THE INTEGRAL MISSION

W. HERMSEN[1] and C. WINKLER[2]
[1] *SRON-National Institute for Space Research, Sorbonnelaan 2, NL–3584 CA Utrecht, The Netherlands*
[2] *ESA/ESTEC, Research and Scientific Support Department NL–2200 AG Noordwijk, The Netherlands*
On behalf of the INTEGRAL Science Working Team

The International Gamma-Ray Astrophysics Laboratory (INTEGRAL), to be launched in October 2002, is dedicated to the fine spectroscopy (ΔE: 2 keV FWHM @ 1 MeV) and fine imaging (angular resolution: 12′ FWHM) of celestial gamma-ray sources in the energy range 15 keV to 10 MeV with concurrent source monitoring in the X-ray (3-35 keV) and optical (V, 550 - 850 nm) range. The mission is conceived as an observatory led by ESA with contributions from Russia and NASA. The INTEGRAL observatory will provide to the science community at large an unprecedented combination of imaging and spectroscopy over a wide range of gamma-ray energies. This paper summarises the key scientific goals of the mission, shortly presents the scientific payload as an introduction to the papers in these proceedings by the instrument teams and it will give an overview of the science ground segment including the science data centre, science operations and key elements of the observing programme.

1 Introduction

The International Gamma-Ray Astrophysics Laboratory (INTEGRAL) is dedicated to the fine spectroscopy (ΔE: 2 keV FWHM @ 1 MeV) and fine imaging (angular resolution: 12′ FWHM) of celestial gamma-ray sources in the energy range 15 keV to 10 MeV. INTEGRAL was selected in 1993 as the next ESA medium-size scientific mission (M2) and is now scheduled for launch in October 2002. ESA is responsible for the overall spacecraft and mission design, instrument integration into the payload module, spacecraft integrations and testing, spacecraft operations including one ground station, science operations, and distribution of scientific data. Russia will provide a PROTON launcher and launch facilities, and NASA will provide ground station support through the Deep Space Network. The scientific payload complement and the INTEGRAL Science Data Centre (ISDC) will be provided by large collaborations from many scientific institutes of ESA member states, USA, Russia, Czech Republic and Poland, nationally funded, and led by Principal Investigators (PI).

The INTEGRAL observatory will provide to the science community at large an unprecedented combination of imaging and spectroscopy over a wide range of X-ray and gamma-ray energies including optical monitoring.

2 Scientific objectives

INTEGRAL is a 15 keV - 10 MeV gamma-ray mission with concurrent source monitoring at X-rays (3 - 35 keV) and in the optical range (550 - 850 nm). All instruments are co-aligned, have large FOV's, and cover simultaneously a very broad energy range when observing high energy sources (Table 1).

The scientific goals of INTEGRAL will be attained by fine spectroscopy with fine imaging and accurate positioning of celestial sources of gamma-ray emission. Fine spectroscopy over the entire energy range will permit spectral features to be uniquely identified and line profiles to be determined for physical studies of the source region. The fine imaging capability of INTEGRAL within a large field of view will permit the accurate location and hence identification of the gamma-ray emitting objects with counterparts at other wavelengths, enable extended regions to be distinguished from point sources and provide considerable serendipitous science which is very important for an observatory-class mission. In summary, the scientific topics to be addressed include: (i) compact objects: *white dwarfs, neutron stars, black hole candidates and high energy transients*; (ii) extragalactic astronomy: *galaxies and clusters, AGN, cosmic diffuse background and gamma-ray bursts*; (iii) stellar nucleosynthesis: *hydrostatic nucleosynthesis (AGB and WR stars), explosive nucleosynthesis (supernovae, novae)*; (iv) Galactic structure and the Galactic Centre: *cloud complex regions, mapping of the continuum and line emission, ISM, cosmic-ray distribution*; (v) particle processes and acceleration: *transrelativistic pair plasmas, beams, jets*; (vi) identification of high-energy sources: *unidentified gamma-ray objects as a class.*

The last topic, the quest for the identification of high-energy gamma-ray sources is high on the list of topics in gamma-ray astronomy for already 25 years. It started with the publication of the first COS-B catalogue of gamma-ray sources in 1977 (Hermsen et al.), which was followed by the second COS-B catalogue (Swanenburg et al. 1981). The status prior to the CGRO mission was reviewed by Bignami and Hermsen (1983). After the launch of CGRO in 1991, EGRET continued the high-energy observations and gathered in the 3rd EGRET catalogue (Hartman et al. 1999) a list of 271 compact sources of which about 170 remained unidentified. Of the identified Galactic COS-B and EGRET sources only the few identifications with radio pulsars are definit, thanks to the detection of the timing signature in the gamma-ray data. Other proposed identifcations based on coincidences in position are still uncertain due to the modest angular resolution of EGRET. In these proceedings the problem of the identification of the unidentified gamma-ray sources is addressed by a number of authors (Grenier, Caraveo, Mirabel and Perrot). The main problem sofar is indeed the large error regions around the EGRET positions, which result in large numbers of candidate counterparts when deep searches are made at other wavelengths (see e.g. for deep searches with XMM Caraveo, 2002). Sofar, sensitive searches for counterparts in the INTEGRAL hard X-ray/ soft gamma-ray range have been unsuccesful due to the apparent peculiar spectral shape of the average unidentified gamma-ray source: maximum luminosity at gamma-ray energies, at least a few orders of magnitude higher than the luminosity in the classical X-ray range below 10 keV. INTEGRAL observations might force a break through by detecting a sizable fraction of the EGRET sources, and most importantly with high positional accuracy. The latter will allow a better targetted search for the counterparts in e.g. the X-ray, optical and radio bands. The confidence that INTEGRAL will be in a position to detect the unidentified EGRET sources has increased significantly by the results of all sky searches for EGRET counterparts in the COMPTEL data, exploiting the exposure collected over the total 9-year CGRO mission. The first results are presented in this meeting for a deep search in the Galactic Anti Centre (Bronsveld et al. 2002). For a few sources in the Anti-Centre INTEGRAL should be able to detect these sources up to about 1 MeV since they appear to be sufficiently strong and have their maximum luminosities around 1 MeV. These COMPTEL results confirm that the average spectral shape of the unidentified gamma-ray sources resembles those of the normal radio/gamma-ray pulsars (the Crab spectral shape being the exception) and the millisecond pulsar PSR J0218+4232 (Kuiper et al. 2000, 2002a,b), as well as those of blazar-type AGN, which led already to the proposed identification with a microquasar by Paredes et al. (2000) (see also Mirabel in these proceedings).

Table 1: Key parameters of the INTEGRAL scientific payload as they were provided for AO1. The listed IBIS sensitivities are for more conservative in-orbit background estimates than for SPI, and will (for each instrument) be redetermined once the actual background in orbit is known

	Spectrometer SPI	Imager IBIS	X-ray Monitor JEM-X	Optical Monitor OMC
Energy range	20 keV - 8 MeV	15 keV - 10 MeV	3 keV - 35 keV	(500 - 850) nm
Detector area (cm^2)	500	2600 (CdTe) 3100 (CsI)	1000 2 units	CCD + V-filter 2048×1024 pix.
Spectral res.	2.2 keV @ 1.3 MeV	9 keV @ 100 keV	13 keV @ 10 keV	–
Field of view (fully coded)	16°	9° x 9°	4.8°	5.0° x 5.0°
Angular res.	2° FWHM	12′ FWHM	3′ FWHM	17.6″/pixel
10σ source location	1.3°	$< 1'$	$< 30''$	6″
Cont. sens. (3σ, 10^6 s) (ph cm^{-2} s^{-1} keV^{-1})	10^{-7} @ 1 MeV	5×10^{-7} @ 100 keV	1.3×10^{-5} @ 6 keV	18.2^{m_v} (3σ, 10^3 s)
Line sens. (3σ, 10^6 s) (ph cm^{-2} s^{-1})	5×10^{-6} @ 1 MeV	2×10^{-5} @ 100 keV	1.7×10^{-5} @ 6 keV	–
Timing acc. (3σ)	0.129 ms	0.062 ms – 30 mins	0.122 ms	variable in units of 1 s
Mass (kg)	1309	628	65	17
Power (W)	250	220	52	12
Data rate (kbps)	20	57	7	2

3 Scientific Payload

The INTEGRAL payload consists of two main gamma-ray instruments, the Spectrometer SPI and Imager IBIS, and of two monitor instruments, the X-ray Monitor JEM-X and the Optical Monitoring Camera OMC.

The design of the INTEGRAL instruments is largely driven by the scientific requirement to achieve - to the maximum extent possible - complementarity in fine spectroscopy and accurate imaging. As shown in Table 1, the payload does meet this goal. Each of the main gamma-ray instruments, SPI and IBIS, has both spectral and angular resolution, but they are differently optimised in order to complement each other and to achieve overall excellent performance. This optimisation remained opportune, observations after the INTEGRAL payload selection showed that - in general - line emissions do occur on a wide range of angular and spectral extent: That is, broad lines seem preferably to be emitted from point-like sources and narrower lines from extended sources. In sky regions like Vela and Cygnus, INTEGRAL will have to meet the challenge of disentangling point-like and extended, narrow-line and broad-line components to understand e.g. the total ^{26}Al-line emission (see e.g. Knödlseder et al. 2001 and Lavraud et al. 2001, resp.) for which COMPTEL found evidence for a mix of extended and sharper structure, but could not resolve it. The INTEGRAL continuum and/or line sensitivities are increased by an order of magnitude or more compared to the succesful earlier instruments like SIGMA (continuum) and OSSE and COMPTEL (lines). The two monitor instruments (JEM-X and OMC) will provide complementary observations of high-energy sources at X-ray and optical energy bands. A short overview of the INTEGRAL payload is given below, detailed descriptions of the instruments and the science they will address, can be found in the various instrument papers in these proceedings.

3.1 Spectrometer SPI

The spectrometer SPI will perform spectral analysis of gamma-ray point sources and extended regions with an energy resolution of 2 keV (FWHM) at 1 MeV. This will be accomplished using an array of 19 hexagonal high purity Germanium detectors cooled by active cooling to an operating temperature of 85 K. The total detection area is 500 cm^2. A hexagonal coded aperture mask is located 1.7 m above the detection plane in order to image large regions of the sky (fully coded field of view = 16°) with an angular resolution of 2°.

In order to reduce background radiation, the detector assembly is shielded by an active BGO veto system which extends around the bottom and side of the detector almost completely up to the coded mask. A plastic veto between mask and upper veto shield ring further reduces background events.

3.2 Imager IBIS

The imager IBIS provides powerful diagnostic capabilities of fine imaging (12 arcmin FWHM), source identification and spectral sensitivity to both continuum and broad lines over a broad (15 keV - 10 MeV) energy range. The energy resolution is < 7 keV @ 0.1 MeV and 60 keV @ 1 MeV. A tungsten coded aperture mask (located at 3.2 m above the detection plane) is optimised for high angular resolution imaging. Sources ($> 10\sigma$) can be located to $< 60''$. As diffraction is negligible at gamma-ray wavelengths, the angular resolution obtainable with a coded mask telescope is limited by the spatial resolution of the detector array. The IBIS design takes advantage of this by utilising a detector with a large number of spatially resolved pixels, implemented as physically distinct elements.

The detector uses two planes, a front layer (2600 cm^2) of CdTe pixels (ISGRI), each (4x4x2) mm (wxdxh), and a second one (3100 cm^2) of CsI pixels (PICsIT), each (9x9x30) mm. The division into two layers allows the paths of the photons to be tracked in 3D, as they scatter and interact with more than one element (This offers the possibility to operate IBIS in the additional "Compton mode"). The aperture is restricted by a passive tungsten shield. The detector array is shielded in all other directions by a BGO scintillator veto system.

3.3 X-Ray Monitor JEM-X

The Joint European X-Ray Monitor JEM-X supplements the main INTEGRAL instruments and plays a crucial role in the detection and identification of the gamma-ray sources and in the analysis and scientific interpretation of INTEGRAL gamma-ray data. JEM-X will make observations simultaneously with the main gamma-ray instruments and provides images with $3'$ angular resolution in the 3 - 35 keV prime energy band.

The baseline photon detection system consists of two identical high pressure imaging microstrip gas chambers (Xenon at 1.5 bar, 90% Xenon and 10% Methane) each viewing the sky through a coded aperture mask (4.8° fully coded FOV), located at a distance of 3.2 m above the detection plane. The total detection area is 1000 cm^2.

3.4 Optical Monitoring Camera OMC

The Optical Monitoring Camera OMC consists of a passively cooled CCD in the focal plane of a 50 mm lens. The CCD (1024 x 2048 pixels) uses one section (1024 x 1024 pixels) for imaging, the other one for frame transfer before readout. The FOV is $5^\circ \times 5^\circ$ with a pixel size of $17.6''$. The OMC will observe the optical emission from the prime targets of the INTEGRAL main gamma-ray instruments with the support of the X-Ray Monitor JEM-X. OMC offers the first opportunity to make long observations in the optical band simultaneously with those at X-rays and gamma-rays. Variability patterns ranging from 10's of seconds, hours, up to months and years will be monitored. The limiting magnitude will be 19.2^{m_v} (3σ, 10^3 s), which corresponds to $\sim$40 photons cm^{-2}s^{-1}keV^{-1} (@ 2.2 eV) in the V-band. Multi-wavelength observations are particularly important in high-energy astrophysics where variability is typically rapid. The wide band observing opportunity offered by INTEGRAL is of unique importance in providing for the first time simultaneous observations over seven orders of magnitude in photon energy for some of the most energetic objects in the Universe.

4 The INTEGRAL Ground Segment

The ground segment consists of three major elements, ESA's Mission Operations Centre (MOC), the INTEGRAL Science Operations Centre (ISOC), and the INTEGRAL Science Data Centre (ISDC) plus two ground stations provided by ESA and NASA, respectively. We will shortly describe the tasks of the three centres.

4.1 Mission Operations Centre MOC

The MOC, located at ESOC in Darmstadt, Germany, will implement the observation plan received from the ISOC within the spacecraft system constraints into an operational command sequence. In addition, MOC will perform all classical spacecraft operations, real-time contacts with spacecraft and payload, maintenance tasks and anomaly checks (including payload critical health and safety). MOC will determine the spacecraft attitude and orbit, and will provide raw science data to the ISDC.

4.2 INTEGRAL Science Operations Centre ISOC

The ISOC, provided by ESA and located at ESTEC in Noordwijk, the Netherlands, is responsible for issuing the Announcement of Opportunity (AO) for observing time and handling the incoming proposals (succesfully accomplished for the first year of operations) and for processing these into an optimised observation plan, consisting of a timeline of target pointings plus the corresponding instrument configuration. This observation plan will then be forwarded to MOC to be uplinked to the spacecraft. Furthermore, the ISOC will validate any changes made to parameters describing the on-board instrument configuration and it will keep a copy of the scientific archive produced at the ISDC. Finally, the ESA Project Scientist at the ISOC will decide on the generation of TOO alerts (Targets of Opportunity) in order to update and reschedule the observing programme.

4.3 INTEGRAL Science Data Centre ISDC

The ISDC, located in Versoix, Switzerland, will receive the complete raw science telemetry plus the relevant ancillary spacecraft data from the MOC. Science data will be processed, taking into account the instrument characteristics, and raw data will be converted into physical units. Using incoming science and housekeeping information, the ISDC will routinely monitor the instrument science performance and conduct a quick-look science analysis. Most of the Targets of Opportunity showing up during the lifetime of INTEGRAL will be detected at the ISDC during the routine scrutiny of the data. Scientific data products obtained by standard analysis tools will be distributed to the observer and archived for later use by the science community. Facilities will be provided to support the science community in the analysis of INTEGRAL data.

5 Mission scenario

INTEGRAL (with a payload mass of 2019 kg and a total launch mass of ~4000 kg) will be launched in October 2002 by a Russian PROTON launcher into a highly eccentric orbit with high perigee in order to provide long periods of uninterrupted observation with nearly constant background and away from the radiation belts. The parameters of the orbit are: period 72 hours, inclination 51.6°, initial perigee height 10 000 km, initial apogee height 153 000 km. The particle background radiation affects the performance of high-energy detectors, and scientific observations will therefore be carried out while the spacecraft is above an altitude of nominally 40 000 km. The particle background of the local spacecraft environment will be continuously measured by the on-board radiation monitor: this device allows the optimisation of the observing time before or after radiation belt passages and solar flare events, and provides essential information about the actual background. A nominal altitude of 40 000 km implies that ~90% of the time spent on the orbit can be used for scientific observations. However, a number of in-orbit activities have an influence on the net amount of orbit time (e.g. slews, eclipses, restrictive spacecraft operations, instrument calibrations) such that the average observation efficiency becomes ~85% per year. The real-time scientific data rate (including instrument housekeeping) is 86 kbps. This rate is too low to allow all scientific information to be transmitted to the ground, e.g. it is not likely that PICsIT can be operated in orbit in photon-by-photon mode.

The spacecraft employs fixed solar arrays: this means, that the target pointing of the spacecraft (at any point in time) will remain outside an avoidance cone around the sun and anti-sun. This leads to a minimum angle between any celestial source and the sun/anti-sun of 50° during the nominal mission life (2 years) outside eclipse seasons and 60° during extended mission life (year 3+). During eclipse seasons of the nominal mission (few weeks per year) 60° will be applied.

Because of the dithering deconvolution requirements by SPI, the spacecraft will routinely, during nominal operations, perform a series of off-source pointing manouevres, known as "dithering". These dithering patterns consist of sets of different pointings at sky positions around the nominal target positions (at the centre). The dithering points are separated by 2°.The exposure time per point is 30 minutes. Two dither patterns will be employed: a 7 point hexagone and a 5×5 point raster, both centred on the target position. If required by observers, dithering can be disabled.

6 Observation programme

INTEGRAL will be an observatory-type mission with a nominal lifetime of 2 years, an extension up to 5 years is technically possible. Most of the observing time (65% during year 1, 70% year 2, 75% year 3+) will be awarded to the scientific community at large as the General Programme. Proposals, following a standard Announcement of Opportunity (AO) process, will be selected on their scientific merit only by a single Time Allocation Committee. These selected observations are the base of the general programme. The first call (AO-1) for observation proposals was issued on 1 November 2000 with a proposal submission deadline by 16 February 2001. The AO-1 process was completed in August 2001. The selected proposals are grouped in different grades, A, B and C, with the highest priority for scheduling for grade A. Table 2 lists the selected grade A proposals which will most likely be realized in the first year of INTEGRAL operations and should deliver the first harvest of scientific results. The list of scientific goals gives a good overview of the planned and expected science from INTEGRAL observations. Finally, there are accepted proposals for Gamma-Ray Burst and Target-of-Opportunity follow-up observations.

The remaining fraction of the observing time (i.e. 35% year 1, 30% year 2, 25% year 3+) will be reserved as guaranteed time (Core Programme) for, mainly: (i) the institutes (PI

Table 2: Time Allocation Committee approved grade A targets for the first year of INTEGRAL observations (AO-1)

Scientific goals	PI	Target	RA(J2000) [deg]	Dec(J2000) [deg]	Obs. time [ksec]
INTEGRAL observations of a 2.22 MeV candidate	McConnell	GRO J0332-87	53.00	-86.72	230
Probing core collapse: 44Ti and 60Co nucleosynthesis in SN1987A	Knoedlseder	LMC/SN 1987A	83.87	-69.27	1500
INTEGRAL view of Mkn 3 and: Mkn 6, two Seyfert galaxies with strong absorption and radio jets	Bassani	Mkn 3	93.90	71.04	300
Inv. Compton catastrophe and pair creation in the intraday-variable sources 0716+714 and 0836+71	Wagner	0716+714	110.47	71.34	400
Exposing the binary heart of η-Carinae with gamma-rays	Butt	η-Carinae	161.27	-59.68	200
Probing the physics of high-energy spectra of NGC 4151 and IC 4329A with INTEGRAL	Zdziarski	NGC 4151	182.64	39.41	200
A study of the ADAF phenomenon in nearby AGN	Dean	NGC 4258	184.74	47.30	100
Probing an intermediate mass Black Hole	Dean	NGC 4395	186.45	33.55	100
The physics of AGN: a deep understanding of 3 C273	Courvoisier	3C 273	187.28	2.05	500
A hard X-ray investigation of bright IR galaxies	Della-Ceca	NGC 4736	192.72	41.12	100
The hard X-ray and corr. multi-ν properties of the Blazar 3C 279	Collmar	3C 279	194.05	-5.79	300
Buried quasars in ultraluminous infrared galaxies	Mirabel	Mkn 231	194.06	56.87	100
Investigation of non-thermal hard X-ray emission in Coma cluster	Vikhlinin	Coma cluster	194.95	27.98	500
Observations of type II Seyfert galaxies	Deluit	NGC 4945	196.36	-49.47	150
Broad band observations of CenA with INTEGRAL/RXTE	Rothschild	Cen A	201.37	-43.02	450
INTEGRAL obs. of the reflection componant in Seyfert galaxies	Fabian	MCG 6-30-15	203.97	-34.29	200
INTEGRAL obs. of the ultra-luminous infrared galaxy Mkn 273	Dermer	Mkn273	206.18	55.89	100
Probing the physics of high-energy spectra of NGC 4151, IC 4329A	Zdiarski	IC 4329A	207.33	-30.31	200
Cosmic-ray acceleration in SN 1006: synchr. radiation and nonthermal bremsstrahlung in hard X-rays	Reynolds	SN 1006	225.73	-41.95	900
The nature of the hard X-ray componant in Sco X-1	v.d. Klis	Sco X-1	244.98	-15.64	175
A multiwavelength study of Sco-X-1 and it's relativistic jets	Stella	Sco X-1	244.98	-15.64	175
Ultra deep exposure of the Galactic Centre region	Sunyaev	Galactic Centre	266.42	-29.01	2000
Deep gamma-ray observations of the galactic nuclear region	Goldwurm	Galactic Centre	266.42	-29.01	1000
Spectral observations of SS 433	Cherepashchuk	SS 433	287.96	4.98	500
The many faces of GRS 1915+105	Hannikainen	GRS 1915+105	288.80	10.95	600
Cygnus X-1 in the hard state	Makzac	CygX-1	299.59	35.20	300
The Cygnus-X region; a nucleo-synthesis lab. for INTEGRAL	Knoedlseder	Cygnus	318.30	41.27	1000
To the bottom of the explosion forming Cas A:observing 44Ti and the hard X-ray emission	Vink	Cas A	350.85	58.81	1500

collaborations) which have developed and delivered the instruments and the ISDC (guaranteed PI time), and (ii) for Russia and NASA for their contributions to the programme (PROTON launcher and Deep Space Network ground stations, respectively). A small fraction goes to the Mission Scientists and the ISOC.

The Core Programme will consist of three elements:

1) Deep exposures of the central Galactic radian ($\pm$ 30° in longitude and $\pm$ 20° in latitude centered on (l,b)=(0,0). Individual pointings of 30 min exposure each are on a rectangular pointing grid with 2.4 and 1.2° spacing, respectively.

2) the Survey of the Galactic Plane to map its gamma-ray continuum and line emission, to detect as yet unknown persistent sources (e.g. recent Galactic supernovae) and to facilitate the study of transient sources. This survey will be made out of weekly scans ("slew, stop, stare") along a saw-tooth path. The scan pointings cover a band of $\pm 6.5°$ in Galactic latitude, the actual coverage is larger (i.e. $\sim \pm 20°$), however, due to the wide field-of-views of the main instruments.

3) pointed observations including ToO's. For AO-1, the INTEGRAL Science Working Team selected one pointed observation, covering the Vela region.

For more detailed information on the INTEGRAL observation plan, please consult the ISOC pages on the WWW:

http://www.rssd.esa.int/Integral/isoc/

For more detailed information on INTEGRAL in general:

http://www.rssd.esa.int/Integral/integral.html

References

1. G.F. Bignami and W. Hermsen, *Annual Rev. Astron. Astrophys.* **21**, 67 (1983).
2. P. Bronsveld *et al*, these proceedings.
3. P. Caraveo, these proceedings (2002).
4. I. Grenier, these proceedings (2002).
5. R. Hartman *et al*, *ApJS* **123**, 79 (1999).
6. W. Hermsen *et al*, *Nature* **269** 5628 494 (1977).
7. J. Knoëdlseder *et al*, Proc. 4th INTEGRAL Workshop "Exploring the Gamma-Ray Universe", ESA SP-459, 47 (2000).
8. L. Kuiper *et al*, AA **359**, 615 (2000).
9. L. Kuiper *et al*, *ApJ* in press (2002a).
10. L. Kuiper *et al*, these proceedings (2002b).
11. B. Lavraud *et al*, Proc. 4th INTEGRAL Workshop "Exploring the Gamma-Ray Universe", ESA SP-459, 79 (2000).
12. I.F. Mirabel, these proceedings (2002).
13. J.M. Parades *et al*, *Science* **288**, 2340 (2000).
14. C.A. Perrot, these proceedings (2002).
15. V. Schönfelder *et al*, *A&AS* **143**, 145 (2000).
16. B.N. Swanenburg *et al*, *ApJ* **243**, L69 (1981).