EXAM REPORT TOPICS

Dear students IAC2003,

In this document you find a listing of suggested topics for reports (werkstukken) to fulfil requirements for the IAC exam. With each topic you find mentioned the lecturer. You may decide to work on a report with a colleague student, although of course you are also free to do so on an individual basis. Also mentioned with most topics are some literature suggestions. In some cases this concerns an essential key reference which then would advisably be used for the report. In other cases (notably my own) you find a listing of publications that would provide you with a good overview of important papers relating to the subject, and it will be up to you to select the ones you need (in addition of course to other works you find relevant).

Once you have decided for a topic, please contact the lecturer to mark it as yours. Check for requirements concerning the report (e.g. # pages, level, etc.), and if necessary about an oral discussion on the report after the lecturer has seen it through. Once the lecturer and you agreed upon these practical issues, please also contact me (also free to do so beforehand), and inform me about your choice (and final result, always welcome to send me a copy too !).

While the course is still running, this document will be continuously updated, so that new topics may appear (still some lecturers left to do so). Finally, if you have an original idea for a topic yourself, you are more than welcome to pursue this. Please contact me, so that we may decide upon your guiding lecturer.

Wish you good luck and lots of fun with writing your report, looking forward to some nice works,

Rien van de Weygaert

Kapteyn Institute,

9700 AV Groningen

tel.: 050-3634086

e-mail: weygaert@astro.rug.nl

1. **Evidence for Dark Energy**.

- *Peter Katgert*
  Sterrewacht Leiden, UL

- A discussion on the observational evidence for a cosmological constant Lambda or, in a wider context, for the reality of Dark Energy. Is it realistic to measure the real equation of state of the vacuum ?

2. The Cyclic Universe.

- *Bob Sanders,*
  Kapteyn Institute, RUG
- *Literature:*
  - Steinhardt & Turok, astro-ph/0204479 and references therein.

3. The self-reproducing inflationary Universe.

- *Bob Sanders,*
  Kapteyn Institute, RUG
- *Literature:*
  - Linde, Scientific American, Nov. 1994
    (and references given at end of article)

4. Parallel Universes.

- *Bob Sanders,*
  Kapteyn Institute, RUG
- *Literature:*
  - Tegmark, astro-ph/0302131 and references therein.

5. The Wheeler-deWitt equation and the wave function of the Universe.

- *Bob Sanders,*
  Kapteyn Institute, RUG
- *Literature:*
  - Hartle, in *The Very Early Universe*,
    Eds. Gibbons & Hawking, Cam.Univ.Press, 1982.

6. Large extra dimensions and the Brane World

- *Bob Sanders,*
  Kapteyn Institute, RUG
- *Literature:*
  - Arkani-Hamed et al., Physics Today, Feb. 2002;
  - Randall & Sundrum, hep-ph/9905221, hep-th/9906064;
  - Dvali et al., hep-ph/0102216

7. The anthropic principle in cosmology

- *Bob Sanders,*
  Kapteyn Institute, RUG
- *Literature:*
  - Linde, hep-th/0211048
  - Mueller, astro-ph/0108259

8. **Neutrinos and Cosmology**.

- *Jan Smit,*
  Instituut voor Theoretische Fysica, UvA, &
  Instituut voor Theoretische Fysica, UU

- The idea is to give a review of the relevance of neutrinos to the physics of the early universe. This topic is rather large, and it seems best to concentrate on one or more of the items below:
  - relic neutrinos and the cosmological mass bound
  - neutrinos in mixed dark matter
  - neutrinos and nucleosynthesis
  - leptogenesis (see below for baryogenesis) Although instructor is not an expert on the astrophysical side of these topics, but can help with the particle physics aspects, is of course very interested in the astrophysical data.

- *Literature:*
  - A.D. Dolgov,
    Cosmological Inplications of Neutrinos,
    hep-ph/0208222;
  - S. Sarkar,
    Neutrinos from the Big Bang,
    hep-ph/0302175;
  - S. Hannestad,
    Neutrino masses and the number of neutrino species from WMAP and 2dfGRS,
    astro-ph/0303076; and further references to be chosen appropriately.

9. **Cosmological constraints on neutrino mass**.

- *Leo van den Horn*
  Instituut voor Theoretische Fysica &
  Sterrenkundig Instituut Anton Pannekoek (CHEAF), UvA

- Give a discussion on constraining observations and theoretical implications on a possible finite neutrino restmass.

10. **Cosmological constraints on neutrino flavours**.

- *Leo van den Horn*
  Instituut voor Theoretische Fysica &
  Sterrenkundig Instituut Anton Pannekoek (CHEAF), UvA

- From the abundance of Helium-4 one can put constraints on the number of neutrino flavors. Give a thorough discussion on the theoretical background, the nature and strength of observational constraints and on related constraints from physical experiments.

11. Baryogenesis.

- *Jan Smit,*
  Instituut voor Theoretische Fysica, UvA, &
  Instituut voor Theoretische Fysica, UU

The idea is to give an review of the basic 'out-of-equilibrium decay' mechanism, as described in my lectures ('leptogenesis') and in the book by Kolb and Turner, and further references to be chosen appropriately.

12. Primordial Nucleosynthesis: Observations

- *Leo van den Horn*
  Instituut voor Theoretische Fysica &
  Sterrenkundig Instituut Anton Pannekoek (CHEAF), UvA

Provide a discussion and review of relevant observational constraints

- *Literature:*
  - K.A. Olive, G. Steigman, T.P. Walker, 2000
    Primordial Nucleosynthesis: theory and observations,
    Phys. Rep., **333**, 389-407

13. Cosmic Flows and Redshift Space Distortions

- *Rien van de Weygaert*
  Kapteyn Instituut, RUG

- Due to the matter migration flows accompanying the formation of structure in the Universe, maps of galaxies in redshift space are a combination of their true spatial distribution and systematic distortions resulting from the peculiar velocities of galaxies. Investigate the possible effects, provide an overview on the attempt to theoretically describe this and discuss results on the basis of (recent) galaxy redshift surveys.

- *Literature suggestions:*
  - Dekel, A., 1994
    Dynamics of Cosmic Flows
    ARAA, 32, 371-418
  - Strauss, M., Willick, J., 1995
    The density and peculiar velocity fields of nearby galaxies
    Phys. Rep. 261, 271-431
  - Hamilton, A.J.S.
    Linear Redshift Distortions: A Review
    Invited review *Ringberg Workshop on Large-Scale Structure*, 1996
    astro-ph/9708102
  - Szalay, A., Matsubara, T., Landy, S., 1998
    Redshift-Space distortions of the Correlation Function in Wide-Angle Galaxy Surveys
    Astrophys. J., 498, L1-L4
  - Madgwick et al., 2003
    The 2dF Galaxy Redshift Suvery: galaxy clustering per spectral type
    astro-ph/0303668

14. Power Spectrum Estimation

- *Rien van de Weygaert*
  Kapteyn Instituut, RUG

- The density fluctuation power spectrum $P(k)$ is one of the most essential ingredients for any theory of structure formation: to a large extent it determines the mode, nature and rate of the emergence of galaxies, clusters and all elements of the cosmic foam in the Universe. Trying to determine the power spectrum from the many sources of information on cosmic structure is one of the major activities of cosmological studies. Provide a discussion of the various methods. Concentrate in particular on the machinery that has been developed to extract significant estimates of $P(k)$ from galaxy redshift surveys.

- *Literature suggestions:*

  - Feldman H.A., Kaiser N., Peacock J.A., 1994
    Power-spectrum Analysis of Three-dimensional Redshift Surveys
    Astrophys. J., 426, 23-37
  - Vogeley M.S., Szalay A.S.
    Eigenmode Analysis of Galaxy Redshift Surveys. I. Theory and Methods
    Astrophys. J., 465, 34-53
  - Tegmark M., Taylor A.N., Heavens A.F., 1997
    Karhunen-Loève Eigenvalue Problems in Cosmology: How should we tackle large data sets
    Astrophys. J., 480, 22-35
  - Hamilton A.J.S., 1997
    Towards optimal measurement of power spectra - I. Minimum variance pair weighting and the Fisher matrix
    MNRAS 289, 285-294
  - Hamilton A.J.S., 1997
    Towards optimal measurement of power spectra - II. A basis of positive, compact, statistically orthogonal kernels
    MNRAS 289, 295-304
  - Tegmark M., Hamilton A.J.S., Xu Y., 2002
    The power spectrum of galaxies in the 2dF 100k redshift survey
    MNRAS 335, 887

15. Weak Lensing by Large Scale Structure

- *Rien van de Weygaert*
  Kapteyn Instituut, RUG

- The finding of cosmic shear induced by the inhomogeneous matter distribution in the Universe has triggered enormous activity in trying to infer cosmological parameters, estimating the cosmic power spectrum and ultimately mapping the dark matter distribution throughout the Universe on the basis of the slight distortions of galaxy images by weak lensing by the cosmic mass distribution. Provide a review of the theoretical predictions, of analysis methods, achieved results and future prospects.

- *Literature suggestions:*
  - Kaiser N., Squires G., 1993
    Mapping the Dark Matter with Weak Gravitational Lensing
    Astrophys. J., 404, 441
  - Mellier Y., 1999
    Probing the Universe with Weak Lensing
    ARAA, 37, 127
  - Jain B., Seljak U., White S.D.M., 2000
    Ray-tracing simulations of weak lensing by Large-Scale Structure
    Astrophys. J., 530, 547-577
  - Vale C., White M., 2003
    Simulating Weak Lensing by Large Scale Structure
    astro-ph/0303555
  - Massey R., et al., 2003
    Weak lensing from Space II: Dark Matter Mapping
    astro-ph/0304418
  - Refregier A., et al., 2003
    Weak lensing from Space III: cosmological parameters
    astro-ph/0304419

16. Cosmology and Clusters of Galaxies

- *Rien van de Weygaert*
  Kapteyn Instituut, RUG

- Clusters of galaxies are the most massive fully collapsed and virialized objects in the Universe. The population of clusters and its evolution are sensitive probes of underlying cosmology and of the spectrum of density fluctuations. In particular interesting is the mass spectrum $n(M)$ of clusters of mass M. On the basis of theoretical predictions one can infer its sensitivity to the cosmological mass density Ω_m, on the power spectrum of density fluctuations and in particular its amplitude (expressed in terms of σ_8, the root mean square of density fluctuations within a sphere of radius $8h^{-1}$Mpc). Discuss the theoretical framework of predicted cluster mass spectra (both analytically as well as by means of N-body simulations). In addition, discuss the constraints on cosmological parameters obtained from such studies, in particular on the basis of samples of X-ray clusters. Finally, show how these in combination with CMB experiments yield estimates of in particular Ω_m and Ω_Λ.

- *Literature suggestions:*
  - Press W., Schechter P., 1974
    Formation of Galaxies and Clusters of Galaxies by Self-Similar Gravitational Condensation
    Astrophys. J., 187, 425
  - Bond J. R., Cole S., Efstathiou G., Kaiser N.
    Excursion set mass functions for hierarchical Gaussian fluctuations
    Astrophys. J., 379, 440
  - Bahcall N., Cen R., 1993
    The Mass Function of Clusters of Galaxies
    Astrophys. J., 407, L49
  - Eke V., Cole S., Frenk C., 1996
    Cluster evolution as a diagnostic for Ω
    MNRAS, 282, 263
  - Eke V., Cole S., Frenk C., 1998
    Measuring Ω_o using cluster evolution
    MNRAS 298, 1145
  - Jenkins A., et al., 2001
    The mass function of dark matter halos
    MNRAS, 321, 372
  - Sheth R., 1998
    An excursion set model for the distribution of dark matter and dark matter haloes
    MNRAS 300, 1057

- Sheth R., Mo H.J., Tormen G., 2001
Ellipsoidal collapse and an improved model for the number and spatial distribution of dark matter haloes
MNRAS 323, 1
- Sheth R., Tormen G., 2002
An excursion set model of hierarchical clustering: ellipsoidal collapse and the moving barrier
MNRAS, 329, 61
- Pierpaoli E., Scott D., White M., 2001
Power-spectrum normalization from the local abundance of rich clusters of galaxies
MNRAS, 325, 77
- Reiprich T.H., Boehringer H., 2002
The Mass Function of an X-ray flux-limited sample of galaxy clusters
Astrophys. J., 567, 716
- Rosati P, Borgani S., Norman C., 2002
The Evolution of X-ray Clusters of Galaxies
ARAA, 40, 539-77

17. Thermalization and Spectral Distortions of the cosmic background radiation

- *Rien van de Weygaert*

  Kapteyn Instituut, RUG

- The cosmic microwave background radiation provides the strongest observational foundation for the standard Hot Big Bang theory. The fact that its electromagnetic spectrum is almost perfectly Blackbody sets severe constraints on 1) the thermalization processes and epoch of the radiation and 2) spectrum distorting processes. While the anisotropies in the CMB provide a wealth of information on the Universe around the epoch of recombination ($z \sim 1089$), the CMB Planck spectrum forms a probe of the Universe out to redshifts $z \sim 10^7$. Investigate in detail the physical processes that lead to the thermalization of the CMB, and discuss the possible observational spectral signatures incurred by distorting energetic processes at $z < 10^7$. Discuss the observational constraints on the various observational signatures.

- *Literature suggestions:*

  - Sunyaev R.A., Zeldovich Ya.B., 1980

    Microwave background radiation as a probe of the contemporary structure and history of the universe

    ARAA, 18, 537
  - Stebbins A., 1997

    The Cmbr-Spectrum a Theoretical Introduction

    The Cosmic Microwave Background, Kluwer Academic Press;

    Ed. C.H. Lineweaver, J.G. Bartlett, A. Blanchard, M. Signore, and J. Silk, p.241
  - Hu W., 1995

    Wandering in the Background: A Cosmic Microwave Background Explorer

    Ph.D. thesis, Univ. California at Berkeley

    website: http://background.uchicago.edu/~whu/thesis/thesispage.html
  - Zeldovich Ya.B., Sunyaev R.A., 1969

    The Interaction of Matter and Radiation in a Hot-Model Universe

    Astrophysics and Space Science, Vol. 4, p.301
  - Sunyaev R.A., Zeldovich Ya.B., 1970

    The Interaction of Matter and Radiation in a Hot-Model Universe, II

    Astrophysics and Space Science, Vol. 7, p.20
  - Sunyaev R.A., Zeldovich Ya. B., 1970

    The spectrum of primordial radiation, its distortions and their significance

    Comments on Astrophysics and Space Physics, vol.2, p.66-73
  - Chan K.L, Jones B.J.T., 1975

    Distortions of the 3^oK background radiation spectrum: observational constraints on the early thermal history of the Universe

    Astrophys. J., 195, 1

- Danese L, De Zotti G., 1977
The relic radiation spectrum and the thermal history of the Universe
Nuovo Cimento, Rivista, Serie 2, vol. 7, July-Sept. 1977, p. 277-362.
- Danese L., De Zotti G., 1982
Double Compton Process and the Spectrum of the Microwave Background
A&A, 107, 39
- Burigana C., Danese L., De Zotti G., 1991
Formation and evolution of early distortions op the microwave background spectrum: a numerical study
A&A, 246, 49
- Burigana C., De Zotti G., Danese L., 1991
Constraints on the Thermal History of the Universe from the Cosmic Microwave Background Spectrum
A&A, 379, 1
- Hu W., Silk J., 1993
Thermalization and spectral distortions of the cosmic background radiation
Phys. Rev. D. 48, 485
- Fixsen et al., 1996
The Cosmic Microwave Background Spectrum from the Full COBE FIRAS Data Set
Astrophys. J., 473, 576

18. Cosmic Microwave Background Anisotropies: Characteristic Angular Scales

- *Rien van de Weygaert*
  Kapteyn Instituut, RUG

- Four characteristic angular scales are imprinted on the spectrum of Microwave Background Anisotropies. These are the scale corresponding to the radiation-matter equality ℓ_{eq}, the scale ℓ_A corresponding to the cosmic sound horizon at the epoch of decoupling, the diffusion scale ℓ_D due to (Silk) scattering diffusion and finally the scale $\ell_{K\Lambda}$ at which either the curvature or the cosmic constant takes over from matter as dominant factor behind the expansion of the Universe. Provide a discussion how the various relevant physical processes (Sachs-Wolfe, acoustic oscillations, Silk diffusion damping, Integrated Sachs-Wolfe, etc.) are relating to these characteristic scales and how this leads to differences in angular power spectrum of cosmic microwave background fluctuations.

- *Literature suggestions:*

  - Hu W., Dodelson S., 2002
    Cosmic Microwave Background Anisotropies
    ARAA, 40, 171-216
  - Hu W., Sugiyama N., Silk J.,
    The Physics of the Microwave Background Anisotropies
    Nature, Vol. 386, p. 37-43
  - Hu W., 1995
    Wandering in the Background: A Cosmic Microwave Background Explorer
    Ph.D. thesis, Univ. California at Berkeley
    website: http://background.uchicago.edu/~whu/thesis/thesispage.html
  - Hu W., Sugiyama N., 1995
    Anisotropies in the Cosmic Microwave Background: an Analytic Approach
    Astrophys. J., 444, 489
  - Bond J.R., 1996
    Theory and Observations of the Cosmic Background Radiation
    in "Cosmology and Large Scale Structure", Les Houches LX, eds. R. Schaeffer, J. Silk, M. Spiro, J. Zinn-Justin, Elsevier
  - Seljak U., Zaldarriaga M., 1996
    Line-of-sight integration approach to cosmic microwave background anisotropies
    Astrophys. J. 469, 437

- Hu W., website:
  - *An Introduction to the Cosmic Microwave Background*
  http://background.uchicago.edu/~whu/intermediate/intermediate.html
  - *A Tour of CMB Physics*
  http://background.uchicago.edu/~whu/physics/tour.html
  - *Cosmological Parameters in the CMB*
  http://background.uchicago.edu/~whu/metaanim.html
- CMBFAST website:
  http://cmbfast.org/

19. CMB Experiments: Maps, Power Spectra and Cosmological Parameter Estimation

- *Rien van de Weygaert*
  Kapteyn Instituut, RUG

- On the basis of the raw data of CMB temperature measurements across the sky obtained through microwave background experiments (e.g. COBE, Boomerang and WMAP), a data analysis machinery should process this into maps of the MWB sky, of the power spectrum C_l and ultimately significant estimates of cosmological parameters. Describe the various steps of this process, in this concentrating particularly on the mapmaking procedures and the estimation of the power spectrum. The latter involves a discussion on the statistical and numerical methods developed to obtain optimal estimates of C_l, including a description of the CMBFAST package for fast theoretical power spectrum computation.

- *Literature suggestions:*

  - Hu W., Dodelson S., 2002
    Cosmic Microwave Background Anisotropies
    ARAA, 40, 171-216
  - Seljak U., Zaldarriaga M., 1996
    Line-of-sight integration approach to cosmic microwave background anisotropies
    Astrophys. J. 469, 437
  - Jungman G., Kamionkowski M., Kosowsky A., Spergel D., 1996
    Cosmological Parameter Determination with Microwave Background Maps
    Phys. Rev. D., 54, 1332
  - Bond J.R., Efstathiou G., Tegmark M., 1997
    Forecasting cosmic parameter errors from microwave background anisotropy experiments
    MNRAS 291, L33
  - Zaldarriaga M., Spergel D., Seljak U., 1997
    Microwave Background Constraints on Cosmological Parameters
    Astrophys. J., 488, 1
  - Tegmark M., 1997
    CMB mapping experiments: A designer's guide
    Phys. Rev. D., 56, 4514
  - Tegmark M., 1997
    How to make maps from cosmic microwave background data without losing information
    Astrophys. J., 480, L87
  - Bond J.R., Jaffe A.H., Knox L., 1998
    Estimating the power spectrum of the cosmic microwave background
    Phys. Rev. D., 57, 2117

- Hinshaw et al., 2003
  Wilkinson Microwave Anisotropy Probe (WMAP) First Year Observations: The Angular Power Spectrum
  Astrophys. J. in press (WMAP website)
- Page et al., 2003
  Wilkinson Microwave Anisotropy Probe (WMAP) First Year Observations: Interpretation of the TT and TE angular power spectrum peaks
  Astrophys. J. in press (WMAP website)
  Wilkinson Microwave Anisotropy Probe (WMAP) First Year Observations: Parameter Estimation Methodology
  Astrophys. J. in press (WMAP website)
- M. Tegmark, website:
  Max Tegmark's CMB data analysis center
  http://www.hep.upenn.edu/~max/cmb/pipeline.html
- WMAP website:
  http://map.gsfc.nasa.gov/m_mm/pub_papers/firstyear.html
- Healpix website:
  http://www.eso.org/science/healpix/
- CMBFAST website:
  http://cmbfast.org/
- Hu W., website:
  Cosmological Parameters in the CMB
  http://background.uchicago.edu/~whu/metaanim.html

20. Cosmic Microwave Background Polarization

- *Rien van de Weygaert*
  Kapteyn Instituut, RUG
- In addition to CMB temperature anisotropies, polarization of the Microwave Background Signal contains a wealth of information on processes in the early Universe (inflationary gravitational waves and primordial velocity field), on the cosmic matter distribution (weak gravitational lensing of the CMB signal) on secondary post-recombination scattering processes. Of the latter in particular that induced by gas ionized by the first generation of stars and galaxies at and around the epoch of reionization provides an exciting new avenue of research, in particular since the polarization detection by DASI and WMAP. Investigate the physical nature of the various sources of CMB polarization, describe their (expected) imprint (E and B modes) and signature (EE autocorrelation, TE cross-correlation), and the way they can and are exploited to infer important cosmological information. In particular, focus on the polarization by the epoch of reionization.
- *Literature suggestions:*
  - Hu W., 1995
    Wandering in the Background: A Cosmic Microwave Background Explorer
    Ph.D. thesis, Univ. California at Berkeley
    website: http://background.uchicago.edu/~whu/thesis/thesispage.html
  - Hu W., Dodelson S., 2002
    Cosmic Microwave Background Anisotropies
    ARAA, 40, 171-216
  - Bond J.R., 1996
    Theory and Observations of the Cosmic Background Radiation
    in "Cosmology and Large Scale Structure", Les Houches LX, eds. R. Schaeffer, J. Silk, M. Spiro, J. Zinn-Justin, Elsevier
  - Hu W., White M., 1997
    A CMB polarization primer
    New Astronomy, 2, 323
  - Kamionkowski M., Kosowsky A., Stebbins A., 1997
    Statistics of Cosmic Microwave Background Polarization
    Phys Rev D55, 7368
  - Seljak U., 1997
    Measuring Polarization in the Cosmic Microwave Background
    Astrophys. J., 482, 6
  - Zaldarriaga M., 1997
    Polarization of the microwave background in reionized models
    Phys. Rev. D., 55, 1822

- Zaldarriaga M., 1998
  Cosmic Microwave Background Polarization Experiments
  Astrophys. J. 503, 1
- Kogut etal., 2003
  Wilkinson Microwave Anisotropy Probe (WMAP) First Year Observations: TE Polarization
  Astrophys. J. in press (WMAP website)
- Hu W., website:
  A Polarization Primer
  http://background.uchicago.edu/~whu/polar/webversion/polar.html
- WMAP website:
  http://map.gsfc.nasa.gov/m_mm/pub_papers/firstyear.html

21. The cosmic star formation history from optical data

- *Paul van der Werf*
  Sterrewacht Leiden, UL

- The first quantitative analysis of the cosmic star formation history at high redshifts was carried out by Madau et al (1996) based on literature data combined with the then new data of the Hubble Deep Field. Give a detailed account of the method, reasoning and conclusions of this work. Also include a critique of this work: what are the weaknesses, loose ends or remaining discrepancies? In your work, make a clear separation between principal arguments and sidelines: all of the principal arguments should be developed in detail, but sidelines only summarized.

- *Literature:*
  - Madau et al., 1996
    MNRAS 283, 1388

22. Semianalytical models of the formation and evolution of the galaxy population

- *Paul van der Werf*
  Sterrewacht Leiden, UL

- In semianalytical models of galaxy evolution, the underlying physical processes are summarized in a few convenient formulae with a small number of free parameters. These parameters are then adjusted so that the model results fit the properties of the galaxy population as we know them. A good description of this approach is given by Cole et al (1994). Give a detailed account of the method, reasoning and conclusions of this work. Also include a critique of this work: what are the weaknesses, loose ends or remaining discrepancies? In your work, make a clear separation between principal arguments and sidelines: all of the principal arguments should be developed in detail, but sidelines only summarized.

- *Literature:*
  - Cole et al., 1994
    MNRAS 271, 781

23. The History of Inflationary Cosmology

- *Bram Achterberg*

  Sterrenkundig Instituut Utrecht, UU

- The history of inflation has undergone a constant evolution since the earliest (little-known) incarnation of an inflationary model of the Early Universe due to Starobinsky (JETP Letters 30, 682, 1979; Phys. Lett. B. 91, 99, 1980). From the 'Old Inflation' of Alan Guth via the 'New Inflation' and 'Chaotic Inflation' due to Linde, there are now even more complicate models such as 'Quintessence'.

  Your assignment is to write a brief history of Inflationary Cosmology, which includes a discussion of the following points:

  + The reasons why inflation has become so popular
  + The problems of Standard Cosmology that Inflation is supposed to solve
  + The main properties of the different models, and the reasons why some of the earlier models have been discarded

- *Literature:*

  The following textbooks can serve as a good starting point:

  - Linde A., 1990
    Particle Physics and Inflationary Cosmology
    Harwood Academic Publishers, New York
  - Liddle A.R., Lyth D.H., 2000
    Cosmological Inflation and Large-Scale Structure
    Cambridge University Press

24. Observational Tests of Inflation

- *Bram Achterberg*

  Sterrenkundig Instituut Utrecht, UU

- Even though inflation takes place long before atoms are formed, the process should leave a 'fingerprint' on the Cosmic Microwave Background (CMWB). These fingerprints include:
  + Temperature variations
  + Polarization

  Your assignment is to discuss
  + How inflation generates density variations and gravitational waves
  + How these then ultimately lead to temperature variations and polarization of the CMWB
  + How present-day and future experiments, such as the recently released first scientific results of the WMAP experiment or ESA's Planck experiment, can constrain models of Inflationary Cosmology.

- *Literature:*

  A good general starting point is:
  - Liddle A.R., Lyth D.H., 2000
    Cosmological Inflation and Large-Scale Structure
    Cambridge University Press
  - Peacock J.A., 1999
    Cosmological Physics, chapter 11
    Cambridge University Press

  - WMAP website:
    http://map.gsfc.nasa.gov/m_mm.html

25. The evolving QSO Luminosity Function

- *Peter Barthel*
  Kapteyn Institute, Groningen

- How many QSOs were there in the past, how bright were they, where are they now?, ...

- *Starting point:*
  - Fan X, et al., 2003
    Astron.J. 125, 1649

26. Quasar abundances and chemical enrichment in the early universe

- *Peter Barthel*
  Kapteyn Institute, Groningen

- What can QSO elemental abundances tell us about the history of chemical enrichment in QSOs and their host galaxies ?

- *Starting point:*
  - Freudling W., et al, 2003
    Astropys. J 587, L67W

27. Damped Ly-alpha absorbers, constraining evolving galactic disks

- *Peter Barthel*
  Kapteyn Institute, Groningen

- What can we learn about early epoch galaxies from a study of the properties of damped Ly-alpha absorbing systems ?

- *Starting point:*
  - A.Wolfe, 1994, review
    in "QSO Absorption Lines", ESO Astrophysics Symposium
    ed. G.Meylan, Springer, p.13

28. The X-ray background: obscured accretion and black holes

- *Peter Barthel*
  Kapteyn Institute, Groningen

- What does the X-ray background tell us about obscuration in distant active objects ?

- *Starting point:*
  - A.Fabian, 2002
    in "Issues in Unification of AGN"
    ASP Conference Series, vol. 258, p. 185

29. Type-2 QSO's

- *Peter Barthel*
  Kapteyn Institute, Groningen
- What are type-2 QSOs ?
- *Starting point:*
  - C. Norman et al., 2002
    Astrophys J. 571, 218