Seminar I: Dark galaxies

General instructions

This document provides preparation instructions for the first of the two seminars forming part of the examination for the 2004 version of the course *Galaxies, 5 points*. The topic of this seminar is *Dark galaxies*, a field still much too young and controversial to have found its way into most undergraduate textbooks.

The point of this exercise is to:

- Practice reading technical research papers (as opposed to popular articles, review papers or textbooks). As a professional astronomer most of the stuff you will read is likely to be of this variety.
- Practice critical reading (for this purpose, speculative and controversial seminar topics have deliberately been chosen).
- Practice creativity. The answers you need may not be in the suggested literature – or in *any* publication for that matter. You may simply have to come up with a solution on your own.
- Practice information retrieval (learning not to waste time reading off-topic papers is an invaluable skill).
- Practice presenting material in front of an audience.

In preparing for the seminar, you should try to:

- Develop some insight into the field of dark galaxies by studying the relevant literature. In doing so, the seminar questions listed may serve as guidance as to what you should focus on.
- Prepare to explain and discuss various concepts and recent results relevant to this field in front of the class. The use of the blackboard or overhead projector is highly encouraged.
- Analyze the enclosed dark galaxy data set and prepare to present your finding to the class (using e.g. blackboard or transparencies).

You are perfectly welcome to collaborate with your classmates when preparing for the seminar, but once there – everyone is on their own. This means that you are not supposed to rely on the calculation, notes, viewgraphs etc. of others.

Suggested reading

A couple of good places to start are:

- Trentham, N., Möller, O & Ramirez-Ruiz, E. 2001, MNRAS 322, 658
- Hawkins, M.R.S. 1997, A&A 328, L25.

Please note that these papers represent the *minimum* reading required for the seminar. It is highly recommended that you study other articles as well. When looking for relevant papers, you may find the following keywords useful:

- Dark galaxies
- Halo substructure
- Missing satellites

- Dark lenses
- Flux ratios

The recommended article databases are:

- http://adsabs.harvard.edu/abstract_service.html (published papers only; requires Observatory computer account)
- http://arxiv.org (preprints, some of which are too strange to ever get published)

Seminar questions

Here are a few examples (i.e. not a complete list) of questions that may come up during the seminar:

- What is a dark galaxy?
- What are the main reasons for scientists to believe that such objects may exist?
- How common are they supposed to be?
- What are their characteristic masses?
- Have any direct detections of dark galaxies been made?
- Is there any indirect evidence for their existence?
- What strategies could be used when searching for dark galaxies ?

A dark galaxy case study

A team of astronomers claim to have found a very faint, ghostlike companion close to the tidal arm of an otherwise apparently isolated galaxy (Fig. 1). Using observational data of somewhat poor quality, they find the redshift of both galaxies to be $z \approx 0.05$ and the central surface brightness of the companion to be $\mu_{0,\mathrm{B}} = 28$ (corrected for inclination), making it an extremely low surface brightness galaxy. At a conference, they also use a low-resolution HI rotation curve to claim an optical mass-to-light ratio, $M/L_{\mathrm{B}} > 1000$, making it a possible dark galaxy candidate.

Following this conference, a number of follow-up observations with much higher accuracy are performed and made publically available. This data, given in Tables 1 & 2 and in Fig. 2, includes Balmer emission line strengths, the HI mass and HI rotation curve of the dark galaxy, in addition to B-band apparent magnitudes and improved redshift measurements for both objects. It is now up to you to analyze this information in order to extract as much as possible about the nature of the claimed dark galaxy.

The following questions may provide some guidance:

- What is the mass of the dark galaxy candidate?
- What is its absolute magnitude?
- What is the mass-to-light ratio? How much of this may be attributed to baryons?
- Does this object qualify as a dark galaxy?
- Would a large population of galaxies like this be able to solve the astrophysical problems for which dark galaxies were originally proposed as solutions?
- Is there any alternative explanation (other than extreme dark matter domination) for the strange properties of this object?

- What future observations or investigations would you propose to get additional clues about the nature of this object?

Erik Zackrisson, February 2004

Table 1: A compilation of the data extracted from the follow-up observations of the two galaxies in Fig. 1.

Galaxy A:		
	z:	0.052
	$m_{\rm B}$:	16.47
Galaxy B:		
	z:	0.046
	$\mu_{\rm B,0}$:	28.2[1]
	$m_{\rm B}$:	23.31
	M(HI) ($M_\odot$):	2×10^9
	$M(\rm H_2)$ ($M_\odot$):	8×10^8

1) Corrected for inclination

Table 2: HI rotation curve of Galaxy B in Fig. 1.

r(")	v_{rot} (km/s)
10	40 ± 10
20	95 ± 15
30	90 ± 10
40	100 ± 10
50	105 ± 15

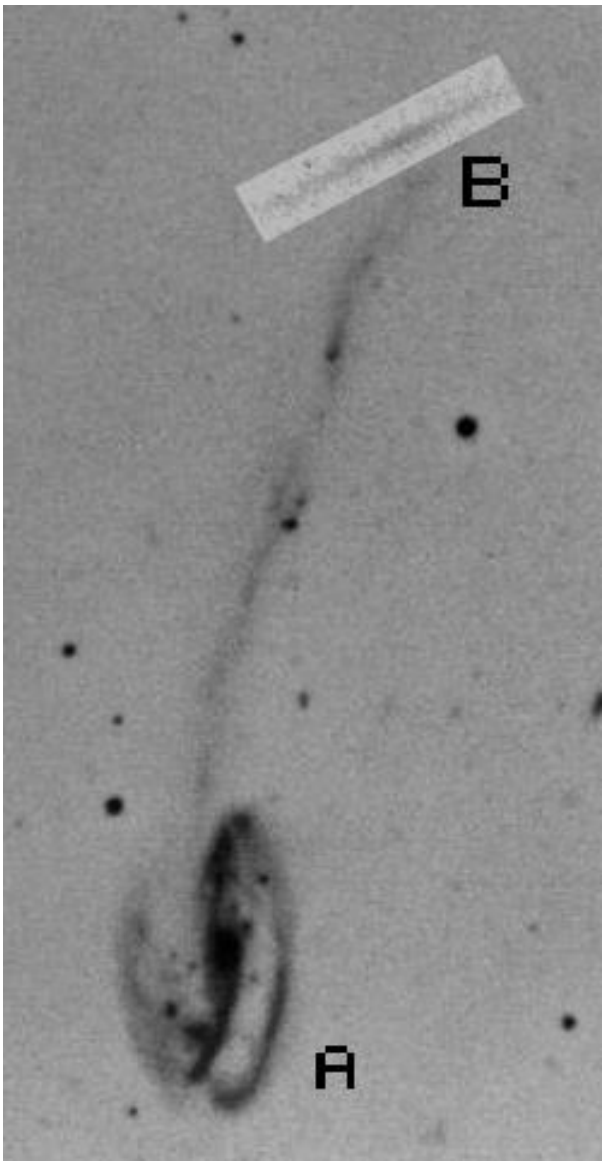

Figure 1: A disturbed galaxy (A) with a tidal arm extending towards a disk-like dark galaxy candidate (B, highlighted).

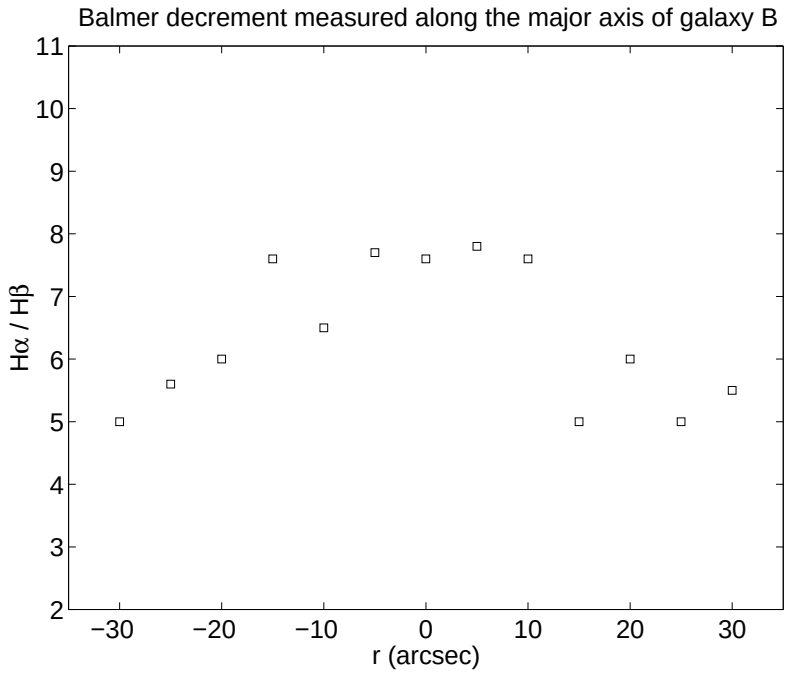

Figure 2: The Hα/Hβ-ratio measured along the major axis of galaxy B in Fig. 1.