



## HORNDESKI GRAVITATSIYASIDA PLAZMA MAVJUD HOLDA FOTON SFERASI

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### Annotatsiya

Ushbu tezisda Horndeski tipidagi modifikatsiyalangan gravitatsiya doirasida sferik-simmetrik qora tuynuk atrofida yorug'lik nurlarining beqaror doiraviy orbitasi — foton sferasi tahlil qilinadi. Metrik funksiya Shvartschild hadiga qo'shimcha ravishda  $a/r^2$  ko'rinishdagi “effektiv Horndeski parametri” bilan umumlashtiriladi. Foton sferasi radiusi uchun analitik formula chiqarilib,  $a$  parametrining ishorasi va miqdoriga bog'liq ravishda foton sferasining siljishi muhokama qilinadi. Natijalar qora tuynuk soyasi va kuchli gravitatsion linzalanish kabi kuzatuvchan effektlarni Horndeski parametrlari orqali cheklash imkonini beradi.

**Kalit so'zlar:** Horndeski gravitatsiyasi, qora tuynuk, foton sferasi, null geodezik, kuchli linzalanish, qora tuynuk soyasi. 1. Kirish

Horndeski gravitatsiyasi skalyar–tenzor nazariyalar ichida ikkinchi tartibli maydon tenglamalarini saqlagan holda eng umumiy sinf hisoblanadi. Bunday nazariyalarda qora tuynuk geometriyasi Umumiy nisbiylik nazariyasidagi Shvartschild yechimidan chetlanishi mumkin. Ayniqsa, qora tuynuk yaqinidagi kuchli maydonda yorug'lik trayektoriyalarining o'zgarishi foton sferasi, kritik ta'sir parametri va qora tuynuk soyasi kabi hodisalar orqali sinovdan o'tkaziladi.

Statik, sferik-simmetrik fazo–vaqt quyidagicha olinadi:

$$ds^2 = -f(r)dt^2 + \frac{1}{f(r)}dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2) \quad (1)$$

Bu yerda metrik funksiya:

$$f(r) = 1 - \frac{2M}{r} - \frac{a}{r^2} \quad (2)$$

$M$  — qora tuynuk massasi,  $a$  — Horndeski sektoridagi qo'shimcha effektlarni ifodalovchi “effektiv” parametr (u musbat yoki manfiy bo'lishi mumkin).



Null geodeziklar uchun ekvatorial tekislikda ( $\theta=\pi/2$ )(foton sferasi beqaror doiraviy orbitaga mos keladi. Statik sferik metrikada foton sferasi sharti standart ko‘rinishda yoziladi:

$$\frac{dr}{d\phi} = \frac{\dot{r}}{\dot{\phi}} = \frac{f(r)r^2 p_r}{p_\phi} \quad (3)$$

Shunday qilib,

$$\frac{dr}{d\phi} = \pm r \sqrt{f(r)} \sqrt{h^2(r) \frac{\omega_0^2}{p_\phi^2} - 1} \quad (4)$$

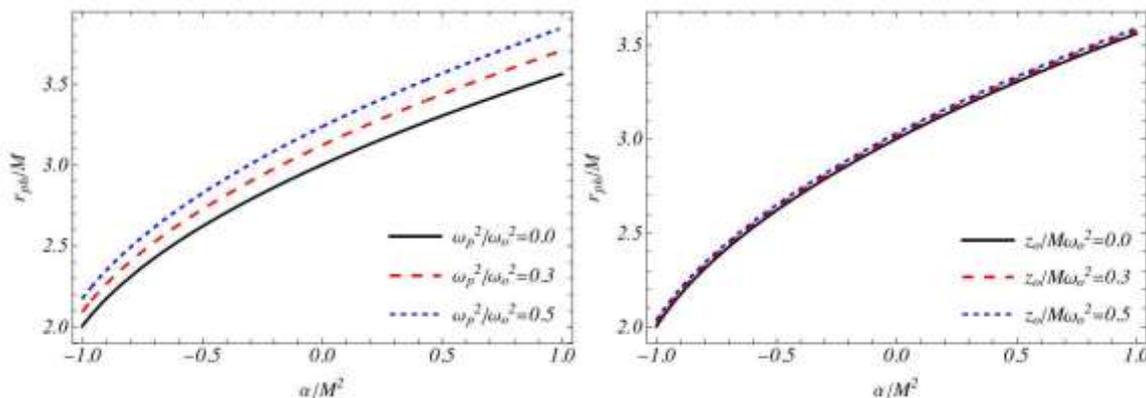
dan:

$$h^2(r) \equiv r^2 \left[ \frac{1}{f(r)} - \frac{\omega_p^2(r)}{\omega_0^2} \right] \quad (5)$$

kelib chiqadi. Foton sferasining fizik ildizi:

$$\left. \frac{d(h^2(r))}{dr} \right|_{r=r_{ph}} = 0 \quad (6)$$

Tahlilimizda  $\omega_p(r)$ . uchun ikkita aniq funksional ko‘rinishni ko‘rib chiqamiz. Avvalo,  $\omega_p(r)$  doimiy bo‘lgan bir jinsli modeldan foydalanamiz; bu model foton yo‘li bo‘ylab elektron zichligi sekin o‘zgaradigan muhitlarni, masalan, kengaygan diffuz plazmani ifodalaydi. Ushbu holat uchun (6)-tenglama sonli usullar yordamida tahlil qilindi. Tegishli grafik 1-rasmda keltirilgan. Ko‘rinib turibdiki, fazo-vaqt parametrining ortishi foton orbitasi radiusining kattalashishiga olib keladi, plazmaning ta’siri esa foton sferasining yanada kengayishiga sabab bo‘ladi.





1-rasm. Ushbu grafik bir jinsli plazma (chap panel) va bir jinsli bo'lmagan plazma (o'ng panel) holatlarida foton sferasi radiusi  $r_{ph}/M$  ning  $\alpha$  parametri bilan bog'liqligini ko'rsatadi; bunda  $\omega_p^2 = \text{const}$  ning turli qiymatlari ko'rib chiqilgan.

Xulosa.

Plazma mavjud sharoitda Horndeski gravitatsiyasidagi foton sferasi vakuumdagiga nisbatan murakkabroq bo'lib, u metrik funksiya bilan bir qatorda dispersiv muhitning sinish ko'rsatkichi va plazma profili ga ham bog'liq bo'ladi. Foton sferasi sharti ko'rinishida yozilib, natijada foton sferasi radiusi **chastotaga bog'liq** kattalikka aylanadi. Bu esa qora tuynuk soyasi va kuchli linzalanish signallarini turli chastotalarda tahlil qilish orqali Horndeski parametrlarini va atrof-muhit plazmasining ko'rsatkichlarini birgalikda cheklash imkonini beradi.

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