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COMMENTS ON H. ARP "THE PERSISTENT PROBLEM OF SPIRAL GALAXIES"

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Abstract

In his paper "The persistent problem of Spiral Galaxies" H. Arp criticises the standard theory of spiral galaxies and demonstrates that introduction of plasma theory is necessary in order to understand the structure of spiral galaxies. In the present paper arguments are given in support of Arp's theory and suggestions are made how Arp's ideas should be developed. An important result of Arp's new approach is that there is no convincing argument for the belief that there is a "missing mass". This is important from a cosmological point of view.

A. Arp's new approach to the theory of galactic dynamics

In what may be an epoch-marking paper, "The Persistent Problem of Spiral Galaxies" (IEEE Trans. Plasma Sci., PS-14, Dec. 1986), H. Arp draws three especially important conclusions.

1. A careful analysis of the "generally accepted" density wave theories shows that these theories cannot be correct. This is important, because they have long prevented progress in the field of theories of galactic dynamics.

2. Next problem is to fill the void which these theories leave. Arp suggests that this may be done by plasma theories. This is likely to be correct. However, his outlines of how this should be done could be strengthened. He bases his arguments mainly on the Chandrasekhar-Fermi paper (1953). With the deepest respect for them, it must be stated that cosmic plasma physics has advanced considerably during the thirty-four years which has passed since its appearance. Especially, it has taken a jump forward with the opening of the X-ray and gamma ray octaves by space research which has given rise to a new model of our cosmic environment, usually referred to as "Plasma Universe".

3. The third conclusion is that there is no evidence for a "missing mass". This will be discussed in D.

B. Plasma Universe

It is fortunate that in the same issue of IEEE Trans. Plasma Sciences in which Arp has published his paper, he can find advice how the new plasma physics should be used for developing his ideas.

Indeed, the Special Issue Review paper by Fälthammar with the title "Magnetosphere-Ionosphere Interactions - Near Earth Manifestation of the Plasma Universe" could give much inspiration. The development of Arp's theory may aim at an analogous paper, for example, with the title "Galactic Dynamics as a manifestation of the Plasma Universe".

When preparing the suggested paper it is important to take account of at least three basic processe.

(a) The decisive role of <u>double layers</u> (IEEE, the same issue, p.779). The existence of double layers in laboratory plasmas was studied already by Langmuir in the 1920:ies. The existence in space of electric fields parallel to the magnetic field was predicted by Alfvén and Fälthammar (Cosmical Electrodynamics 1963, Chapter 5.4.2). The theory of double layers in space has been developed by many authors (for a survey see L. Block). One of the first observational indications of electric double layers in space was the discovery of an unexpected electron distribution indicating an electrostatic acceleration in space (McIllwain). Since then massive evidence of electric fields parallel to the magnetic field have been accumulated. (For a review see Fälthammar 1986, IEEE, see also C.P. Ch. II:6, especially Fig. II:22.)

We know now that in the magnetospheres there are double layers with voltage jumps of kV, in the solar atmosphere exploding double layers of MV or GV (as seen from the solar cosmic rays). Carlqvist has developed a theory of relativistic double layers which in galaxies may accelerate particles up to at least 10^{14} eV (see p. 794 in the same issue of IEEE).

(b) Double layers are very often produced by electric currents and their basic role stresses the necessity of clarifying the <u>circuits in which currents flow</u>. Space is filled by a network of electric currents (see C.P., Ch. II and III). Currents which are homogeneous over large regions exist, but more often currents are "pinched" to thin ubiquitous filaments which are observed almost wherever the resolution is high enough. Surface currents - of the type observed, e.g., in the magnetopause, are also very important. They give space a general "cellular" structure. This is relevant for galactic theories. We know from the magnetosphere that the chemical composition of matter may be different on both sides of an interphase associated with the current layer and it seems necessary that similar phenomena exist also in interstellar and intergalactic space. (If such layers also separate different kinds of matter the universe may be symmetric with respect of matter and antimatter, see C.P., Ch. IV:9 and especially Ch. VI).

(c) Critical Velocity Phenomena, which produce an unexpected high interaction between a neutral gas and a magnetized plasma as soon as their relative velocities exceed a value v_{crit} given by

$$v_{crit} = (2\ eV_{ion}/M)^{1/2}$$

(V_{ion} = ionisation voltage, M = atomic mass). This means that the kinetic energy of an atom moving with the critical velocity equals its ionisation energy. (See C.P., Ch. IV:6 and V.) This effect has been decisive for the formation of the band structure of the solar system, and may play an important role also in several galactic phenomena (Alfvén and Arrhenius, 1976).

C. Structure of the plasma universe

As shown in Fig.1, space should be divided into two different regions: the reliable diagnostics region (out to the reach of spacecraft) where it is possible to build what we mean by a real plasma science, and regions outside the reach of spacecraft which basically are fields of speculation. They should be approached by extrapolation of results from the "reliable diagnostics region".

Furthermore, it is necessary to distinguish between some different kinds of plasma (Fig.2). Two of them, "magneto-hydrodynamic plasma" and "collisionless plasma", are listed in Fig.2. "Dusty plasma" is a third kind of plasma.

D. Symbioses between galactic observers and reliable diagnostic physicists

Because galaxies are outside the field of reliable diagnostics the theory of galaxies must be approached through a symbiosis between galactic observers and magnetospheric-laboratory plasma physicists. Arp's invitation to such a collaboration is certainly very welcome. However when making such extrapolations there are two important caveats.

1. The magnetic field line reconnection approach is misleading and obsolete and must not be used (see p. 779 in IEEE Plasma Science Dec. 1986, same issue).

2. Whereas it is true that all plasmas are ionized gases, it is not true that what the astrophysicists in general mean by "ionized gases" has very much to do with plasmas (see C.P. and especially p. 790-792 in the IEEE issue). They use the concept "ionized gases" in a very restricted sense viz to denote a hypothetical medium that does not possess the complex properties of most real cosmic plasmas. Their "ionized gas" is a medium which may be somewhat similar to the quiescent plasma studied in externally heated cesium plasmas in the laboratory Q-machines), but such a medium is observed only in selected regions in cosmical physics.

Furthermore there are strong arguments for the view that a study of plasma regions of different sizes - from the laboratory and the magnetospheres out to the Hubble distance - should be based on the assumption that the basic properties of plasmas are the same within very large variations in the relevant parameters. This means that essential plasma processes in galaxies may be studied by extrapolation from what is known from heliospheric research.

The emission of two or more arms from the galactic nucleus, suggested by Arp, resembles, to a surprisingly high degree, the emission from the sun of high-density streams in the solar wind. The observed flow of ionized material along the longitudinal magnetic field of which Arp speaks is observed also in the heliospheric case. The main difference seems to be that the galactic gravitation plays a much more important role than solar gravitation does. Furthermore, we need not have some exotic mechanism (like black holes) to produce the ejection. A system of electric currents and the production of torsional hydromagnetic waves may be enough (see Belcher, 1971, 1987). These effects can also transfer additional angular momentum to the arms far out from the center.

E. <u>There is no "missing mass"</u>.

The third and perhaps most important conclusion which Arp draws is that there is no support for the claim that galaxies contain the "missing mass" which the Big Bang believers now as always are looking for. Indeed, for decades they have tried to find new and increasingly exotic kinds of invisible mass. A discussion of this is found in Ch. VI of C. P., which in some respects is based on works by Arp (1966, 1977, 1978).

<u>Conclusion</u>

As guest editor in the IEEE "Special issue on Space and Cosmic Plasma" Anthony Peratt has opened the dams for the new views on our cosmic environment which space research data make necessary. These will now inundate and drown much of the pre-sputnik geophysics-astrophysics. Arp's new approach to the dynamics of galaxies will probably be an important part of this Great Flood.

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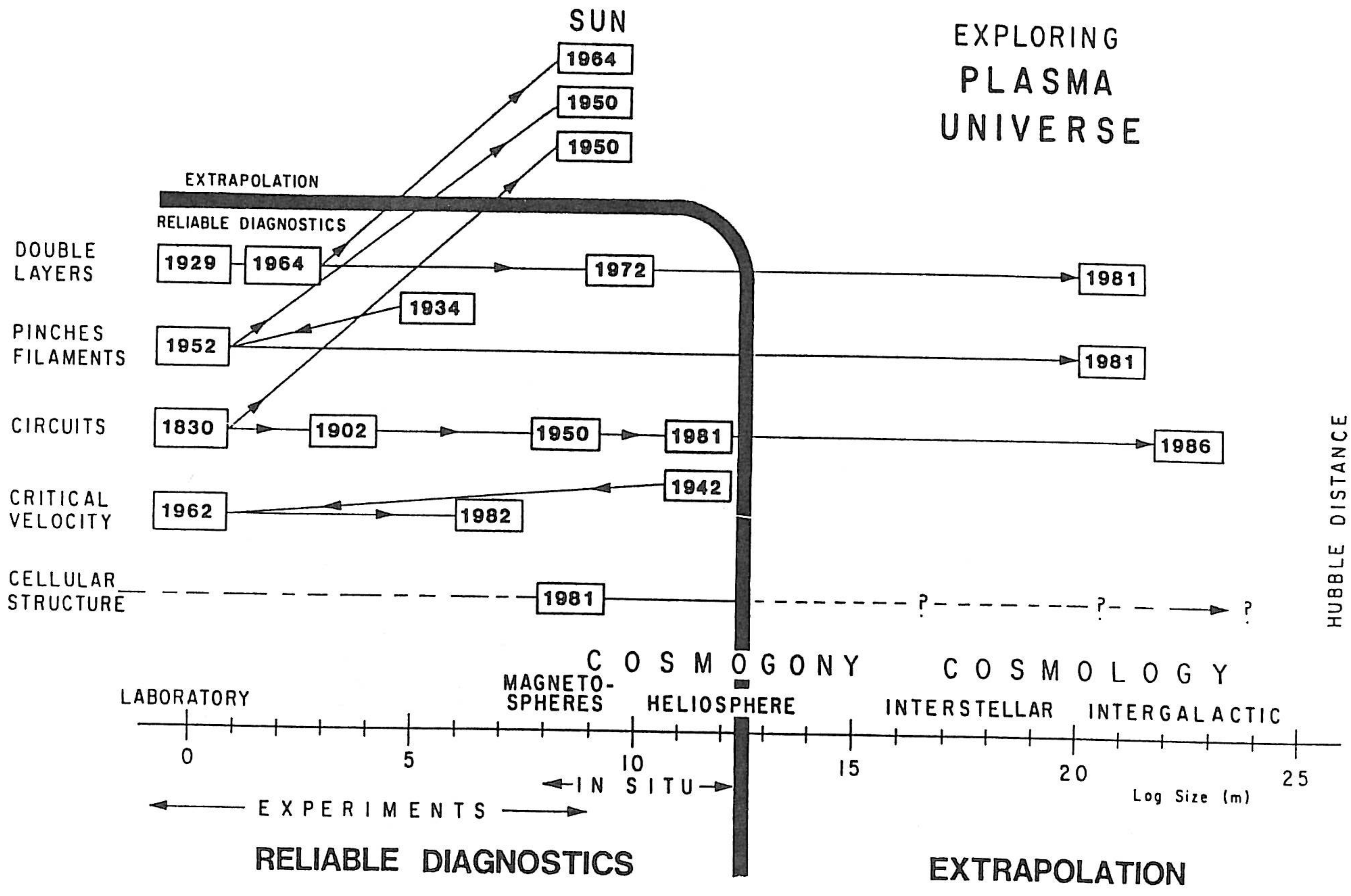

Fig. 1 Exploring the Plasma Universe, Introductory lecture at the MIT Plasma Physics Symposium, Jan. 9, 1987, Cambridge Mass. (In press.)

Fig. 2. Properties of Magnetized Plasmas

	FLUID PLASMA (Magneto-hydrodynamic)	PARTICLE PLASMA (Collisionless)
General properties	Similar to fluid	An assembly of particles in ballastic orbits
Motion in electric field	Thermal motion superimposed by electric field drift	Ballastic orbits in magnetic and electric field
Velocity distribution	Essentially Maxwellian	Often anisotropic Has a tendency to generate very high energy particles: magnetosphere keV solar atmosphere MeV GeV interstellar space possibly 10^{14} eV or more
Exists in:	Solar, stellar photospheres Ionospheres Comet coma	Solar corona Active regions in magnetospheres Comet tails Interplanetary, interstellar, intergalactic space
Radiates	Thermal (essentially visual) radiation No X-rays or γ-rays	X-rays, γ-rays (by collisions with residual particles) "Noise" generation, especially in connection with production of high-energy particles
Energy transfer	<u>Local</u> theories correct	Only <u>global</u> theories correct because currents transfer energy over large distances (often much larger than size of ballastic orbits)
Frozen-in magnetic field	<u>Yes</u>	No
Energy release through magnetic merging	Possible	No. This is like Columbus's mistake

Fig. 2 <u>Properties of magnetized plasmas</u>. From the Introductory lecture at the MIT Plasma Physics Symposium Jan. 9, 1987, Cambridge Mass. (In press.)

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Key words: Spiral galaxies, Plasma Universe, Circuits, Double layers, Missing mass, Reliable diagnostics