clinic tangle', which lies at the root of the chaotic behaviour of orbits. In his original memoir on the three-body problem, which in 1889 won a prize sponsored by King Oscar II of Sweden and Norway, Poincaré failed to understand properly the complexity of the trajectories. It was only after publication of his memoir in *Acta Mathematica* that he realized his mistake. He had to have printed copies of the journal withdrawn to correct his description of the homoclinic tangle.

The authors next consider the question raised by Paul Painlevé in 1897 about the possible existence of singularities in the n -body problem that are not due to collision. This well-formulated problem had to wait 100 years for its resolution through the recent solutions by Gerver and Xia in which bodies travel an infinite distance in finite time. These solutions are of a purely mathematical nature and cannot exist physically, as they require dimensionless bodies and arbitrarily close encounters.

Whereas Painlevé's conjecture is purely mathematical, the question of the stability of the Solar System is of a different nature. Although the problem can be formulated mathematically — as Poincaré did in asking for the infinite time stability of a point-mass planetary system — the real question of interest is more the practical stability of the Solar System over periods of time comparable to its age. Diacu and Holmes treat this question less exhaustively than they do that of collisionless singularities.

Laplace and Lagrange showed between 1799 and 1825 that, as a first-order approximation with respect to the planetary masses, the semi-major axes of the planets do not undergo long-term — or secular — variations. However, this fact is not sufficient to prevent planetary collisions, because even if the semi-major axes of the planets are constant, changes in their eccentricities can induce their orbits to cross.

To ensure the stability of the Solar System,

it is also necessary to provide bounds on the variations of the planetary eccentricities. This task was again carried out by Laplace and Lagrange, who demonstrated the linear stability of the first-order secular equations of the eccentricities and inclinations.

It is surprising that this part of the story is omitted by the authors, for on this topic Laplace gave a brilliant mathematical proof. The authors, to my mind, underestimate the fundamental value of these results, saying they would "refer to the n -body problem and not directly to the Solar System itself". In fact, Laplace's solution — which was fully computed for the whole Solar System by Le Verrier in 1856 — provides a good approximation to the behaviour of the Solar System over a few million years.

The next natural question concerns the modifications that might arise out of the higher-order terms not taken into account in Laplace's computation. Attempts to answer this question formed a quest lasting nearly

Film review Aliens, lies and videotape

Contact

A film by directed by Robert Zemeckis and co-produced by Carl Sagan and Ann Druyan
Warner: 1997

Contact is based on a 1995 novel by Carl Sagan, the astronomer and popularizer of science who died last year. The story's central character, Ellie Arroway (Jodie Foster) is also an astronomer, and devotes her career to searching for radio signals from civilizations on planets orbiting other stars. When she succeeds in detecting a signal, she is propelled into a political controversy for which she is ill-prepared.

The decoded message turns out to be instructions for building a large device, the ultimate purpose of which is unclear. In the last half hour of the film, Ellie tests the device, makes contact with the aliens, but carries back to Earth no objective proof (namely on video) of her experience.

Up until the detection of the signal, this entertaining and thought-provoking film is an accurate portrayal of a radioastronomer's life, showing that scientists, just like other people, are driven by complex emotions. And the main subplot of a senior scientist taking over — and taking all the credit for — a project that has suddenly become successful is sadly not unknown, especially in astronomy.

One early theme is that Arroway is committing professional suicide by her involvement in the search for extraterrestrial intelligence (SETI). Young astronomers who have not yet obtained tenure will recognize the truth in this portrayal. In essence, SETI is a scientific lottery: the winner will certainly achieve scientific immortality, but will anyone win?

I suspect few astronomers would say on the record that life elsewhere in the Universe does not exist. But communicating with another

civilization is a different matter. One of the basic problems is the length of time a technological civilization such as our own would survive; another is the duration of the period in which an advanced civilization would be interested in trying to communicate with other worlds. Where should we look? Which stars should we examine? At what what frequencies should we look for a signal? Finally, there is the question of language.

In *Contact*, the issues of frequency and language are handled deftly, although perhaps cryptically for many lay people. Arroway exclaims "pi times H" upon finding the signal, which all astronomers will immediately interpret as $\pi \times 1,420.406 \text{ MHz}$ — 1,420.406 MHz, being the frequency of a photon emitted as a hydrogen atom, makes a transition between two hyperfine levels in the ground state. The implicit idea is that any technological civilization would know both numbers; this sets the stage for mathematics and science being the universal language.

Refreshingly, the science and terminology adopted in the film are accurate, even though some artistic liberties are taken. (For example, the Very Large Array (VLA) is not located within walking distance of Canyon de Chelly, nor can

you plug headphones into the base of a VLA antenna.) Great care has been taken to get the details right. Although some lay people might find the jargon intimidating, it is enjoyable to hear it used properly, and those unable to follow the details will not miss anything essential to the story. All too often, the level of science in films tends to be abysmal, with simple words or concepts mangled beyond recognition.

The wider issue of whether we should be engaged in SETI, and how much effort should be devoted to the search, is handled in an impassioned speech from Arroway as she seeks private funding after the US National Science Foundation terminates her project. This is pure Sagan, right down to the turtleneck sweater and tweed jacket Arroway wears. One wonders whether he regretted not having shown as much passion as she does here when all NASA funding for SETI was eliminated by Congress in 1993.

The question "Are we alone?" has long intrigued humanity. "What a waste of space if we are alone," say several of the film's characters. *Contact* conveys, eloquently and vibrantly, Sagan's belief that we are not.

Leslie Sage is an assistant editor of *Nature*.