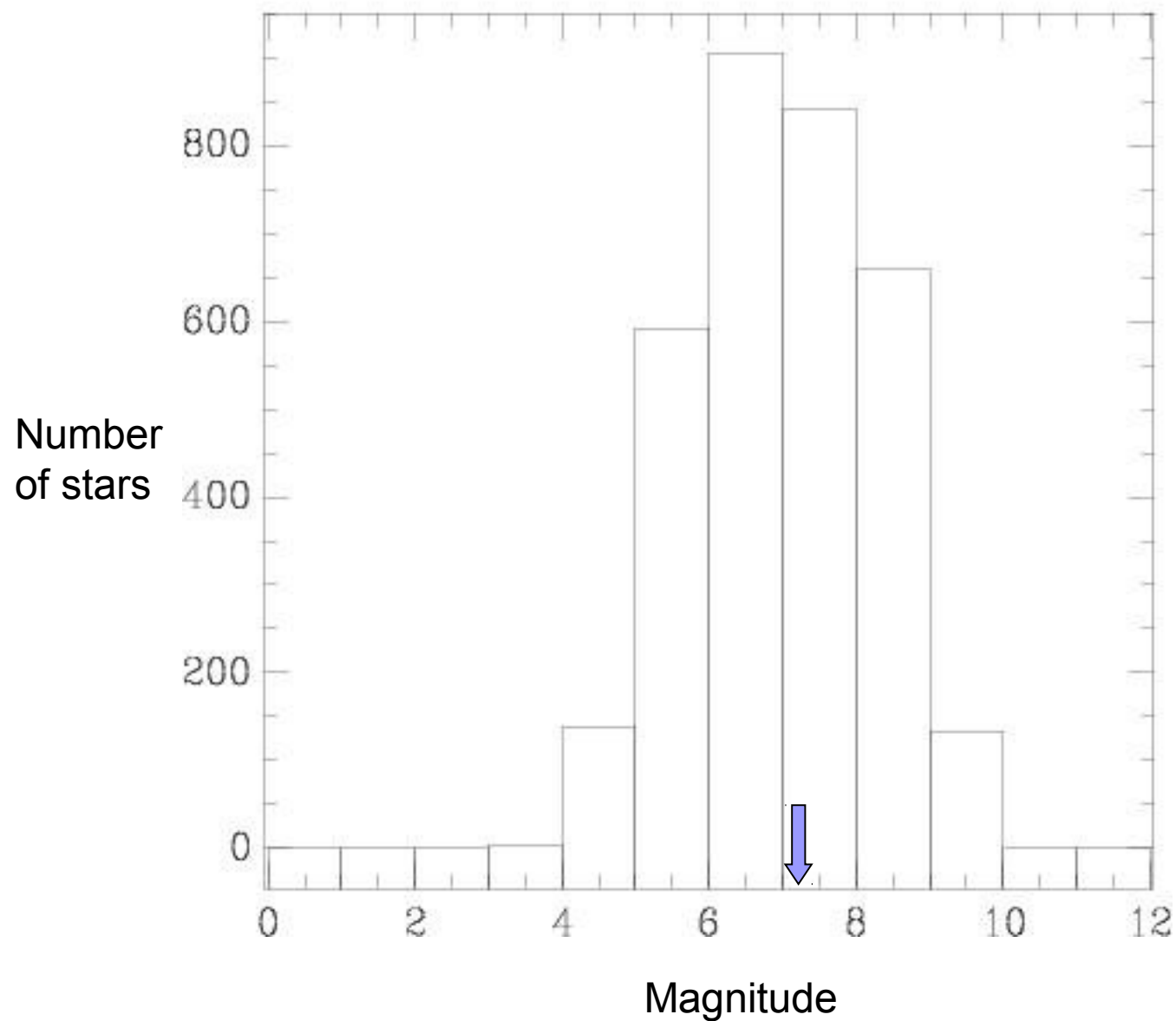
APFS 2009 - ?

- An additional Web presentation for apparent and intermediate places is provided within the framework of [GAVO](#) (German Astrophysical Virtual Observatory): apparent places can be requested "online" for every epoch, even in hourly intervals if desired
- Along with this implementation the apparent places for 3272 stars of the [FK6 Part III](#) are now available
- In addition apparent places for more than [100000 Hipparcos](#) stars have been made accessible, thus extending significantly the available number of stars as well as the range of magnitudes

Histogram of Magnitudes FK6 Part I



Histogram of Magnitudes FK6 Part III



APFS 2009 - ?

- The new **P03 Precession** model replaces the old precession theory within the **IAU 2000A precession nutation** model (now: **IAU 2000/2006 precession-nutation**)
- Whereas the **IAU 2000A precession-nutation** model is accurate to 0.2 mas, the **IAU 2000/2006 precession-nutation** aims at micro-arcsecond accuracy
- It follows that the new precession-nutation model has nearly no influence on the apparent places which are given with milli-arcsecond accuracy.

APFS 2010

- 2010: volume number **51** for "modern" APFS edited by ARI. The Astronomisches Rechen-Institut has become part of the newly established "Zentrum für Astronomie" (ZAH) at the University of Heidelberg since 2005.
- Together with its predecessor - the "Berliner Astronomisches Jahrbuch" - the APFS constitute one of the longest publication series in astronomy. Seen in this context and starting with the year 1776, the volume for APFS 2010 would have volume number **235**.